PHYSICS DAY

STUDENT WORKBOOK

Welcome to $6FM^2$! (Six Flags Magic Mountain)

Our existence and continued success depends on our being able to devise rides where you can safely experience as many different accelerations as possible (very few people would be interested in a ride that moved in a straight line at a constant speed). At $6FM^2$ you will have the opportunity to experience some of the most thrilling and unique methods of being accelerated available in any theme park. Included in the following pages are questions and problems concerning the physics involved in our rides. We hope you will take the opportunity to apply the physics you have learned in the classroom to a real world situation while having fun. For your safety and the safety of others, while you are making your observations and taking measurements the following rules are to be adhered to:

All Park Policies and Codes of Conduct must be complied with

Your activities may in no way interfere with the operation of any ride or with a Park employee's job ; follow the directions of any Park employee

Under no circumstances may you enter a restricted access area

Show proper respect to other Park guests

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(#16 has a bonus question)*

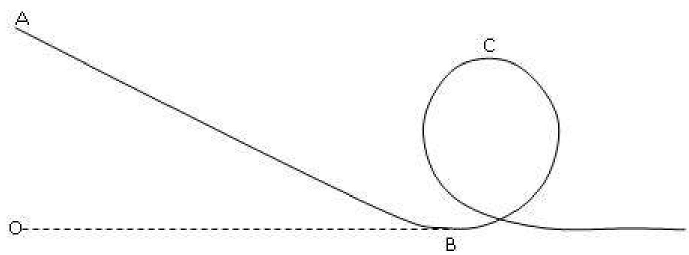
Activity #1 REVOLUTION

OBJECTIVE:
To determine the speed of the train from distance and time measurements.

DISCUSSION:
Estimate the length of the train and time the passage of the train at indicated points along the path in order to calculate speeds.

APPARATUS: Stopwatch

DATA:
Length of train = _______ m
Time for train to pass point:
A: _______ sec
B: _______ sec
C: _______ sec



RESULTS:

Speed at point:

A: __________
B: __________
C: __________

Activity #2 REVOLUTION

OBJECTIVE:
To calculate the speed of the train at points B and C using the principle of conservation of energy.

DISCUSSION:
Either by measuring angles at a known distance or by making estimates using multiples of some known dimension, determine the indicated heights. Calculate the kinetic energy of the train at point A from Objective #1. Assuming that mechanical energy is conserved and knowing the heights of point A and C above point B, calculate the speed of the train at points B and C.

APPARATUS: Triangulation Device

DATA:
Height :
OA: _________ m
BC: _________ m

RESULTS:
Speed at point:
B: __________
C: __________

How do these values compare with those found in Activity #1? Explain the differences.

Activity #3 REVOLUTION

OBJECTIVE:
To calculate the acceleration of the train at various points and compare them with those measured with an accelerometer.

DISCUSSION:
A.) Using the speed at points A and B from Activity #1 and time of travel from A to B, calculate the acceleration of the train down the incline. B.) To calculate the acceleration upon entering the loop at point B, calculate the centripetal acceleration at B using the speed from Activity #1. C.) Calculate the centripetal acceleration at point C in the same way.

APPARATUS: Spring scale and known mass, stopwatch

DATA :
Time for train to pass point:
A to B: _______ sec

Radius at point B: _____ m
Radius at point C: _____ m

RESULTS:
Acceleration:
A to B: ________
at B: ________
at C: ________

ACCELEROMETER RESULTS:
Acceleration:
A to B: ________
at B: ________
at C: ________

Activity #4 REVOLUTION

OBJECTIVE:
Compare the velocity on a frictionless banked curve to actual velocity.

DISCUSSION:
If you stand on the walkway that separates REVOLUTION from the GRAND CAROUSEL, the REVOLUTION track is very close to the walkway. At this point the track is circular and steeply banked. Estimate the angle of the banking (measured from the vertical), the radius of curvature of the track and the speed of the train in this section.

APPARATUS: Sighting device for measuring angles, stopwatch

DATA:
Bank angle: _____________(from vertical)
Radius of curve: ____________
Speed of train: ____________

RESULTS:
Angle with no friction: ____________
(calculate from train speed using: $\tan \theta = v^2 / gR$)

How does this angle compare to the measured angle?

Activity #5 BUCCANEER

OBJECTIVE:
Assuming total mechanical energy is conserved, calculate the speed of the ship at the bottom of its swing. Use this speed to estimate the ship's acceleration at the bottom of the swing and compare it with a direct measurement of the acceleration.

DISCUSSION:
Estimate or measure using triangular methods the change in height of a point on the ship during one-fourth of a swing. Estimate or measure the radius of rotation of the ship. Using a spring scale and mass, ride the ship and measure the apparent weight of the mass at the bottom of the swing.

APPARATUS: Triangulation device, spring scale and mass (0-2 Newton and 50 gram works well)

DATA:
Height: ____________
Radius: ___________
F on mass: ____________
(at bottom of swing)

RESULTS:
Speed at bottom of swing: ____________
Centripetal acceleration (using #1): ___________
Centripetal acceleration (using F): ___________

Activity #6 BUCCANEER

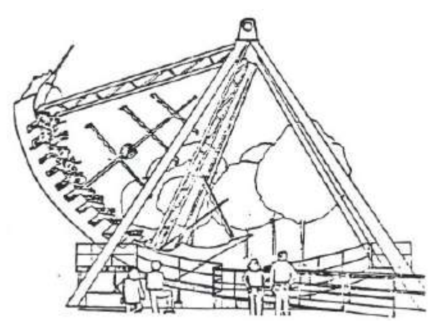
OBJECTIVE:
To determine the frequency and period of oscillation, assuming pendulum motion, by direct measurement. Verify the results by calculation.

DISCUSSION:
Use a stopwatch to measure several complete cycles. Use the estimated measurements to calculate frequency.

APPARATUS: Stopwatch

DATA:
Time: ___________ sec
Number of cycles: ___________

RESULTS:
Frequency: ____________ Hertz
Period: ____________ sec
Verify using equation:



$$f = \frac{1}{2\pi}\sqrt{\frac{g}{R}}$$

Activity #7 COLOSSUS (or equivalent coaster)

OBJECTIVE:
To determine how "close" to being in free-fall one is during the descent of the first major hill on COLOSSUS.

APPARATUS: Stopwatch

DATA:
Time the descent of the first steep incline: __________ seconds   Angle during descent: ___ º

Estimate the distance of "fall" during this incline: ___________ m

RESULTS:
Assuming a constant acceleration during the descent of this first steep incline, compute the acceleration during the descent: __________

For a frictionless incline, a = g sin ***θ***.
Find this theoretical maximum: a = ________ m/s^2

How does the acceleration during the descent compare with the theoretical maximum?

Activity #8 COLOSSUS (or equivalent coaster)

OBJECTIVE:
To determine the energy per unit mass loss to heat by the coaster from the top of the first hill to the top of the second hill.

DISCUSSION:
Measure the height of the first and second hills and measure the speed of the coaster as it passes the top of these hills (this procedure was outlined for REVOLUTION).

APPARATUS: Stopwatch, triangulation device
DATA
Time for coaster to pass a point on the first hill: ___________; on the second hill: ___________
Length of coaster: ___________
Height of first hill: ___________; second hill: ___________

RESULTS:
Use conservation of energy to compute the loss of energy per unit mass as suggested in the objective:
____

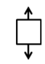
Activity #9 APOCALYPSE or COLOSSUS

OBJECTIVE:
Determine the centripetal acceleration experienced while going over the top of a hill on APOCALYPSE or COLOSSUS and to determine the radius of the curvature of the hill top.

DISCUSSION:
Measure the apparent weight of a known mass with a spring scale while going over the hill. Determine the speed of the train as it passes over the hill.

APPARATUS: 0-5 N spring scale, known mass, Stopwatch

Apparent Weight = F



True weight=mg

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

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

DATA:
True weight of mass: ____________
Apparent weight of mass: __________

	APOCALYPSE	COLOSSUS
Length of the train:		
Time for train to pass top hill:		

RESULTS:

	APOCALYPSE	COLOSSUS
Centripetal acceleration:		
Speed at the top of the hill:		
Radius of curvature:		

Activity #10 APOCALYPSE & COLOSSUS

OBJECTIVE:
Determine the starting horizontal acceleration and stopping deceleration of APOCALYPSE and COLOSSUS.

DISCUSSION:
Measure the angle from the vertical of the mass in the string the instant the coaster leaves the station and at the first big break as it returns.

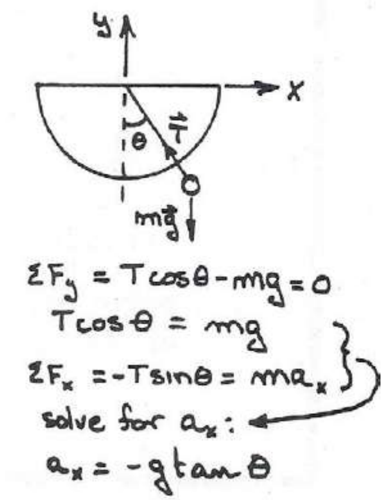
APPARATUS: Protractor, string, mass

DATA:

ANGLE	APOCALYPSE	COLOSSUS
Leaving station: θ_1		
Returning: θ_2		

RESULTS:

	APOCALYPSE	COLOSSUS
Acceleration		
Deceleration		



Activity #11 X2 & COLOSSUS

OBJECTIVE:
Determine the reduction in acceleration down the slope due to friction on the incline.

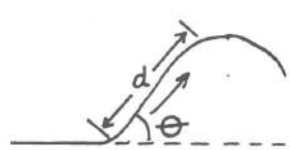
DISCUSSION:
Time the coaster on the incline. Holding a protractor at arms length, determine the angle of incline.

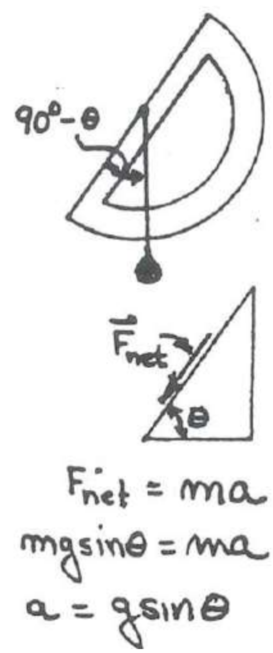
APPARATUS: Stopwatch, protractor

DATA	X2	COLOSSUS
Incline Angle		
Incline Time		

RESULTS:

ACCELERATION	APOCALYPSE	COLOSSUS
a =g sin θ		
$d = \frac{1}{2}at^2$ (assuming $V_o = 0$)		
Reduction due to friction		





Activity #12 NINJA

OBJECTIVE:
To estimate the speed and centripetal acceleration of NINJA as it rounds the curve at the lowest point along the track.

DISCUSSION:
At the lowest point along the track, NINJA rounds a circular section of track just above the JET STREAM pond. If the length of the train and the time for it to pass a fixed point are known, the speed can be estimated. Using the speed and if the radius of the curve is known, an estimate of its centripetal acceleration can be calculated.

APPARATUS: Stopwatch

DATA:
Length of NINJA train = 17.5 meters; Radius of curve: 13 meters
Time for train to pass a fixed point = ____________ seconds
Train speed = ____________ m/s = ____________ mph
Centripetal acceleration = ____________m/s^2 = __________ x g

Check this value vs. that found directly using your vertical accelerometer: _____ g's

Activity #13 TATSU, NINJA & VIPER

OBJECTIVE:
To determine your average speed when riding TATSU, NINJA and VIPER from distance and time measurements.

DISCUSSION:
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) . You can calculate the average speed of the rides once you know the total ride time (from dispatch to return).

APPARATUS: Stopwatch

DATA:

	TATSU	NINJA	VIPER
Total Ride Time (t):	sec	sec	sec
Average Ride Speed:	m/sec	m/sec	m/sec

Using the proportion: 60 mph=88ft/sec, convert the average ride speeds to mph

Average Ride Speed:	m/sec	m/sec	m/sec

Is this what you expected? What factors lead to this speed? Does the average speed really represent the true speed of these rides? Could you suggest another method to find the true average speed?

Activity #14 HORSEPOWER

OBJECTIVE: (note: for this exercise, you may need to ride more than once to get all the data you need, or work in teams to make data collection easier)
Estimate the minimum horsepower motor necessary to pull the coaster train up the first (or last) lift on NINJA, VIPER, TATSU, RIDDLER's REVENGE, GOLIATH, BATMAN or X2. PLEASE COMPLETE AT LEAST 2

DISCUSSION:
Most Six Flags coasters rely on a chain lift system to pull the coaster train up the first or last incline of the ride. If the total mass of the train (M_{total}) is given and the vertical height (h) of the first incline are known, the potential energy gained as the train moves up the first incline can be determined using $\Delta PE = M_{total}H$.

On each ride you'll notice that along the incline there is a stairway and handrail supports. By counting the total number of steps from the bottom of the lift to the top, and assuming that the height of each step is 0.18 meters, a value for the vertical height (h) of the ride can be found. To find the M_{total}, count the number of seats on each coaster train and multiply it by the mass of the rider (M_{riders}). For the purpose of this activity, assume that each seat will be occupied by a standard 60kg Physics student. Add this total to the mass of each coaster (provided).

Assuming mechanical energy to be conserved, the work done by the motor pulling the train up the last incline at constant speed is MgH, here Mg is the total weight of the loaded train and H is the vertical height of the incline. If the total work done by the motor and the time required for the motor to pull the train up the incline are known, as estimate of the minimum power requirement for the motor can be calculated. Alternatively, if the change in potential energy (ΔPE), of the loaded train and the time (t) to ascend is known, the power needed to pull the train up the incline can be found from Power = $\Delta PE/t$. Determine the minimum power and horsepower motor needed.

APPARATUS: Stopwatch

DATA:	NINJA	VIPER	TATSU	RIDDLER	GOLIATH	BATMAN	X2
Train mass (kg)	8,046	5,477	14,546	11,080	8,546	9,932	17,898
# of seats							
M_{riders}							
M_{total} (kg)							
# of lift hill steps							
H							
t							

RESULTS:	NINJA	VIPER	TATSU	RIDDLER	GOLIATH	BATMAN	X2
ΔPE (MgH) = Joules							
Power (ΔPE/t) = watts							
Horsepower (1hp = 750 watts)							

The actual power of the motor used is several times this value since more power is needed to overcome friction and for an additional margin of safety.

Activity #15 VIPER

OBJECTIVE:
To calculate the speed of a rider at the top of each of VIPER'S three vertical loops using energy conservation and compare them with measured results.

APPARATUS: Stopwatch

DISCUSSION:
At the top of the first hill a rider on VIPER is about 45 meters above the loading level. At the top of the first, second and third vertical loops the rider is about 32, 22 and 19 meters, respectively, above the loading level. Neglecting friction and using conservation of mechanical energy, the speed of the rider at the top of each loop can be calculated using these distances. By estimating the length of the VIPER train and measuring the time required for it to pass a point at the top of a given loop, an experimental estimate of the speed can be found.

DATA:
Length of VIPER train = ____________
Times for train to pass the top of loop #1 ____________;
#2 ____________; #3 ____________

RESULTS:

Top of Loop #	Speed (m/s) [conservation of E]	Speed (m/s) [measured]	% Difference
1			
2			
3			

Activity #16 TATSU, RIDDLER & SCREAM

OBJECTIVE:
To obtain an estimate of the speed of a TATSU, RIDDLER'S REVENGE and SCREAM train at the top of the ride's giant loop.

DISCUSSION:
An estimate of the speed of the train at any point can be found if the train's length and the time required for the train to pass that point are known. If L is the length of the train and the time required to pass the point, the speed can be found from v = L/t. Measure the time for the train to pass the top of the loop and pace off the length of the coaster trains.

APPARATUS: Stopwatch

DATA	TATSU	RIDDLER	SCREAM
Train Length (paces)			
Train Length (L=(paces)x(m/pace)			
Time to pass top of loop (sec)			

RESULTS:
Speed at top of loop:
TATSU = ____________m/s;
RIDDLER= ___________ m/s
Scream = ____________m/s

Bonus question (show work on back): after estimating the radius of each loop at the top, claculate the centripet al acceleration that should be experienced. Directly measure this with the vertical accelerometer and compare.

Activity #17 ROARING RAPIDS

OBJECTIVE:
Determine the velocity of the water in the river.

SUGGESTED PROCEDURE:
Estimate the length of travel for the ride and time your trip in the raft.

APPARATUS: Stopwatch

DATA:
Ride length = ___________; Time = ___________

RESULTS:
Velocity = ___________

Activity #18 ROARING RAPIDS

OBJECTIVE
Find the flow rate of water.

SUGGESTED PROCEDURE:
Estimate the width of the river. Given that the average depth is 1.5 feet and using the results from Activity #22, find the flow rate (volume of water per minute).

RESULTS:
Volume/second (in m^3/sec) = ___________

Activity #19 ROARING RAPIDS

OBJECTIVE:
Determine the power needed by the pumps to raise the water to the beginning of the ride.

SUGGESTED PROCEDURE:
The river has a 12.5 foot drop form start to finish. The pumps must raise the water through this height to keep up the flow rate. Use the information from Activity #23 to determine the weight of the water per second that must be raised.

DATA:
Weight of water/second = ___________

RESULTS:
Volume/second (in m^3/sec) = ___________

POWER:
Water has a density of 1000 kg/m^3.
Determine the gravitational potential energy gained per second: _____________W

Activity #20 BATMAN

OBJECTIVE:
To obtain an estimate of the speed of the BATMAN train at the top of the two vertical loops using the principle of conservation of mechanical energy.

DISCUSSION:
Refer to the "Suggestions for Making Measurements" pack sent to your teacher for an equation derived using conservation of mechanical energy for finding the speed of the REVOLUTION train at point C when the height of C above some reference level, its speed at another point (A) and its height at A above the same reference level are known. This method can be used to determine the speed of the train at the top of the vertical loops on BATMAN also. The equation given in the booklet is:

$$v_c = \sqrt{v_A^2 + 2g(h_A - h_c}$$

In this case, let v_A and h_A be the speed and height of the BATMAN train above the ground at the top of the first incline, and v_C and h_C its speed and height at the top of either loop. The heights h_A and h_C (as supplied by Six Flags) are given below and v_A can be found using the method described in Activity #16.

APPARATUS: Stopwatch

DATA:
Length of train = L = (# paces) x (meters/pace) = (__________) (__________) = __________ m
Time for train to pass over the top of the first incline = t = ____________ sec
Height above ground: first incline = 32.0 m; first loop = 23.5 m; second loop = 19.2 m

RESULTS:
Speed at top of:

First incline = v_A = L/t = (____________) (____________) = ____________ m/s

Loop #1 = $(v_c)_1 = \sqrt{(\_\_\_\_\_)^2 + 2(\_\_\_\_\_)[(\_\_\_\_\_) - (\_\_\_\_\_)]} = \_\_\_\_\_ m/s$

Loop #2 = $(v_c)_2 = \sqrt{(\_\_\_\_\_)^2 + 2(\_\_\_\_\_)[(\_\_\_\_\_) - (\_\_\_\_\_)]} = \_\_\_\_\_ m/s$

Six Flags states the speed of the train at the top of both loops is about 9.6 m/s. This should be roughly 2/3 the values you have found. Explain the difference.

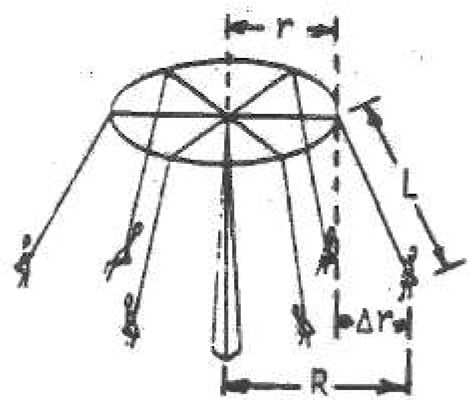
Activity #21 SWASHBUCKLER

OBJECTIVE:
To determine the maximum speed of a SWASHBUCKLER rider.

DISCUSSION:
The maximum speed of the rider can be determined from $v = 2\pi R/T$ where $2\pi R$ is the circumference of the path of the swing and rider and T is the period of rotation (the time for one rotation) when SWASHBUCKLER is rotating at its maximum speed.

To find T, measure the time for 5 rotations and divide by 5. Note in the drawing that $R = r + \Delta r$ where r is the radius of the circle swept out by the swing support arms and Δr is the horizontal deflection of the swings at maximum speed. Six Flags gives r to be about 4 meters and the length (L) to be about 3 meters. Knowing L, Δr can be calculated from $\Delta r = L\sin\theta$. Measure the angle of deflection θ with a protractor/inclinometer when the swings are moving at maximum speed vmax.

APPARATUS: Stopwatch, protractor/inclinometer



DATA
5T = __________s, T = __________ s; θ = ____________(from vertical)
How is the angle θ affected by the mass of the person in the swing?

RESULTS
Δr = Lsin θ = (____________)sin(____________) = ____________ m

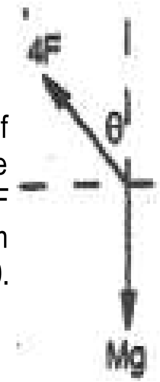
R=r + Δr = (____________) + (____________) = ____________ m

$$v_{max} = \frac{\text{Circumference}}{t} = \frac{2\pi R}{t} = \frac{2(\_\_\_\_\_\_)(\_\_\_\_\_\_)}{(\_\_\_\_\_\_)} = \_\_\_\_\_\_\_\_ \text{ m/s}$$

Activity #22 SWASHBUCKLER

OBJECTIVE:
To determine the tension in the chains supporting the swing chair.

DISCUSSION:
The force diagram of the forces on the chair/rider combination is shown here. Mg is the combined weight of the chair and rider and 4F is the total force exerted on the chair by the 4 support chains. The sum of the vertical components of the forces gives $4F \cos\theta - Mg = Ma_{vertical} = 0$, since $a_{vertical} = 0$. solving for F gives $F = Mg/(4\cos\theta)$. Thus, if the mass of the chair/rider combination and the deflection angle of the chains from the vertical are known, the tension in each chain can be found. With a protractor/inclinometer measure θ. Assume the chair is occupied by a standard 60 kg Physics student and that the chair has a mass of 10 kg.



APPARATUS: Protractor/inclinometer

DATA:
θ = ____________ ; M = 60kg + 10kg (chair) = 70kg

RESULTS:

Tension in each chain = F = $\dfrac{Mg}{4\cos\theta}$ = $\dfrac{(\_\_\_\_\_\_\_\_)(\_\_\_\_\_\_\_\_)}{4\cos(\_\_\_\_\_\_\_\_)}$ = ______________ N

Activity #23 SWASHBUCKLER

OBJECTIVE
At maximum speed, compare the measured angle of deflection of a swing with a value calculated from Newton's second law.

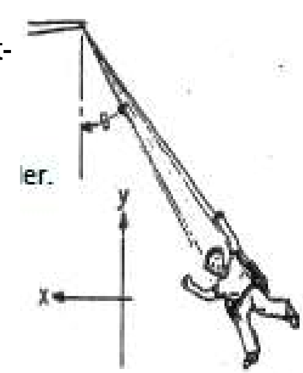
DISCUSSION
In the diagram at the right, assume only the rider's bottom is in contact with the swing. On the diagram, draw the free body diagram showing all the forces on the rider. If you have done it correctly, there are only two forces on the rider. His/her weight mg in the –y direction and the normal forces N directed upward at an angle θ with the +y-axis exerted by the seat on his/her bottom. Applying Newton's second law,

$\Sigma F_y = N\cos\theta - mg = 0 \rightarrow N\cos\theta = mg$

$\Sigma F_x = N\cos\theta - mg = 0 \rightarrow N\cos\theta = mg$

Combining the two equations gives:
$mg\tan\theta = mv^2/R \rightarrow \theta = \tan^{-1}[v^2/(gR)]$

Thus, if the radius (R) of the swing's path when v = vmax and vmax is known, θ can be calculated and compared with that found by direct measurement. Measure the angle the swing and rider make with the vertical, with a protractor/inclinometer. Determine v_{max} and R using the method described in Activity #22.



APPARATUS Stopwatch, Protractor/inclinometer

DATA
v_{max} = ____________ m/s; R = ____________ m; θmeasured = ____________ °

RESULTS:
$\theta_{calculated} = \tan^{-1}\dfrac{[(vmax)^2]}{gR} = \tan^{-1}\dfrac{[(\_\_\_\_\_\_\_\_)^2]}{[(\_\_\_\_)(\_\_\_\_)]}$ = ____________ °

% difference between $\theta_{measured}$ and $\theta_{calculated}$ = ____________ %

Activity #24 GRAND CAROUSEL

OBJECTIVE:
To determine the speed and centripetal acceleration of a rider while on the GRAND CAROUSEL.

DISCUSSION:
If the circumference of the path of a rider and his/her period of rotation when the GRAND CAROUSEL is moving at maximum speed are known, the speed and centripetal acceleration of the rider can be determined. The circumference can be found by pacing around the circumference of the outer row of horses before or after the ride and the period can be measured with a stopwatch.

An angle measurement made with a protractor/accelerometer while standing next to an outer horse will also give a value of he centripetal acceleration (help is available in the "Suggestions for Making Measurements" section of the pack sent to your teacher) which can be compared with the first value.

APPARATUS: Stopwatch, protractor/accelerometer

DATA:
Circumference = (____________ paces) (____________ m/pace) = ____________ m

R = (Circumference/2π) = (____________)/2π = ____________ m

Period = Time for 1 revolution = ___________ sec

θ = Angle read off protractor/accelerometer = ____________

RESULTS:
Speed = $\frac{\text{Circumference}}{T} = \frac{(\_\_\_\_\_\_\_\_\_\_\_\_)}{(\_\_\_\_\_\_\_\_\_\_\_\_)}$ = ____________ m/s

Centripetal Acceleration:
Method 1: $a_C = \frac{4\pi^2 R}{T^2} = \frac{4(\_\_\_\_\_\_\_\_\_\_\_\_)^2(\_\_\_\_\_\_\_\_\_\_\_\_\_)}{(\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_)^2}$ = ____________ m/s^2

Method 2: $a_C = g \tan\theta$ = (____________) tan (____________) -____________ m/s^2

Difference between values of a_C for by Methods 1 & 2 = ____________ %

Activity #25 BUMPER CARS

DATA & MEASUREMENTS:

(note: an unloaded bumper car has a mass of 213 kilograms)

Below, you will be asked to determine the top velocity of the cars. Pick two points in the ride and estimate or measure the distance between them. Then, using a stopwatch time several cars to determine how long it takes them to move from one point to the next.

1) Length used for velocity determination: l = ____________

2) Times used for velocity determination:

t_1 = ___________ t_2 = ___________ t_3 = ___________

3) Calculate the average velocity.

4) Estimate the mass of two members of your group in kg Person 1 = __________kg Person 2 = __________ kg

5) Calculate the aproximate momentum of cars 1 and 2.

OBSERVATIONS

1) During a collision, is momentum conserved? Prove this for one situation with calculated values.

2) Do the same thing for kinetic energy.

3) If the time of impact for a head-on collision (assume similar speeds) is 0.1s, how much force is exerted **on an average sized passenger** of 75kg? (not the force exerted on the car system)

Activity #26 SCREAM

Stand outside the ride at a place where you can watch the coaster. Watch a rider and try to determine what forces the rider feels on his/her body at various points during the ride. Would the seat be pushing on the rider's bottom? Would the shoulder harness be holding the rider in the seat? Would the side of the car be pushing on the rider? Would the back of the seat be pushing the rider forward? Would the shoulder harness prevent the rider from flying forward?

Consider what is happening as the coaster is in the following situations. For each of the situations predict what forces you or another rider would feel:

- going up the first hill
- going down the first hill
- making a sharp left or right hand turn
- going over the top of a hill when right side up
- going through the top of a loop upside down
- leaving a loop while right side up

Watch the way the riders move. Does their hair hang down?

1) Now ride the ride or interview someone who did. Try to remember the forces you felt at some of the points listed above. Work with a group. Assign each person a specific point at which to collect data. Do your observations agree with your predictions made above? Discuss.

2) As you go through the top of the first loop try to remember the force you felt. Did the seat push on your bottom or did the shoulder harness hold you in your seat?

3) Describe the force you felt at the top of the loop.

4) What would your weight be on SCREAM at 4.5 g's?

Height Data Table

Object measured:

Measurers:				Averages
θ_2 (degrees)				
θ_1 (degrees)				
b (m)				
h_o (m)				

Height Data Table

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Measurers:				Averages
θ_2 (degrees)				
θ_1 (degrees)				
b (m)				
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Measurement Suggestions and Useful Formulae

Knott's Berry Farm is compact, so you will need to explore areas appropriate for making measurements, which do not interfere with the operations of the park.

To find distances use string knotted at known intervals, cloth measuring tapes or your known pace length.

To find heights you will measure the angles from your eye to the height at two locations in line of sight along a measured distance between the two angles. Have someone help you read the angle on the inclinometer because very slight errors in reading angles cause major errors in calculations. (See Diagram on next page)

When measuring speeds find a location that parallels the tracks and take several readings to find the average value.

When using accelerometers, be sure to have them secured around your wrist so there is no possibility that they may come loose to hurt yourself or others. (See Diagram on next page) A lift is the portion of the track where the ride is “pulled” to a height from which it “falls”.

Useful Formulae:

$KE = 1/2\, mv^2$

$PE = mgh$

$h = \{[\sin\varnothing_1 \sin\varnothing_2 / (\sin(\varnothing_1 - \varnothing_2))] \bullet b\} + h_o$

$v = d/t$

$g = 10\ m/s^2$

$v = 2\pi r/T$

$v = gt$

$a_c = v^2/r$

$p = mv$

$w = Fd$

$a = \dfrac{V_f - V_i}{t}$

$J = kg \bullet m^2/s^2$

freefall: $d = 1/2\, gt^2$

$F = ma$

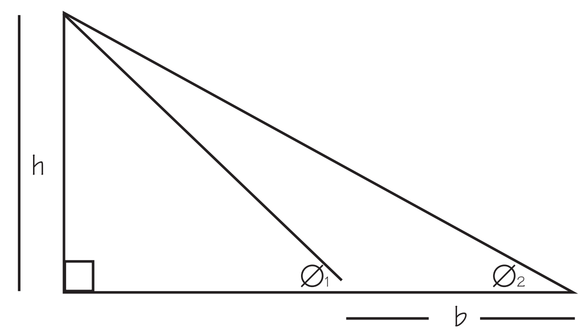
$T = 2\pi(L/g)^{1/2}$

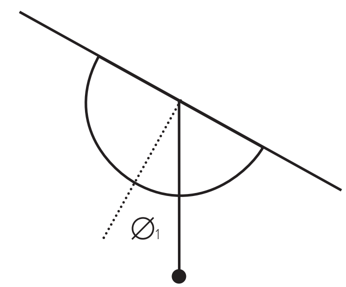
$P = w/t$

$a_c = \dfrac{4\pi^2 r}{T^2}$

To measure height:

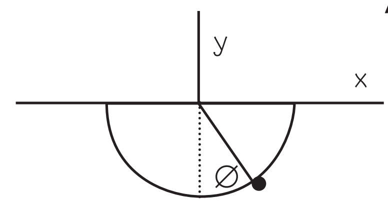
$$h = \frac{[\sin\varnothing_1 \sin\varnothing_2]b}{\sin(\varnothing_1 - \varnothing_2)} + h_o$$





$$a_x = -g \tan\varnothing$$

To measure Horizontal Acceleration use a plumb bob



Measure from 90º