NOTES

High School Physics Day

ACTIVITY	LOCATION	TIME
Early Ride Time	Select Rides	8 – 10 am
Dr. Flubber-Paper Airplane Demonstration	Charles M. Schulz Theatre	8 – 10 am
Roller Coaster Drop-off	Charles M. Schulz Theatre	8 – 9:30 am
Roller Coaster Judging	Charles M. Schulz Theatre	9:30 – 10 am
Roller Coaster Awards with Snoopy	Charles M. Schulz Theatre	10:15 – 11:00 am
Dr. Flubber Presentation	Charles M. Schulz Theatre	11:15 – 11:45 am
Rubber Band Car Drop Off	Boardwalk Ballroom	8 – 9:30 am
Paper Tower	Boardwalk Ballroom	9 – 10 am
Fermi Questions	Boardwalk Ballroom	10 – 11 am
Scavenger Hunt Certificate Distribution	Boardwalk Ballroom	11:00 am – 1:00 pm
Paper Airplane	Boardwalk Ballroom	12:00 – 1:00 pm
Rubber Band Car	Boardwalk Ballroom	1:00 – 2:00 pm

Activities, locations and event times are subject to change.

Student Name ____________________

School Name ____________________

Teacher's Name ____________________

Knott's BERRY FARM

PHYSICS DAY

Knott's BERRY FARM

PHYSICS FUN DAY

Welcome to the annual Physics Fun Day at Knott's Berry Farm. The planners hope you have both an enjoyable and educational day. To make the day safe for all we ask you to keep the following rules in mind:

1. Only hand-held equipment of the type found in Amusement Park Physics Kits (sold by science vendors) has been approved by Knott's officials for use on the rides this day. Wristbands provided with kits must be used.
2. Follow the directions of Knott's employees. Do not distract ride operators. They need to pay attention to the safe operation of the rides.
3. Check in with your teacher and team on a regular basis.
4. Wear appropriate clothing.

To make the most of your day of physics, the following pieces of equipment would be helpful:

- **Pencil**
- **Stop watch 0.01 sec.**
- **Vertical Accelerometer**
- **Horizontal accelerometer**
- **Inclinometer**
- **Soft linear measuring device (knotted string, cloth measuring tape)**

When making measurements at Knott's, work in a team of two, three, or four. One team member should plan to keep track of the "stuff" while others stand in line for a ride.

Before coming to Knott's you should discuss the measurements you will need to make and calibrate your equipment. Measurement suggestions and useful equations are included in this guide. Plan your day to include the Physics competitions and presentations inside of the Boardwalk Ballroom. Several thousand physics students are expected to attend Physics Day at Knott's. Knott's will open at 8am exclusively for physics students. There are many rides demonstrating numerous physics concepts. If a line for one ride is too long, go to another ride. When you finish with your measurements, store your equipment in a locker and continue to explore the park in a less quantitative manner.

NOTES

1. When operating at full speed, what time is required for 5 revolutions.

   time = ________seconds

2. Use information from above to determine the angular speed in both radian/second and revolutions per minute.

   __________rad/s __________rpm

3. In the space provided to the right, draw a free body diagram labeling the forces acting on a Surfside Glider vehicle in motion about the center mast (C).

4. With the ride operating at full speed, measure the tether angle. (We define the tether angle as the angle made between the vertical and the support cables.)

   tether angle = _______degrees

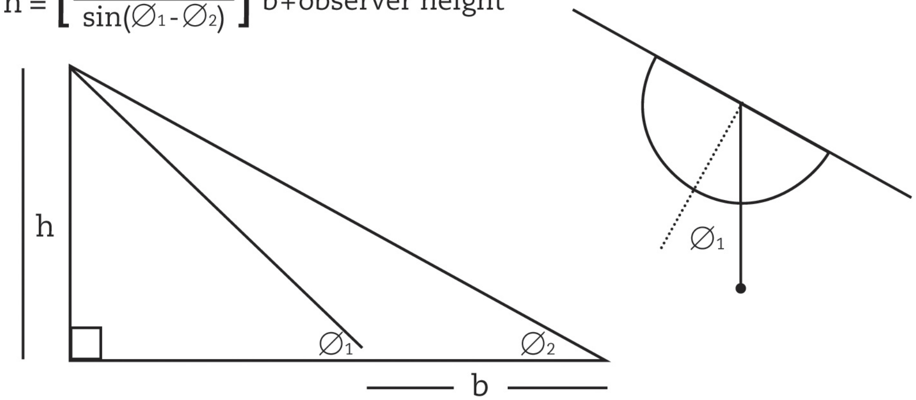
5. Use the tether angle from above or your accelerometer whilst on the ride to determine the centripetal acceleration.

   centripetal acceleration = ___________ m/s^2

DRAWINGS & NOTATIONS

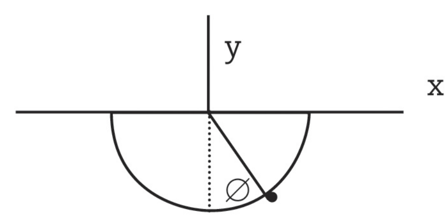
To measure height:

$$h = \left[\frac{\sin\varnothing_1 \sin\varnothing_2}{\sin(\varnothing_1 - \varnothing_2)}\right] b + \text{observer height}$$



$a_x = -g \tan\varnothing$

To measure Horizontal Acceleration use bb in tube



Measure from 90°

MEASUREMENT SUGGESTIONS & 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:

$KE = 1/2\ mv^2$

$PE = rngh$

$v = d/t$

$g = 10\ m/s^2$

$v = 2\pi r/T$

$v = gt$

$a_c = v^2/r$

$p=mv$

$w=Fd$

$a = \dfrac{v_f - v_1}{t}$

$\omega = \varnothing/t$

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

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

$F=ma$

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

$P = w/t$

$a = \dfrac{4\pi^2 r}{t}$

$\theta = (2\pi)/t$

height = $\{[\sin\varnothing_1 \sin\varnothing_2 / (\sin\varnothing_1 - \sin\varnothing_2)] \bullet b\}$ + observer's height

1. With regard to the first drop, measure and record below the following:

   a. the maximum height, h_2 = ________m

   b. the minimum height, h_1 = ________m

   c. the decent angle, θ = _________ degrees

2. Using the above values, calculate the increase in speed as the Coast Rider vehicle transitions these heights. Assume almost zero initial speed at the top.

3. Knott's technical ride information suggests this ride's top speed is 16.5 m/s. Offer a reasonable explanation for your answer's deviation.

4. Assume one Coast Rider vehicle with four passengers has a mass of 500 kg. What minimum power is required of the electric motor that moves such a vehicle up the first hill?

Power = _________ Watts or Power = _________HP

Equipment Needed: Stopwatch

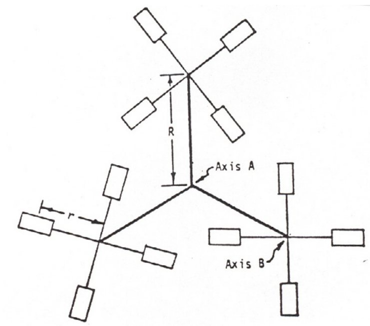
1. Estimate the speed of the Sierra Sidewinder as it travels closest to the station.

2. Calculate the centripetal acceleration of the Sierra Sidewinder as it passes closest to the station.

3. If the speed of the Sierra Sidewinder at the top of the initial drop is 3.1 m/s and it falls through 13 m, what is the speed at the bottom? (Assume a frictionless fall.)

4. Estimate the change in Potential Energy required raising a fully loaded Sierra Sidewinder to the top of the first hill?

Familiarize yourself with the diagram of this ride as shown to the right. (Hint: rotational or angular velocity, $\omega = \theta/t$; RPM = rotations per minute; 1 rotation = $2\pi\theta$; $\omega_{max} = \omega_A + \omega_B$; $\omega_{min} = \omega_B - \omega_A$.)



1. When on the ride, pick a landmark in the non-moving "ground" frame of reference. Determine the time for a full rotation about axis B, t_B, and for axis A, t_A.

   t_B, = ________s t_A.= ________s

2. With the data at hand, calculate the following:

   a. rotational velocity about axis A, ω_A = ____________RPM
   b. rotational velocity about axis A, ω_A = ____________rad/s
   c. rotational velocity about axis B, ω_B = ____________RPM
   d. rotational velocity about axis B, ω_B = ____________rad/s
   e. maximum rotational velocity = _____________rad/s
   f. minimum rotational velocity = ______________rad/s

3. Obtain the length for radii r and R as referenced in the diagram above. Measure the accelerations during the ride by holding your accelerometer sideways. Knowing your mass, calculate the maximum and minimum centripetal forces experienced. (2.2 pounds = 1 kg)

   Your mass ___________
   maximum acceleration ________g
   minimum acceleration ________g
   maximum centripetal force _________N
   minimum centripetal force _________N

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Draw a free body diagram of the forces acting on the rider as the car moves over the crest of the hill.

2. Estimate the height of the cover on the top of the first lift.

   $\varnothing_1$ =　　　$\varnothing_2$ =　　　b =

   h = __________

3. Estimate the speed in m/s of the outbound coaster as it crosses over Grand Avenue (the street outside of the main gates).

   Distance used =

   Time =

   V_{avg} = _______

*Questions 2 & 3 are to be completed **in the parking area** in front of the park **BEFORE** you enter or **AFTER** you leave.*

Wheeler Dealer Bumper Cars

1. What purpose does the metal arm at the top of the car serve?

2. Who's Law is best used to describe what happens most between the bumper cars and what does it say?

3. What is the purpose of the rubber bumpers on the cars?

4. Observe a collision and describe it using conservation of momentum concepts.

Supreme Scream

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Estimate the height of the riders before they get shot down (answer in meters).

$\varnothing_1$ = $\varnothing_2$ =   b =   **h = __________ m**

2. Measure how many seconds the first drop takes. Use this time and the freefall equation to estimate the distance you fall during the first drop (answer in meters). Show how you would calculate the average velocity for the initial downward motion during the first drop. Assume constant acceleration.

t =   **d = __________ m**

3. Draw a free body diagram showing the net force acting on the riders just before the end of the first drop.

4. Using your accelerometer, measure the vertical acceleration descending from the tower during the first drop.

a = _______ m/sec^2

*5. Using your accelerometer, measure the maximum deceleration at the bottom of the first drop.

a = _______ m/sec^2

Pony Express — The Ride

Equipment Needed: Stopwatch

1. Stand in the area in front of the loading area. Look at the mechanism used to push the "horses" for the acceleration. Measure the time the ride is pushed by the accelerating mechanism.

2. The acceleration of the riders is .6g as they leave the station. What maximum velocity does this produce?

3. Through what distance do the riders accelerate as they leave the station?

4. Look at the "horses" as they leave the last turn and approach the loading area. Describe the mechanism used to slow the "cars." How do you think these devices work?

5. If the track is 381 meters what is the average speed of the ride in mph?

Silver Bullet

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Estimate the length of the Silver Bullet train.

2. What is the minimum power of the motor which lifts the Silver Bullet train to the top of the first incline? (Assume the Silver Bullet has a mass of 10,000 kg)

   Power, min. _______ HP

3. Calculate the increase in speed resulting from the initial drop of 33.2 m (109 ft.).

   Speed Increase _______ m/s

4. Estimate the angular velocity, ω, of the Silver Bullet as it travels through the lower elevated spiral.

   Angular Velocity _______ rad/sec

5. Estimate the radius of the lower elevated spiral and calculate the anticipated centripetal acceleration.

   Radius _______ m

   Centripetal Acceleration, a_c _______ m/s^2

Xcelerator

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Estimate the height of the highest point of Xcelerator's track.

   $\varnothing_1$ = $\varnothing_2$ =   b =

   h = __________ m

2. While on the ride use your horizontal accelerometer to determine the "g" value as the ride leaves the station.

   g = _________ "g's"

3. If your top speed is 36m/s calculate the acceleration experienced by the riders at the end of the ride.

   t = ______ sec   **d = ______ m**   **v = ______ m/s**   **a = ______ m/s^2**

*4. While on the ride determine the "g's" as the ride "falls" down the first hill.

   g = _________ "g's"

DRAGON SWING

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Using an accelerometer, measure the centripetal acceleration experienced at the bottom of the arc of the Dragon Swing.

   a = _______ m/sec^2

2. Estimate the length of the pendulum "arm" or "radius of the rotation of the ship" (in meters). Explain how you did this.

   L = _______ M

3. Assuming mechanical energy is conserved, calculate the speed of the ship at the bottom of the swing.

   v = _______ m/sec

4. Calculate the theoretical centripetal acceleration at the bottom of the swing.

   a = _______ m/sec^2

5. Compare the measured acceleration from question #1 and the theoretical acceleration from question #4 and explain the difference.

LA REVOLUCION

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Determine the complete angle through which the riders move.

   a = _______ degrees

2. Estimate the length of the swinging arm from the pivot point to the passenger end.

   L = _______ m

3. Determine the period of La Revolucion.

   t = _______ sec

4. Calcuate the centripetal acceleration at the lowest point in the swinging motion.

   a = _______ m/s^2

*5. Measure the centripetal acceleration at the lowest point in the swinging motion.

   a = _______ m/s^2

JAGUAR!

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. The track is 793m long. What is the average speed of the train?

   V = _______ m/s

2. Compare the speed of Jaguar from post 98 to 104 as it passes the Carousel and Cantina to its speed after it leaves the U-turn from post 124 to 130.

   Distance before turn = Time before turn =

   Distance after turn = Time after turn =

   $V_{avg\ before}$ = _______ **$V_{avg\ after}$ = _______**

3. Estimate the cars average speed around the Jaguars watergun fountain loop.

   time = _______ **distance = _______** **V_{avg} = _______**

4. Calculate the centripetal acceleration of the riders as they go around the loop.

*5. Now compare the calculated value to the measured acceleration using an accelerometer.

MONTEZOOMA'S REVENGE®

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Knott's reports the train leaves the station moving at 24.6 m/s. Calculate the train's acceleration in g's. (Show your work)

   t =

   a = __________

2. Use an accelerometer to estimate the train's take off acceleration. (Show data and calculations)

   a = __________

3. What is the deceleration of the coaster when the first big braking starts? (Explain your method and calculations).

   a = __________

4. Use the ratio of the return tower height and forward tower height to estimate the efficiency of the roller coaster as a percent (%).

   Forward tower height: $\varnothing_1$ = $\varnothing_2$ = **b =** **h =**

   Return tower height: $\varnothing_1$ = $\varnothing_2$ = **b =** **h =**

   e = __________ %

SOL SPIN

1. How many passengers is this ride capable of carrying?

2. Who among the riders experience the greatest tangential velocity and when does this occur? Assuming the riders each have a mass of 60 kg, what must be the minimum mass of the "counterweight" at the end of the opposite arm?

3. Describe the reason why passengers are seated sequentially in their relative locations by the ride operators?

HangTime

1. Assuming the distance of the track is 2,200 ft, what is the average speed of the ride in m/s?

2. One of the five gravity defying inversions you experience on this ride is known as an "Immelman". Describe this maneuver.

3. Using the video app on your cellphone, estimate the time for the riders to pass a point at the bottom of the first drop?

4. What is the length of the "HangTime"?

5. Knott's Berry Farm Physics day averages 3,000 students estimate the number of hours would be required, under optimal conditions, for all students to ride HangTime?

Wipeout

1. From the rider's perspective, does the ride rotate/revolve and move in a clockwise/counter clockwise direction? Circle the correct answers.

2. Measure the maximum tilt angle obtained by the riders.

3. Estimate the number of complete "cycles per second"?

4. Calculate the angular speed, in rad/s, of passengers at a distance of 3.5 meters from the center.

5. Convert your answer in question #4 to their tangential speed in m/s?

Timber Mountain Log Ride

Equipment Needed: Inclinometer, stopwatch, accelerometer, and measuring tape

1. Estimate the number of riders to ride the log ride as of its 30th anniversary on July 11, 1999 (Assume the ride is operational 340 days a year for an average of 10 hours per day).

2. Knott's reports that the water's path is 670 rn in length. What is your average velocity on the trip?

   Time used =

   V_{avg} = ________

3. Determine the height and angle of the outside chute at the end of the

   $\varnothing_1$ = $\varnothing_2$ = b =

   h = ________

   $\varnothing$ = ________

4. Using conservation of energy, estimate the speed at the bottom of the outside chute. Show your work.

5. The weight of a log is 2224N. Estimate the momentum of a fully loaded log at the base of the outside chute. Show your work.