30th ANNUAL
AMUSEMENT PARK PHYSICS TEST

Wednesday, May 17, 2017

and

Tuesday, May 23, 2017

at

Kennywood

ED HENKE
PHYSICS TEACHER-RETIRED
PITTSBURGH PUBLIC SCHOOLS
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# Table of Contents

<table>
<thead>
<tr>
<th>Rule</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules</td>
<td>3</td>
</tr>
<tr>
<td>Suggestions</td>
<td>4</td>
</tr>
<tr>
<td>Statistics for Physics Calculations</td>
<td>5</td>
</tr>
<tr>
<td>Scoring Rubric for Fermi Questions</td>
<td>6</td>
</tr>
<tr>
<td>Kennywood Fermi Questions</td>
<td>7</td>
</tr>
<tr>
<td>Aero 360</td>
<td>11</td>
</tr>
<tr>
<td>Black Widow</td>
<td>12</td>
</tr>
<tr>
<td>Cosmic Chaos</td>
<td>14</td>
</tr>
<tr>
<td>Exterminator</td>
<td>16</td>
</tr>
<tr>
<td>Gran Prix</td>
<td>17</td>
</tr>
<tr>
<td>Jack Rabbit</td>
<td>20</td>
</tr>
<tr>
<td>Kangaroo</td>
<td>22</td>
</tr>
<tr>
<td>Log Jammer</td>
<td>23</td>
</tr>
<tr>
<td>Noah's Ark</td>
<td>24</td>
</tr>
<tr>
<td>Garfield’s Nightmare (Old Mill)</td>
<td>26</td>
</tr>
<tr>
<td>Paratrooper</td>
<td>29</td>
</tr>
<tr>
<td>Phantom’s Revenge</td>
<td>30</td>
</tr>
<tr>
<td>Pirate</td>
<td>33</td>
</tr>
<tr>
<td>Pittsburg Plunge</td>
<td>34</td>
</tr>
<tr>
<td>Racer</td>
<td>35</td>
</tr>
<tr>
<td>Raging Rapids</td>
<td>37</td>
</tr>
<tr>
<td>Sky Coaster</td>
<td>38</td>
</tr>
<tr>
<td>Sky Rocket</td>
<td>40</td>
</tr>
<tr>
<td>SwingShot</td>
<td>42</td>
</tr>
<tr>
<td>Thunderbolt</td>
<td>43</td>
</tr>
<tr>
<td>Turtle</td>
<td>45</td>
</tr>
<tr>
<td>Volcano</td>
<td>46</td>
</tr>
<tr>
<td>Whip</td>
<td>48</td>
</tr>
<tr>
<td>Inclinometer</td>
<td>50</td>
</tr>
</tbody>
</table>
RULES

• Observe all posted rules and regulations.

• You must not interfere with the safe operation of any ride.

• Do not toss, throw, drop, or otherwise cause any object to fall from any ride.

• Amusement Park Accelerometers sold by PASCO Scientific and CENCO Scientific are permitted (except on the SWINGSHOT) on the condition that each accelerometer has a lanyard attached to it.

• Any student using an Amusement Park Accelerometer MUST attach the device to their wrist with the provided lanyard.

Due to the extreme nature of the SWINGSHOT, Kennywood prohibits ALL carryon items.

Failure to comply with these rules or any instructions given by Kennywood employees will result in immediate expulsion from Kennywood Park and the loss of your admission fee.
SUGGESTIONS

• Bring a 10 meter piece of twine or string with you. Mark off any distances on the string that you want. This makes a very compact "tape measure."

• Know the average length of your stride. This becomes very useful in estimating distances.

• On all wooden roller coasters, the distance between each successive horizontal beam is the same, the vertical wooden columns are also uniformly spaced.

• The radius of the Thunderbolt curve at the bottom of the ravine is 100 FT. or approx. 30.8 meters.

• Know your mass.

• Mass of a Gran Prix car is approximately 182 kg. The masses of the riders are important.

• A Stopwatch or clock able to measure seconds is extremely useful.

• Information and data on the PHANTOM’S REVENGE is supplied with the ride questions.

SOME USEFUL EQUATIONS

\[ C = 2\pi r \]

\[ v_{\text{avg}} = \frac{s}{t} \]

\[ C = \pi d \]

\[ a = \frac{\Delta v}{\Delta t} \]

\[ a_c = \frac{v^2}{r} \]

\[ F_c = ma_c \]

\[ F_c = \frac{mv^2}{r} \]

\[ K.E. = \frac{mv^2}{2} \]

\[ P.E. = mgh \]

\[ \text{Area} \]

\[ \text{Ft} = mv \]

\[ v = Rg \tan \theta \]

\[ v_f = v_i + at \]

\[ v = f\lambda \]

\[ s = v_i t + \frac{1}{2} at^2 \]

\[ T = \frac{1}{f} \]

\[ 2as = v_f^2 - v_i^2 \]

\[ f = \frac{1}{T} \]
PHANTOM'S REVENGE
Length ...................................................... 3500 feet of track
Biggest Drop .............................................. 232 feet
Highest Point above ground ....................... 160 feet (lift hill)
Top Speed .................................................. 85 mph
Train Weight ............................................. approximately 1,100 lbs.
Train Length ............................................. 60' 6"
Ride Time .................................................... 2 min 15 sec (includes 30 sec. to change passengers)

JACK RABBIT
Length ...................................................... 2200 feet of track
Top of Incline ............................................. 48 feet
Top Speed .................................................. 40 mph
Train Weight ............................................. 4,200 lbs. (3 cars @ 1400 lbs. ea)
Train Length ............................................. 30' 6"

RACER
Length ...................................................... 5,300 feet of track (2650 each train)
Highest Point above ground ....................... 70 feet
Top Speed .................................................. 45 mph
Train Weight ............................................. 6,800 lbs. (4 cars @ 1700 ea)
Train Length ............................................. 59' 6"0

THUNDERBOLT
Length ...................................................... 3,100 feet of track
Highest Point above ground ....................... 60 feet
Top Speed .................................................. 48 mph
Train Weight ............................................. 7,200 lbs. (4 cars @ 1800 ea)
Train Length ............................................. 38 feet

LOG JAMMER
Length ...................................................... 1,563 feet
Highest Point above ground ....................... 40 feet
Train Weight ............................................. 300 lbs.

SKY ROCKET
Length ...................................................... 2100 feet
Maximum height .......................................... 95 feet
Max Speed .................................................. 50 mph, 22.2 m/sec
Acceleration time ....................................... 3 seconds.
Empty Train weight ..................................... 6200 lb. (mass = 2818 kg)
Average mass of 1 person ......................... approx. 70kg (wt. =154 lb.)
2 cars in the Sky Rocket Train
6 People ride each car
SCORING RUBRIC FOR FERMI QUESTIONS
Kennywood Physics Test

A. Identifies all numbers
   Shows all calculations
   Explains calculations with a word equation or dimensional analysis.
   Process is clear

B. Identifies most numbers
   Shows most calculations
   Explains calculations with a word equation or dimensional analysis.
   Process is clear

C. Identifies more than half the numbers
   Shows calculations
   Process is clear

D. Attempted to answer but the answer is just numbers.
   The process is not clear

E. No attempt to answer the question
FERMI QUESTIONS

SOME INFORMATION THAT MIGHT ASSIST YOU:
- Kennywood is open about 112 days a year
- Kennywood is open 11 hours a day
- Base your estimates on observations. Do not guess!!

JUSTIFY ALL YOUR ANSWERS (Give reasons for your answers!)

1. MILK BOTTLE STAND  Estimate how many baseballs are thrown at the milk bottles in the course of one day.

2. LAGOON  Use a pre-measured string to get the approximate dimensions of Kennywood Lagoon. Sketch the lagoon here.
   Estimate the area of the lagoon by dividing the lagoon surface into several geometric shapes and calculating the area of each geometric shape.
   If the lagoon is an average of 0.6 meters deep, how many cubic meters of water does the lagoon hold?
   One milliliter of water has a mass of 1 gram. Estimate the total mass of the water in Kennywood lagoon.
   What is the weight of the water in newtons?

3. PICNIC TABLES  Estimate the number of picnic tables in Kennywood. DO NOT GUESS!
   If a gallon of paint covers an area of 500 ft$^2$ (46.38 m$^2$), how many gallons of paint would be needed to paint all the picnic tables in Kennywood?

4. NOAH'S ARK  Estimate the distance traveled by the left end of the Ark since 1950.
   (see the question on Noah's Ark)

5. Estimate the distance between the surface of the lagoon and the top of the tower on the lagoon stage

6. What is the approximate number of pepperoni slices that are used per day at the pizza restaurant next to Kiddieland?

7. Estimate the number of french fries sold today at the Potato Patch.

8. Estimate the number of railroad ties that are used to support the track of the Kennywood Railroad

9. Estimate the approximate distance traveled by the stationary tiger on the outside edge of the Merry-Go-Round in one year?  (Kennywood is open about 112 days a year and 11 hours a day.)

10. Estimate the number of funnel cakes sold today at the funnel cake stand.

11. Estimate the number of blades of grass in the lawn surrounding the clock near the Kennywood Railroad.

12. Estimate the total number of passengers the Phantom's Revenge could carry during one year of operation.

13. Estimate the number of shingles on the roof of the Parkside Terrace Restaurant Building.

14. Estimate the number of grains of salt on all of the soft pretzels sold today in Kennywood.

15. Estimate the total distance walked by all the guests at Kennywood Park this year.

16. If you look in the vicinity of the Merry Go Round, you will find a large, almost circular building housing a yogurt stand and several other food stands. This is the Carrousel Food Court. It has an interesting set of roofs. Estimate the total volume of the building from the ground to the roofs!
17. Assume that a bundle of Cotton Candy could be completely unwound into a single very long thread of Cotton Candy. Estimate the length of the Cotton Candy thread!

18. Estimate the total number of little rocks that are required to construct all the asphalt walkways within Kennywood. You **MAY NOT** pick pieces out of the walkways.

19. Stand by the tables near the Potato Patch. Look at the Thunderbolt. Near the top of the highest track you will see the bullwheel. This wheel is the wheel at the top end of the chain that pulls the Thunderbolt trains up the hills. You will notice that this wheel turns continuously. Estimate the number of revolutions made by the bullwheel since the Thunderbolt opened in 1980.

20. There is a refreshment stand near the Potato Patch. At this stand, you can find a local delicacy know as a Corn Dog on a Stick. Estimate the total surface area of all the corn dogs sold in the last 20 years.

21. Many people order some type of food covered in melted cheese. These foods include backed potatoes, french fries, and taco chips. Estimate the number of gallons of melted cheese used in one season at Kennywood.

22. Look around until you find the Pagoda in Kennywood. One of the foods sold here is Hot Sausage. The sausage is made in bulk form. Bulk form means that the sausage is made in a LONG continuous tube. The hot sausage tube is cut to size before it is cooked. Estimate the length of the line of hot sausage you would have if all of the bulk hot sausage that Kennywood buys this season was unrolled and placed end to end.

23. Estimate the number of leaves found on all of the trees within Kennywood. Do not forget the picnic groves and the areas between the groves and the rides.

24. Estimate the number of incandescent light bulbs in use at Kennywood.

25. Estimate the number of gallons of water that evaporate into the air, in one season, from the clothing, shoes, and hair of people that get wet on the Raging Rapids and the Log Jammer.

26. Estimate the number of gallons of waffle batter needed to make all of the Belgian Waffles sold in one season.

27. Estimate the gallons of ice cream used on the Belgian Waffles sold in one season.

28. The drivers of the bumper cars on the Gran Prix are not known for their ability to avoid collisions. Estimate the number of collisions occurring during one season.

29. How many grams of graphite are used by the all the physics students in calculating the answers to the Fermi Questions?

30. How many INDIVIDUAL Dippindots does Kennywood serve in one day?

31. In one season, how many seconds of free fall are experienced by all the riders of the Sky Coaster?

32. How many paper cups are used at Kennywood in one season?

33. How many trashcan liners are used at Kennywood in one season?
34. What is the speed of the water that shoots straight out of the central nozzle of the fountain by the Pizza Warehouse?

35. In one year, how many square feet of ice cream is covered with chocolate coating at the Golden Nugget?

36. How many gallons of water are used to flush Kennywood's toilets in one season? (Assume one flush per use.)

37. Estimate the number of bolts needed to build the lift hill of the Phantom's Revenge.

38. Estimate the speed of the Phantom's Revenge while it takes one minute to climb the 160 ft. high lift hill.

39. Estimate the linear feet of pipe needed to build the supporting structure of the Phantom's Revenge lift hill.

40. How many coins are dropped on the Pirate Ship in one year?

41. Estimate the number of complete trips made by an individual Racer Train in one year? (A complete trip is defined as traveling over the entire length of the Racer course. NOTE-A single ride on the racer travels only one-half of the Racer’s track)

42. Estimate the number of gallons of Pepsi (all versions) sold in one year at Kennywood. How many, 5000 gallon, tank trucks would you need to carry this much Pepsi?

43. Estimate the number of ice cubes Kennywood uses in one season.

44. How many Potato Patch Fries would be used if they were laid end to end, from the beginning of the Phantom’s Revenge Entrance Ramp to the edge of the Phantom’s Revenge loading platform?

45. Estimate the number of pieces of chewing gum resting on the roof beside the Phantom’s Revenge loading ramp.

46. Estimate the number of popcorn kernels, found in all the boxes of popcorn on in the park today.

47. Estimate the number of people wearing sandals in Kennywood today?

48. Estimate the distance traveled by the riders on the Swingshot during one ride. The arm is 52 feet (15.3m) long from the center of the axle to the passengers’ center of gravity. The SWINGSHOT swings upward 110 degrees to each side of vertical before coming to a stop at the end of the arc.

49. Estimate how many people would be able to stand inside the Penny Arcade during a rain storm.

50. Estimate the time used in one summer to load all the passengers onto the Sky Rocket.

51. Chains support the Wave Swinger seats. How many links are used to manufacture all the chains?

52. For more than 50 years, a cutout of the front of a railroad train has rocked side to side in the area to the left of the Kennywood Railroad. Estimate how many complete rocking motions the cut out makes in one season.

53. Shelter 23 (next to the Log Jammer) is the former location of the Whip. Estimate how many rivets were used to assemble the steel supports for Shelter 23.

54. A circular water fountain is located between the AERO 360 and the Pizza Restaurant. The fountain shoots a vertical water column from the center of the fountain. Calculate the speed of the water column as it leaves the nozzle.

55. In one hour, what is the volume of water flowing out of the fountain in Lost Pittsburgh?
56. Estimate the horizontal force exerted on the glasses of a Phantom’s Revenge Rider traveling at 37.90 m/sec. (see the Phantom’s Revenge information on Page 50) by a 1 gram rain drop that is falling vertically.

You will need to make some assumptions to solve this problem.  Clearly state these assumptions.

Would a 1 gram beetle exert the same force if it bounced off of the glasses and was not damaged? Estimate the force exerted by the beetle. Clearly state your assumptions and your reasoning.

57. The Black Widow Ride has a metal loading platform. That moves away from the center of the ride before the ride begins operation. The loading platform is made up of a number of metal Trapezoids. 

\[ \text{Area}_{\text{trapezoid}} = \frac{(a+b)}{2} \times h \]

**Estimate** the area of the loading platform.

Include an explanation of how you estimated the trapezoidal dimensions.

58. At the Black Widow, **estimate** the speed of one of the metal loading platform trapezoidal sections as it is moves away from the ride before it begins operation.

Include an explanation of how you estimated the distances moved.
AERO 360

The Aero 360 took the place of the Wonder Wheel at the beginning of the 2000 season.

The Aero 360 built by Zamperla, Inc. of Parsippany, NJ; whirls 24 riders counter clockwise in a vertical circle while 24 additional riders travel clockwise in another vertical circle. All riders are turned upside down as they go over the top of the circle.

Each arm carries a 24 passenger gondola and a counter weight. The gondolas and passengers weigh more than the counterweights.

Devise and explain a method for measuring or calculating the radius of the circle traveled by the riders.

Use your method to determine the passengers' radius. Show your work here.

The passengers travel along the circumference of a large circle. Show how you would calculate the circumference of the circle.

The Aero 360 moves at a constant speed.
Do the riders experience a constant centripetal force along the entire circular path?

Explain the reasons for your answer.

Verify the answer to the centripetal force question and explain how you did the verification.
The Black Widow swings the rotating passenger gondola riders back and forth. At the fullest extent of the pendulum motion, the rider farthest from the ground is 147 feet (44.8 m) above ground level and the pendulum has swung 120° from vertical. At the lowest point the pendulum is traveling at 68 miles per hour (110 km/hr)

Estimate the length of the pendulum.

Using the equation for the period of a pendulum, \( T = 2\pi \sqrt{\frac{l}{g}} \), calculate the period of a pendulum from your estimated length.

Measure the period of the pendulum. Why is the measured period so different from the calculated period.

What is the gravitational potential energy of a 100 kg rider at 44.8 meters above the ground?

What is the kinetic energy of the rider at the lowest point on the arc of travel?

The kinetic energy should theoretically be equal to the gravitational potential energy. Why are they different?

The rider experiences a rotation sitting in the gondola and a swinging pendulum motion.
Identify the number of accelerations experienced by the rider.

Identify which, if any, of the accelerations are not constant and explain why you believe this to be true.

How does the rotating gondola apply a centripetal force to the passengers?

Estimate the radius of the gondola.

Calculate the circumference of the gondola.

Measure the gondola’s period of rotation.

Calculate the tangential speed of the rotating gondola.

Calculate the centripetal force applied to the 100 kg. rider and express it in terms of the riders weight.

Will all riders experience the same sensations while the pendulum is at its highest point above the ground?

EXPLAIN
COSMIC CHAOS

Cosmic Chaos combines multiple motions in one ride.

Describe all the motions each rider experiences during the operation of the ride.

Draw and label a free body diagram of the ALL the forces acting on a person sitting at the highest point, A1, at position A.

Draw and label a Free Body Diagram of ALL the forces acting on a person sitting at the lowest point, A2, at position A.

What is the difference in the free body diagrams of the forces acting at the A1 and A2 at position A?

At which point, A1 or A2 is more centripetal force applied by the seat? Explain why this is so.

Draw and label a free body diagram of the ALL the forces acting on a person sitting at position B.
How are the forces at point B different from the forces at points A1 and A2? How does this affect the rider’s experience?

How many velocity vectors does the rider have?

Do the individual velocity vectors produce an increased or decreased resultant velocity when added?

Explain how this occurs.

Does the sum of the velocity vectors approach or equal zero at any point on the ride?

Explain how you determined this?
EXTERMINATOR

Background Information
Track length is 420 meters
The curves or turns are NOT banked. Vertical and horizontal accelerometers work well on this ride.

Good Luck, this is a dark ride!!

What are the maximum accelerations that you were able to produce in the vertical and horizontal directions?

You and a group of friends can increase or decrease the speed of the individual Exterminator cars. Describe a process that you use to increase or decrease the speed of the Exterminator.

How could you and our friends increase or decrease the vertical acceleration of the Exterminator car?

Describe a process by which you can decrease the rate at which your car spins.

Describe a process by which you can increase the rate at which your car spins.

How could you and your friends increase or decrease the horizontal accelerations of the Exterminator car? Identify the physics principals used to change the horizontal accelerations.
GRAN PRIX

With a group of friends, estimate the dimensions of the floor plates over which the cars drive in the Gran Prix.

Length = _________________  Width = _________________

WITH FRIENDS OUTSIDE OF THE RIDE

Use the floor plates to estimate the distance traveled by the cars.

Length (4 plates) = __________  Width (4 plates) = __________

Get the car up to speed and WITH FRIENDS OUTSIDE OF THE RIDE measure the average time needed to travel in a straight line across 4 plates.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
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<td>3</td>
<td></td>
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<tr>
<td>$T_1$</td>
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</table>

CALCULATE THE AVERAGE MAXIMUM SPEED! SHOW ALL WORK!!

AVG. MAX. SPEED = (DISTANCE TRAVELED ACROSS 4 PLATES)/$t_1$
WITH FRIENDS OUTSIDE OF THE RIDE, Measure the average time needed to accelerate to maximum speed.

<table>
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<tr>
<th>Trial</th>
<th>Time</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<td>2</td>
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<td>3</td>
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<tr>
<td>$T_2$</td>
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</tbody>
</table>

Calculate the acceleration of the car as it GAINS speed.

\[
\text{acceleration} = \frac{\text{change in velocity}}{t_2}.
\]

SHOW YOU WORK!!!

Check this acceleration with an accelerometer, if you have one.

Does the calculated value agree with the value from the accelerometer?

ACCELERATION = ________________.
Allow the car to coast to a stop in straight line from full speed.

WITH FRIENDS OUTSIDE OF THE RIDE.

MEASURE THE STOPPING TIME.

USE THE FLOOR PLATES TO ESTIMATE THE STOPPING DISTANCE.

FIND THE AVERAGE ACCELERATION OF THE CAR AS IT STOPS.

<table>
<thead>
<tr>
<th>$v_o$</th>
<th>Stopping distance</th>
<th>$t_{stop}$</th>
<th>$a$</th>
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<tbody>
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<td></td>
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<td></td>
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</table>

Use any of the following equations to calculate the acceleration of the stopping car:

$$v = v_o + at$$
$$s = v_o t + 0.5at$$
$$a = \frac{\Delta v}{\Delta t}$$

Check this acceleration with an accelerometer, if you have one.

Does the calculated value agree with the value from the accelerometer?

THE CAR'S NEGATIVE ACCELERATION IS _________________

If a Gran Prix car traveling at full speed strikes another car broadside and stops in 0.1 seconds, What is the force needed to stop the car???(Ft=mv)
JACK RABBIT

Describe the sensations that you felt while you rode the Jack Rabbit.

Did your body sense exactly what was going on? Explain.

Approximately how high above ground level is the bend in the track just before the double dip? (This bend is directly above the station.)

Estimate the vertical distance the Jack Rabbit drops in the first part of the "double dip". (You can observe this part of the ride from the path next to the Penny Arcade)

What additional distance does the Jack Rabbit drop in the second part of the "double dip"?

Estimate the speed of the Jack Rabbit at the bottom of the double dip.

Average speed = length of train/time for train to pass a fixed point

The mass of the train and its passengers is M. Calculate its Potential Energy at the top of the double dip.
Calculate the Kinetic Energy at the bottom of the double dip.

What has happened to the "lost" Potential Energy?

<table>
<thead>
<tr>
<th>JACK RABBIT</th>
<th>TRIAL 1</th>
<th>TRIAL 2</th>
<th>TRIAL 3</th>
<th>TRIAL 4</th>
<th>AVG.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height above ground level before the double dip</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Distance dropped in part 1 of double dip</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Distance dropped in part 2 of double dip</td>
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<td></td>
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<tr>
<td>Train Length</td>
<td></td>
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<tr>
<td>Time for train to pass a fixed point at bottom of double dip</td>
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<tr>
<td>TRAIN SPEED at bottom of double dip</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Potential Energy</td>
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<tr>
<td>Kinetic Energy</td>
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</tbody>
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The kangaroo travels around a circle at a constant speed. It takes its name from the ramp near the entrance gate. The ramp causes the cars to hop like kangaroos.

Experienced riders frequently put new riders into the cars at position #4 in the diagram.

Assume that all riders in the diagram have equal masses. Draw a free Body Diagram for each rider.

Are any of the riders in Equilibrium? Explain why or why not!

Why do the riders in position #4 experience more force that the other riders?
Log Jammer

The Log Jammer is a single car roller coaster with a little water thrown in for some excitement.

Ride the Log Jammer several times or observe others riding the Log Jammer.

Does the seating arrangement affect the final splash that is produced?

Does the seating arrangement affect the final speed of the car when it finally hits the pool of water?
Justify your answer.

What conditions produce the largest splash? Show sketches or calculations!

What conditions produce the smallest splash? Show sketches or calculations!

Is it possible to produce a splash so small that no one in the log gets wet?
Experiment and describe your results.
NOAH'S ARK

Noah's Ark has sailed Kennywood Park for many years. Without fail it has continued to rock upon unseen waves.

How long does it take to rock back and forth once? (Period of Oscillation)

Calculate how many times a minute the Ark rocks back and forth. (Frequency)

Estimate by any means that you can devise, the distance the end of the Ark rocks upward above the horizontal. (amplitude)

If a spring were stretched from the end of the Ark and generated only a transverse wave that had a speed of 3 meters per second, what would be the wavelength of the wave? (velocity=frequency x wavelength)
What would be the other characteristics of the wave?

What is the total vertical distance traveled by the end of the deck in one up and down motion?

Amplitude = _______________  Wavelength = _______________
Frequency = _______________
Period = _______________
After you enter Garfield’s Nightmare, the boat is lifted up and over a wheel. How high does the wheel lift the boat?

Explain how you obtained your answer!!!

Do you believe that the wheel is the only energy source that moves the boats?  

EXPLAIN!!

The 3-D glasses used in Garfield's Nightmare are diffraction gratings with the lines drawn vertically. The line arrangement is shown in diagram #1.
A diffraction grating is a piece of plastic or glass that has many, very closely spaced lines drawn or scratched on its surface. A diffraction grating is used to change the direction of a light beam. See diagram #2

If a diffraction grating has 1000 lines per centimeter.  
What is the distance between these lines?

Write your answer on the line that says d =  

Show your calculation here. Record your answer in the data table on the next page.

The diffraction gratings diffract (bend) light through a range of angles. The angle depends upon the wavelength of light entering the diffraction grating.

How does your brain interpret different wavelengths of light?  
Please answer in complete sentences.

Which colors appear closer to you when you wear the glasses?

Which colors appear farther away from you when you wear the glasses?
From the information you have been given, calculate the distance between the diffraction grating lines. Show your work below.
The wavelength of red light is $7 \times 10^{-5}$ centimeters.
The wavelength of blue light is $4 \times 10^{-5}$ centimeters.

The diffraction angle is the direction change caused by the diffraction grating. The diffraction angle is calculated using the equation $\sin q = \frac{l}{d}$

<table>
<thead>
<tr>
<th></th>
<th>$q$ diffraction angle (degrees)</th>
<th>$l$ wavelength (cm)</th>
<th>$d$ distance between lines (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue light</td>
<td></td>
<td>$4 \times 10^{-5}$</td>
<td></td>
</tr>
<tr>
<td>Red light</td>
<td></td>
<td>$7 \times 10^{-5}$</td>
<td></td>
</tr>
</tbody>
</table>

Label the red light beam and the blue light beam below on diagram #3

The 3-D Effect is a result of how your brain interprets the different diffraction angle for each color.

Using what you know about the physics of optics, how do you think your brain converts this angle difference into a 3-D Effect?
PARATROOPER

The paratrooper seats look like parachutes. These seats are attached to an inclined wheel that travels at a constant speed.

Describe the sensations at positions A, B, C, and D.

Do the riders travel at a higher speed at A than at C? Explain how you arrived at your answer.

Explain how the ride produces the different sensations at each position.
PHANTOM'S REVENGE

The Phantom's Revenge uses portions of The Steel Phantom. The first two hills were part of the Steel Phantom. The second hill now drops 232 feet into the Monongahela River Valley.

The graph on the next page gives some information about a portion of the Phantom's Revenge track and the ground under it. The information is given in the English System, the measurement system used during the construction.

Some useful information about the Phantom's Revenge
Highest drop = 232 ft. = 70.7 m
Top Speed = 85 miles / hour = 124.66 ft/sec = 37.90 m/sec
Ht. of first hill (lift hill)= 160 ft. = 48.77 m
Ht of second hill = 115 ft. = 35.05 m
Ride Time = 2 min 15 sec = 2.25 min. = 135 sec. (includes 30 sec to change passengers)
Distance traveled = 3500 ft. = 1066.8 m.
Each of the two trains carry 28 riders

If you assume that no energy is lost during the coasters descent to a lower elevation on the track, what is the amount of kinetic energy produced by the drop from the highest elevation shown and the lowest elevation shown?

Show all work here.
Ground and Track Elevations of a Portion of the Phantom's Revenge

- Ground Level (feet above sea level)
- TopOfTrack (Feet above sea level)
What would be the top speed of the Phantom's Revenge if there were no energy losses during the ride

Describe a method to calculate how many people can ride the Phantom's Revenge in one year. The explanation should be detailed.
PIRATE

The Pirate Ship is a good example of a pendulum. However, you must admit it is a little different than any you have seen at school.

Estimate the length of the pendulum.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Length</th>
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<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Length_{avg}</td>
<td></td>
</tr>
</tbody>
</table>

Measure the period of the pendulum.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Period_{avg}</td>
<td></td>
</tr>
</tbody>
</table>

Use the Equation:

\[ T = 2\pi \sqrt{\frac{l}{g}} \]

to calculate the period of the pendulum. SHOW ALL OF YOUR WORK!

If a difference exists between the measured period and the theoretical period, what do you believe is the reason for the difference?
PITTSBURG PLUNGE

1. Estimate the volume of water displaced by the loaded boat.

2. Estimate the weight or mass of the boat. Explain how you get this answer.

3. Estimate the speed of the boat as it enters the water. Explain how you get this answer.

4. Estimate how much water is in the wave and splash that is created when the boat slides down the hill into the water. Explain how you get this answer.

5. Is the amount of water in the wave and splash different from the amount of water displaced by the loaded boat as it sits in the water?
**RACER**

The Racer is a twin roller coaster that races one train against the other. Your task is to determine what makes one train faster than the other.

Watch or ride five or more races.

Time the individual trains along with another person or group of persons.

<table>
<thead>
<tr>
<th>THE RACER</th>
<th>TIME 1</th>
<th>TIME 2</th>
<th>TIME 3</th>
<th>TIME 4</th>
<th>TIME 5</th>
<th>TIME 6</th>
<th>TIME 7</th>
<th>TIME 8</th>
<th>RACES WON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train 1</td>
<td></td>
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<td>Train 2</td>
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<tr>
<td>Train 2</td>
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</table>

Does one train always beat the other train?

Does the winning train always finish on the left side or the right side of the platform?

Can you find any pattern to the way in which the trains win races?
If you see a pattern, does that pattern stay the same throughout the day? EXPLAIN

The train always finishes on the opposite side of the loading platform from where it started the race. The trains never cross paths. How do the trains "switch" to the other side and where does this occur?
RAGING RAPIDS

The Raging Rapids boats are loaded and unloaded from a rotating platform that turns at a constant speed.

Estimate the number of wooden planks that are needed to build the top surface of the rotating loading platform.

How many rotations per minute does the loading platform make?

Using the length of your stride, estimate the radius of the platform. (The foot of the stairway is at the center of the rotating platform.)

Calculate the circumference of the platform. \( C = 2\pi R \)

What is the tangential speed of the platform edge?

What **angular acceleration** do persons undergo as they walk from the inner edge of the rotating platform to the outer edge of the platform?

What **linear acceleration** do persons undergo as they walk from the inner edge of the rotating platform to the outer edge of the platform?

*Check this acceleration with an accelerometer, if you have one.*

*Does the calculated value agree with the value from the accelerometer?*
SKY COASTER

 Interesting Facts:
The bottom ends of the support towers are 60 feet apart (17.96 m).
The support towers are 189.5 feet high (56.74 m).
The launch tower is 180 feet high (53.89 m).
One to three people can ride simultaneously.
The launch tower is 187 (55.99 m) feet from the support towers.
The rider is 9.5 feet (2.84 m) above the tower base at the bottom of the arc.
The rider is 180 feet (53.89 m) below the top of the support tower at the bottom of the arc.

How fast should the rider be traveling at the bottom of the arc if there is no friction?

What percentage of the initial potential energy is not converted to kinetic energy?

Based upon your answer to the last question, what is the actual speed of the riders at the bottom of the arc?

What is the centripetal acceleration on the rider at the bottom of the arc?

How many "g's" does the rider experience at the bottom of the arc?
What is the ideal period of oscillation for the rider?

What is the actual period of oscillation?

Does the speed and period change from rider to rider?

If the speed and period change from rider to rider, what are the variables that affect the speed and period?
The Sky Rocket, Kennywood’s newest steel roller coaster, opened in June 2010. It is unique because it is the only roller coaster in the United States to use the roller coaster element known as a Cutback. The first element on the Sky Rocket is the Outside Top Hat. The Outside Top Hat can be seen in the right side of the picture above. The Sky Rocket enters the Cutback after leaving the Top Hat. The Cutback is a modified corkscrew that sends the Sky Rocket in the opposite direction from which it enters the Cutback. Only one other coaster in the world, Space Mountain: Mission 2 in Disneyland Paris, has a Cutback.

Most roller coasters use conventional rotary electric motors. These motors have a spinning rotor (armature) that consists of magnets that spin within the stator, a cylindrical combination of wire coils that produce a torque to spin the rotor.

The Sky Rocket uses a Linear Synchronous Motor (LSM) to launch the cars. A LSM is a flat electric motor that produces thrust instead of torque.

The cylindrical stator of a conventional electrical motor is opened and laid out flat to form the flat sheet stator of the LSM. Skyrocket’s stator is located under the tracks, next to the loading platform. The vertical white plate sticking up between the tracks next to the loading platform is part of the LSM stator.

Electric current moving through the LSM stator creates an electromagnetic field. There are permanent magnets connected to the bottom of the Sky Rocket train. The electromagnetic field pushes the permanent magnets along the track. Since the magnets are connected to the bottom of the Sky Rocket train, it moves forward along the track with the magnets.

The magnets serve as an equivalent of the rotor in conventional electrical motors.

LSM’s are also used to push trains, lift elevators, operate hydraulic cylinders, and replace chain and belt driven conveyor systems in factories.

You can find more information on Linear Synchronous Motors at http://www.magnemotion.com/technology/LSM/main.shtml
As you walk to the loading platform, estimate the length of the Stator (length of the vertical white plate between the tracks next to the loading platform). This is the distance traveled while the Sky Rocket train is accelerated.  

*(SHOW YOUR WORK HERE)*

Estimate the vertical distance between the tracks in the station and the tracks with the white plate, on the ground, next to the station.  

*(SHOW YOUR WORK HERE)*

Using the idea of conservation of mechanical energy (loss of potential energy = gain in kinetic energy), calculate the speed of the Sky Rocket as it starts to travel over the vertical white plate on the stator portion of the LSM. Remember, the Sky Rocket accelerates while over the stator.  

*(SHOW YOUR WORK HERE)*

Since you now know the speed as the acceleration begins, the speed when the acceleration ends (see the useful information at the beginning of this ride section), and the distance traveled while accelerating, calculate the acceleration of the Sky Rocket train.  

*(SHOW YOUR WORK HERE)*

How many g’s is this acceleration?  

*(SHOW YOUR WORK HERE)*

Since you now know the acceleration and can estimate the mass of the Sky Rocket train and passengers, calculate the Force (thrust) generated by the LSM.  

*(SHOW YOUR WORK HERE)*

Convert the accelerating force into pounds.  

*(SHOW YOUR WORK HERE)*
NOTE: Due to the extreme nature of the ride, Kennywood prohibits ALL carryon items.

This ride is a swing that carries 32 passengers.

The arm is 52 feet (15.3m) long from the center of the axle to the passengers’ center of gravity.

Top speed is 45 Miles per Hour at the bottom of the swing.

\[ (45 \text{ miles/hour}) = (66 \text{ ft per second}) = (19.41 \text{ m/sec}) = (69.9 \text{ km/hr}) \]

The SWINGSHOT swings 110 degrees from the vertical, to each side, before coming to a stop at the top of the arc.

The ride is pushed or pulled by mechanical devices throughout the entire length of the SWINGSHOT’s circular arc. The SWINGSHOT is not a gravity operated swing like the swings on a playground.

Calculate the centripetal force exerted on the riders at the bottom of the swing.

SHOW ALL YOUR WORK

Is this the centripetal force throughout the ride?

If this is not the centripetal force throughout the ride, estimate the rate at which the centripetal force changes as the ride operates. SHOW ALL YOUR WORK
Estimate the vertical distance through which the Thunder Bolt has dropped by the time it reaches the bottom of the ravine in which part of it is built.

Describe what you experience as the Thunder Bolt reaches the bottom of the ravine and begins to climb the other side of the ravine.

Use an accelerometer, if you have one.
Does the accelerometer give you any indication of what is occurring? EXPLAIN !!!

In the sketch, diagram and name the forces acting on your body at the bottom of the ravine.

Show the forces that act at point A.

A very rough approximation of the Thunderbolt's path as it drops into the ravine.

What is the relationship between the vertical forces?
Measure the time it takes to travel through the circular curve at the bottom of the ravine. The radius of the curve is 100ft. or approximately 30.8 m. Calculate the speed of the coaster with the following equation.

\[ v = \frac{s}{t} = \frac{0.5 \times 2 \times 3.14r}{t} \]

Calculate the Centripetal Acceleration that acts on your body at the bottom of the ravine. Check this acceleration with an accelerometer, if you have one. Does the calculated value agree with the value from the accelerometer? SHOW ALL OF YOUR WORK!

Calculate the centripetal force that acts on your body at the bottom of the ravine. SHOW ALL OF YOUR WORK!

How does this acceleration compare to the acceleration of gravity? (g = 9.8 m/s²)
The Turtle is one of the oldest rides in Kennywood.

Ride the Turtle a few times and sit in a different position each time: A, B, C and D.

The ride provides a different experience at each of the positions.

Draw a free body diagram of the forces for each of the positions. You view point should be as an observer standing outside the ride.

Which position provides the roughest ride? Why
VOLCANO

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

The suspended cars of the Volcano will swing out at some angle when they travel in a circle. The angle depends upon the radius of the circular path and the speed of the wheel. You will attempt to calculate the speed of the passenger cars by two methods.

One method states an equation without proof that can be used to calculate the speed of the passenger cars.

You are left on your own to calculate the speed of the passenger cars in any other manner that you choose.

One Method (You will have to observe 6 to 10 rides to get this data)
Estimate the radius of the circular path of the passenger cars at approximately 15 seconds after the ride starts.

\[ R = \text{_________} \]

Measure the angle that the passenger car makes with the perpendicular to the ground at approximately 15 seconds after the ride starts.

Use this equation to calculate the velocity of the wheel 15 seconds after the ride begins.
YOUR WAY

Calculate the velocity any other way that you wish. Justify your work!

<table>
<thead>
<tr>
<th>θ</th>
<th>R</th>
<th>v</th>
</tr>
</thead>
<tbody>
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</table>

\[ v = \sqrt{Rg\tan(\theta)} \]
**WHIP**

The Whip is one of the oldest rides at Kennywood Park. It has been moved twice to reach its current location. It was first moved to the picnic shelter next to the Log Jammer to make room for the Thunder Bolt. It was moved to its current location when Lost Kennywood opened.

The large sprocket wheels turn at a constant speed during the largest part of the ride. What do you think causes the effects you experience during the ride.

Estimate the average speed of the cars (m/sec) on the straight portions of the ride.
Distance traveled =
Time =
Average speed =

The average speed of the cars in the turns may be a little more difficult to determine. Carefully observe the floor. Do the cars always travel the same path? Sketch the path of the cars.

If anything is different in the turns? Describe the difference!

Based upon what you have just described, what should happen to the linear speed in the turns. **WRITE OUT THE ANSWER AND JUSTIFY YOUR ANSWER!!!**
Ride the Whip several times.
Describe, in writing, what your body feels during the ride.

Use an accelerometer, if you have one.
Does the accelerometer give you any indication of what is occurring? Explain.

Is your body fooled by the motion of the ride, or does your body correctly experience what is really happening. Justify your answer!!!
To Estimate a Height:

- Hold this paper vertically with the Sight Line at the top.
- Stand 10 meters from measured object.
- Sight the top of the object along the heavy black sight line.
- A string hung from Point C. will hang across the estimated height.

Note: Values assume 7 m is held 1.5 m above the ground.