PRE-IB PHYSICS	***GROUP #***
Name: ___________________________________	
Period: ________ Date: ___________________	

DEVIL PHYSICS

BADDEST CLASS ON CAMPUS

PHYSICS DAY AT BUSCH GARDENS

General Guidelines:

1. **Data collection is a group effort among your lab team. Completion of the lab is an individual effort. I expect to see identical data between the members of each group. I do not expect to see identical data on the reports of others outside your group and I do not expect to see identical or paraphrased answers on the final report.**
2. **Your signature at the end of your report affirms that the work on your report is your own. Any instances of cheating will be referred to the IB administrator for disciplinary action.**
3. **You are expected to collect data for the three primary rides assigned to your group. If one of the assigned rides is closed, you can substitute the 4th ride for the closed ride. There is no excuse for completing the data collection on your assigned rides. Failure to collect the required data will result in a reduced grade on your final report. Once you have completed the data collection for your assigned rides, you are free to do whatever you want to do until departure time.**
4. **If you do not like to ride roller coasters, you may use the data collected from your teammates.**
5. **Attach the Data Collection Worksheet you used to collect data at Busch Gardens to the back of this report.**
6. **Remember to consult the PIB Physics Day Data Guide when appropriate.**

Names of Lab Team Members			

Scorpion Worksheet

INSTRUMENTS REQUIRED:
Vertical Accelerometer, Stopwatch

Prior To Physics Day

1. Problem: If a coaster train of length 15m passes a point at the bottom of the hill in 0.75 seconds, how fast is the coaster moving?

   ____

2. Prediction: The Scorpion hill is about half the height of the Montu hill. If the Montu achieves a speed of 60 mph, what will be the approximate speed of the Scorpion?

	20 mph		30 mph		40 mph		50 mph		60 mph

3. What will be the maximum g-force experienced on the Scorpion?

	2.0 g's		2.5 g's		3.0 g's		3.5 g's		4.0 g's

What To Measure On The Ride

1. Measure the g-force at the bottom of the first hill.
2. Measure the g-force at the top of the vertical loop.
3. Measure the g-force while moving through the top horizontal loop.
4. Notice whether you ever felt upside down.
5. Do you feel pushed to the side

What To Measure Off The Ride

1. Measure the time for the coaster to pass a point at the bottom of the first hill.
2. Estimate the banking angle in the two horizontal loops near the end of the ride (use the estimates of two of your lab partners in addition to your own).

Data Table

	Trial #1	Trial #2	Trial #3	Average
Measured On The Ride				
G-Force at Bottom of First Hill				
G-Force at the Top of the Vertical Loop				
G-Force in the Top Horizontal Loop				
Measured Off The Ride				
Time to Pass a Point at the Bottom of the Hill				
Banking Angle Estimate				

Questions

1. As the coaster goes into the banked turns, do you feel pressed up against the sides of the car or do you feel you're sitting upright? If you feel pressed up against the sides, indicate whether you're pressed against the inside or the outside of the turn. Why is the banking angle so critical?

____

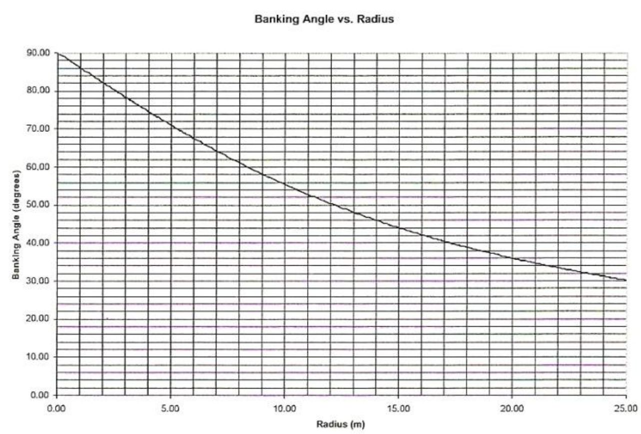
____

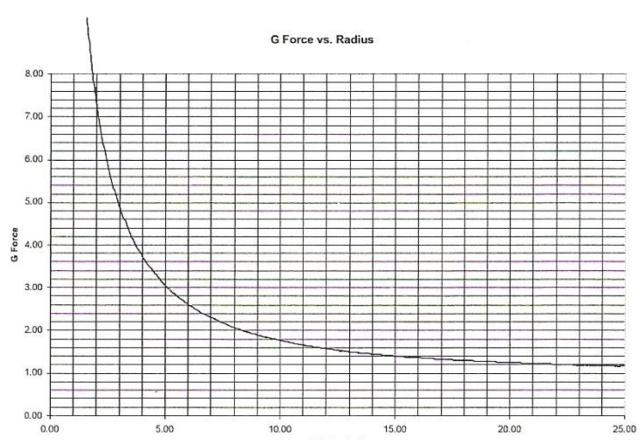
Problems

1. Using the measurement of the time to pass a point at the bottom of the hill, compute the speed of the coaster at the bottom of the hill. The length of the coaster is 10.7m.

____

____





2. The graphs above indicate the banking angle of the carrousel (the horizontal circles near the end of the Scorpion), and the g-force experienced there. These graphs are based on the actual speed of the coaster in those turns.

a. The actual radius of the carrousel is 8.1 meters. According to the graphs, what should the banking angle be?

____

b. How close does this come to your estimate of the banking angle?

____

c. What is the g-force associated with this radius of 8.1 meters?

____

d. How does that compare with your measured value of G?

____

e. How does it compare with the value from the graph of G-Force vs. Time found in the PIB Physics Day Data Guide?

____

f. If the radius is doubled to 16.2m, what happens to the banking angle and g-force?

____

g. If the radius is cut in half to 4m, what happens to the banking angle and g-force?

____

h. What banking angle corresponds to a g-force of 5?

____

i. What is the smallest radius of curvature that would be safe? What is your criteria for "safe"?

____

3. The graph of G-Force vs. Time in the PIB Physics Day Data Guide was produced with a CBL and TI-83 calculator and a Low-g accelerometer probe.
   a. How do your g-force readings for the bottom of the first hill and the top of the vertical loop compare to the graph?

   ____

   b. How long does the graph indicate that you felt heavy (greater than 2 g's) in the carrousel?

   ____

Montu Worksheet

INSTRUMENTS REQUIRED:
Stopwatch (No instruments allowed on the ride

Prior To Physics Day

1. Prediction: Will you ever leave your seat when you are upside down?

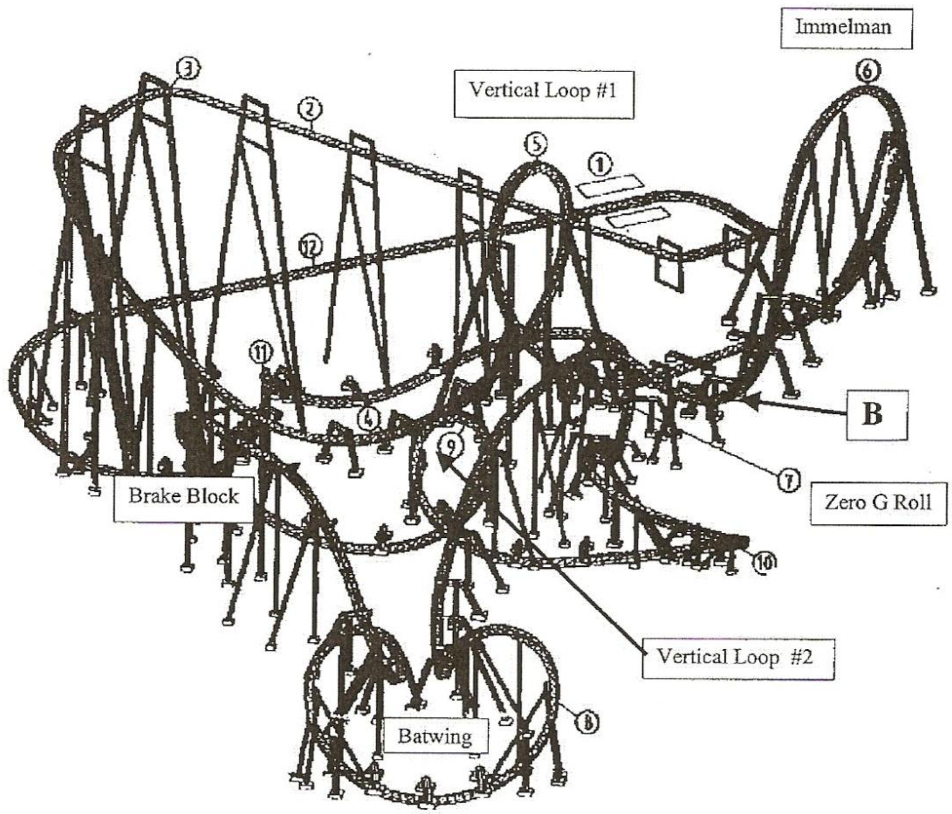
	YES		NO

2. Prediction: Where will the heaviest feeling on the ride be experienced (see description next page)?

	Top of the Vertical Loops		Top of the Immelman Zero-G Roll		
	Middle of the Batwing		Bottom of the First Hill		Brake Block

3. Problem: Given that the coaster is 11.6m long, find its speed if it takes 0.75 seconds to pass a post?

____



The Montu is known as an inverted roller coaster. It features a 40.0 m first drop; seven inversions; a maximum g force of about 4, and approximately seven occasions where the g force exceeds 3; and a zero g roll, where passengers come close to weightlessness. In the 27 m tall Immelman, named after a German stunt pilot, the riders start over the top of the loop in an inverted position and then are rotated 180 degrees to an upright position as they come down the loop. In the Batwing, riders go over the top of both loops upside down, disappearing underground in the middle. With maximum speeds over 60 miles per hour, one of the largest-ever vertical loops on an inverted coaster (32 m), ¾ mile of track, and the whole experience being spent seated under the track with your feet dangling, the Montu is an intense experience.

What To Notice On The Ride

1. Pay attention to your feelings when you are upside down. Do you ever leave your seat? Do you "feel" upside down?
2. Where on the ride do you feel the heaviest? Sit in the second row and check the G-Force Meter to find the heaviest point. Record the actual g-force and the place where it occurred.
3. Where on the ride do you feel heavy for the longest period of time? Where on the ride did you feel normal?
4. Ride once near the front of the coaster and once near the rear. Notice the differences

What To Do Off The Ride

1. Measure the time for the coaster to pass the top of the second vertical loop (#9). Start the stopwatch when the front of the front car reaches the top of the loop and stop the stopwatch when the back of the last car reaches the top of the loop

Data Table

Measured On The Ride	**Trial #1**	**Trial #2**	**Trial #3**	**Average**
Maximum G-Force				
Location of Maximum G-Force				
Measured Off The Ride	**Trial #1**	**Trial #2**	**Trial #3**	**Average**
Time to Pass the Top of the Second Vertical Loop				

Questions

1. Describe the places on the ride where you felt normal and explain why. Where did you feel the heaviest? Where did you feel the lightest?

____

____

2. Explain you experiences in the inversions. Which of them felt light? Did you ever leave your seat?

____

____

3. At the bottom of the first drop, the speed is 27 m/s. Just before the flat spin at the end of the ride, the speed is 18 m/s. The g-force at both places is 3.4. How can the force be so strong at the end of the ride when the speed is much slower?

____

____

4. Why is the second vertical loop much smaller than the first vertical loop?

____

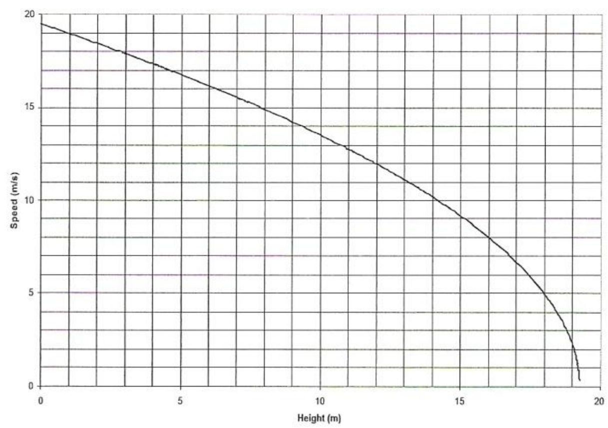
____

5. How is riding in the front car different from riding in the last?

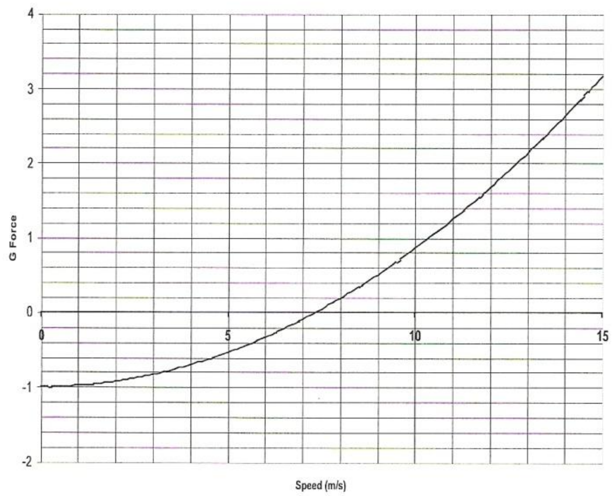
____

____

Speed vs Height



G Force vs Speed



Problems

1. Using the average time for the coaster to pass the top of the vertical loop, compute the speed at the top of the second loop. The coaster length is 11.6 meters.

   ____

   ____

2. The graphs above represent the top of the second vertical loop (#9). The top graph indicates how the speed at the top of the loop depends upon the height of the loop above the ground level. (The actual loop is 13m above the ground level with the base of the loop in a trench 6 meters deep.) The bottom graph indicates how the force factor at the top of the loop depends upon the velocity at the top with a fixed radius of 5.5m.

   a. What range of velocities would produce a light feeling at the top of the loop (g-force less than 1 and greater than 0)?

      ____

   b. What is the minimum velocity required to get the coaster through the loop without it falling off? ____________

   c. Find the height of a loop for which this minimum value of velocity is obtained. ____________________

   d. What height of the loop would prevent the coaster from reaching the top? ______________________

   e. A coaster designer has proposed to redesign the loop with a height of 8 meters. What would be the velocity at the top and the resulting g-force at the top? ________________________________

3. Answer the following questions based on the graph of G-Force vs. Time at the end of the PIB Physics Day Data Guide.

a. Where on the ride will you feel normal? ____

b. Which points on the ride have the greatest g-forces? ____

c. Where is the g-force the greatest, and how does this compare with your guess? ____

d. On which upside-down point do you experience the lowest g-force? ____

e. On which upside-down points do you feel heavier than normal? ____

f. How do these graphical readings compare to your experiences? ____

Ubanga-Banga Bumper Cars Worksheet

INSTRUMENTS REQUIRED:
Horizontal Accelerometer, Stopwatch

Prior To Physics Day

1. Prediction: When you strike a car from the rear, you feel pushed:

	Forward		Backward		Left		Right

2. Prediction: When you are struck from the rear, you feel pushed:

	Forward		Backward		Left		Right

3. Prediction: When you are struck on the left side, you feel pushed:

	Forward		Backward		Left		Right

4. Prediction: When you strike a car on its side, you feel pushed:

	Forward		Backward		Left		Right

5. Prediction: Running into the back of a car that is stationary will have a ***larger*** / ***smaller*** g-force than running into the back of a car that is moving in the same direction as you.
6. Prediction: When you strike a car on its side, you feel pushed:

	3 mph		5 mph		7 mph		9 mph

What To Measure On The Ride

1. Using the Horizontal Accelerometer, measure the maximum angle to which the balls deflect in a collision with a stationary car. (Hold the Horizontal Accelerometer parallel to your direction of motion.) Note both the magnitude and direction of the motion of the balls in the tube. Pay attention to striking and also to being struck.
2. Using the Horizontal Accelerometer, measure the maximum angle to which the balls deflect in a collision with a car that is travelling in the same direction as you are. (Hold the Horizontal Accelerometer parallel to your direction of motion.) Note both the magnitude and direction of the motion of the balls in the tube. Pay attention to striking and also to being struck.
3. Pay attention to the motion of the balls when you are struck from the side. In that situation, you will need to hold your horizonal accelerometer parallel to the direction of the car striking you.

What To Measure Off The Ride

1. Measure the time it takes the cars going full speed to pass between two posts.

Data Table

	Trial #1	Trial #2	Trial #3	Average
Measured On The Ride				
Stationary Collision Angle				
Stationary Collision Deflection				
Moving Collision Angle				
Moving Collision Deflection				
Measured Off The Ride				
Time Between Posts				

Questions

1. Using the chart below, determine the horizontal g-forces associated with your stationary and moving collisions

   Stationary: ______________________________

   Moving: ______________________________

Angle	20	25	30	35	40	45	50	55	60
G Force	0.4	0.5	0.6	0.7	0.8	1.0	1.2	1.4	1.7

2. How does the force of being hit compare with the force of hitting?

   ____

3. When you strike a car from the rear, you feel pushed:

	Forward		Backward		Left		Right

4. When you are struck from the rear, you feel pushed:

	Forward		Backward		Left		Right

5. When you are struck on the left side, you feel pushed:

	Forward		Backward		Left		Right

6. When you strike a car on its side, you feel pushed:

	Forward		Backward		Left		Right

7. Which of the following conditions would produce greater forces? (check all that apply)

	Harder bumpers		Softer Bumpers		Higher Speeds		Lower Speeds

Problems

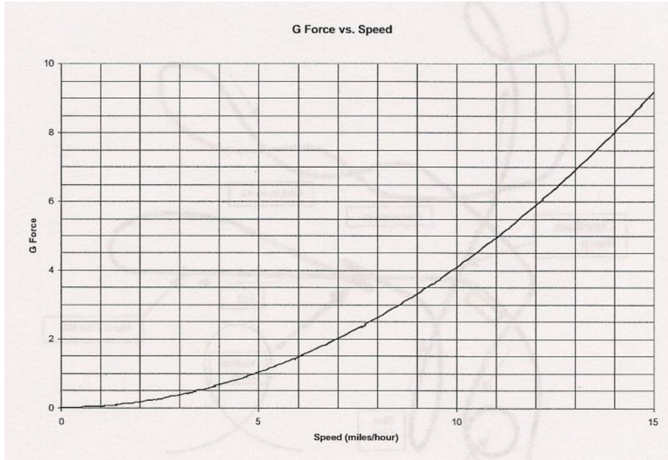
1. Using the time between posts, compute the speed of the bumper cars in m/s. The posts are 7.6m apart.

   ____

2. Compute the speed in miles/hour by multiplying the m/s speed by 2.24.

   ____

3. The graph below indicates the relationship between the g-force in a stationary collision between bumper cars and the speed of the collision. This graph assumes that the final speed is zero.



a. What happens to the force of the collision when the speed is doubled?

____

b. What happens to the force of the collision when the speed is quadrupled?

____

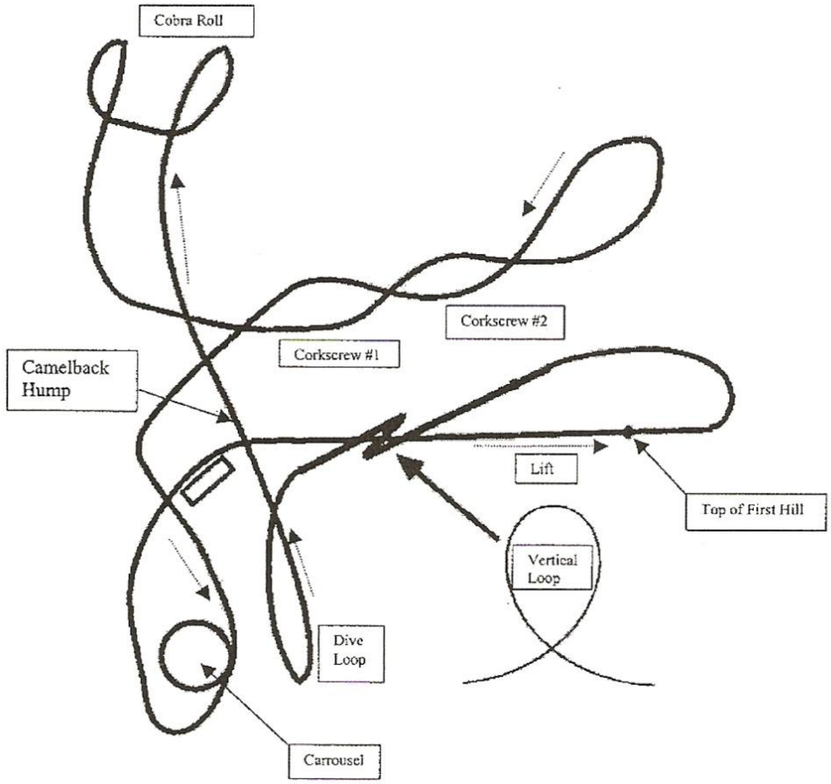
c. What would be the maximum safe speed in a bumper car collision? What criteria did you use to determine this?

____

____

Kumba Worksheet

INSTRUMENTS REQUIRED:
Stopwatch (No instruments allowed on the ride)



The Kumba features a double corkscrew; a Cobra Roll; a 33 m tall Vertical Loop that takes the ride around the original lift hill; a Dive Loop that mimics a stunt plane's maneuver; and a 42.9 m drop on the first hill. In addition, the Kumba has a highly banked circular turn called the carrousel, which produces heaviness for several seconds, and a Camelback Hump that does just the opposite, giving the riders a few seconds of near weightlessness. The coaster has three wheels: a Road Wheel above the track to ride on; a Guide Wheel beside the track to keep the train from rocking side to side; and an Uplift Wheel beneath the track to ensure that the train stays on the track through all its twists and turns. With maximum speeds of up to 62 miles/hour, seven inversions, and multiple opportunities to experience forces of greater than 3 g's, the Kumba is an awesome physics experience

Prior To Physics Day

1. Problem: Find the speed of a coaster train whose length is 20m and which takes 0.75 seconds to pass a post.

   ____

2. Prediction: As the coaster goes around the carrousel near the end of the ride, you will feel:

	pushed to the outside		pushed to the inside		not pushed to the left or right

3. Prediction: As the coaster goes around the carrousel, you will feel:

	Heavy		Light		Normal

4. Prediction: When the coaster cars are inverted, you will feel:

	heavy		light		like you are falling		sometimes heavy and sometimes light

5. What is the average speed of the coaster, expressed in miles/hour:

	15		20		25		30		35		40		45		50		55

6. Prediction: What is the highest g-force on the ride?

	3.0		3.2		3.4		3.6		3.8		4.0		4.2

7. Prediction: How many times does the coaster ride exceed 3-g's:

	2		3		4		5		6		7		8		9

What To Notice On The Ride

1. Pay attention to your feelings during the carrousel section of the ride, near the end. Estimate how heavy you feel and whether you feel pushed to the left or right. Can you get your feet off the floor?
2. You will be inverted seven times. Pay attention to the similarities and differences in these inversions, i.e. do you feel heavy or light; do you ever leave your seat; etc.
3. The g-force at the bottom of the first hill is about 3.4. Where on the ride is the g-force greater than this? Where is the g-force the greatest, and what is that value? What is the g-force in the carrousel? (Sit in the second row in view of the mounted G-Force Meter to record the measured value.

What To Measure and Notice Off The Ride

1. Time the coaster from the point where the middle car passes the top of the first hill until the middle car reaches the top of the second corkscrew.
2. Measure the time for the coaster to pass the top of the first corkscrew. (Start the stopwatch when the front of the first car reaches the top of the corkscrew, and stop it when the back of the last car reaches the top of the corkscrew.)
3. Watch the ride from the beginning to the end to determine where it moves the fastest and where it moves the slowest.

Data Table

	Trial #1	**Trial #2**	**Trial #3**	**Average**
Measured On The Ride				
Point of Highest G-Force				
G-Force in Carrousel				
Measured Off The Ride				
Time it takes the coaster to go from the top of the first hill to the top of the second corkscrew				
Time it takes the coaster to pass the top of the first corkscrew				

Questions

1. Describe the differences in the times that you were upside down. Did you ever leave your seat? Which time did you feel the lightest? ____

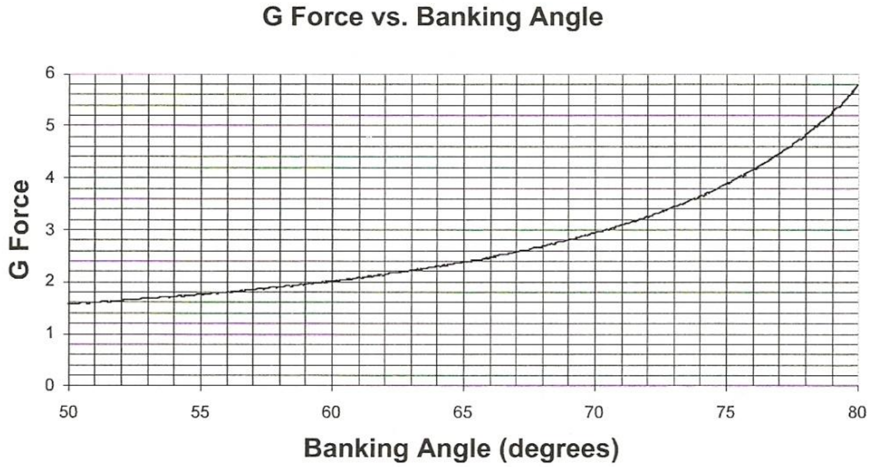
____
2. Where did you feel the heaviest during the ride? ____
3. Were you able to pick up your feet during the carrousel? ____
4. Were you thrown to the left or right or were you upright in the carrousel? ______________________________
5. The Kumba has so many twists and turns that it can be disorienting. This is especially true when your eyes tell you that you are upside down but you don't feel upside down. You also go from feeling light to feeling heavy many times. Where were your senses the most confused? ____
6. Give a general explanation for where on the ride you go fast and where you go slow. ______________________

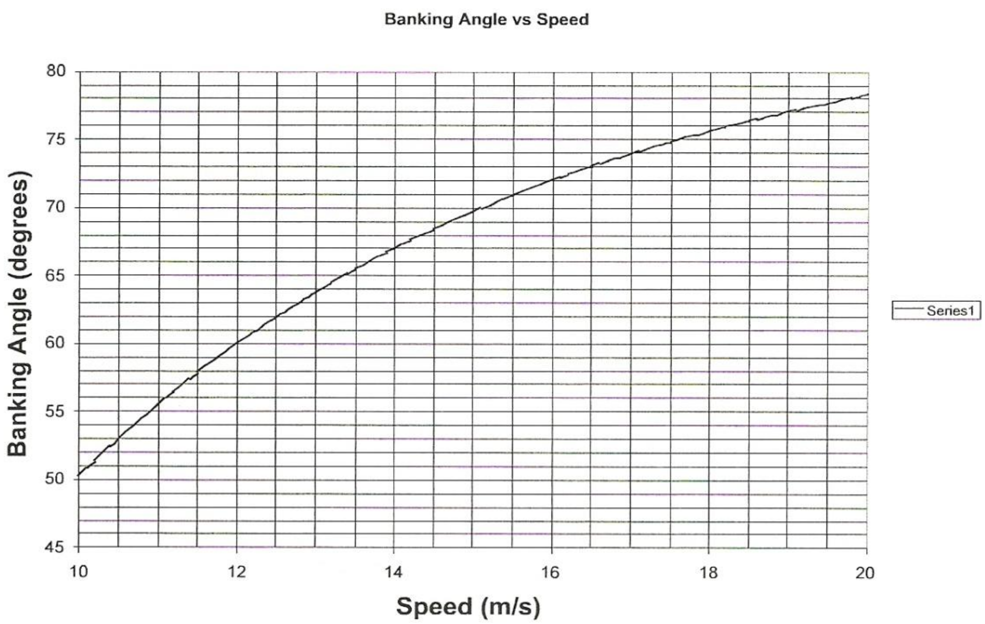
____
7. Generally speaking, where do you feel heavy and where do you feel light – at the tops of hills, at the bottoms, on the curves, going down hills, being upside down, etc.? ____

____

Problems

1. The graphs below are based on the carrousel, which is the horizontal circle near the end of the coaster ride.





a. The velocity in the carrousel is 15 m/s. What is the banking angle? ____________________

b. What is the g-force that corresponds to this banking angle? ____________________

c. How does the g-force compare to what you measured on the ride? ____________________

d. If you wanted to design a coaster that experienced 2 g's in the carrousel, what would the speed of the coaster need to be? ____________________

e. What is the maximum safe banking angle? What criteria did you use to pick this angle? ____________________

____

2. Using the time it takes the coaster to pass a point at the top of the corkscrew, compute the speed of the coaster at the top of the corkscrew. Coaster length = 13.1 meters. ____________________

3. Using the time for the coaster train to go from the top of the first hill to the top of the second corkscrew, compute the average speed of the coaster. The distance between those two points is 770 meters. Find the average speed in miles/hour

by converting m/s to mph. ____

____

4. List the g-forces on the inversions as obtained by the G-Force vs. Time graph at the end of the PIB Physics Day Data Guide. How does this compare with your feelings on the ride?

Vertical loop bottom	Going into dive loop	Going into Camelback	Going into Cobra Roll	Coming out of Cobra Roll	Corkscrew bottom #1	Corkscrew bottom #2	Carrousel

____

____

5. List the maximum g-forces at the bottoms of the hills. How do these figures compare with your measurements of where the force was the greatest?

Vertical loop bottom	Going into dive loop	Going into Camelback	Going into Cobra Roll	Coming out of Cobra Roll	Corkscrew bottom #1	Corkscrew bottom #2	Carrousel

____

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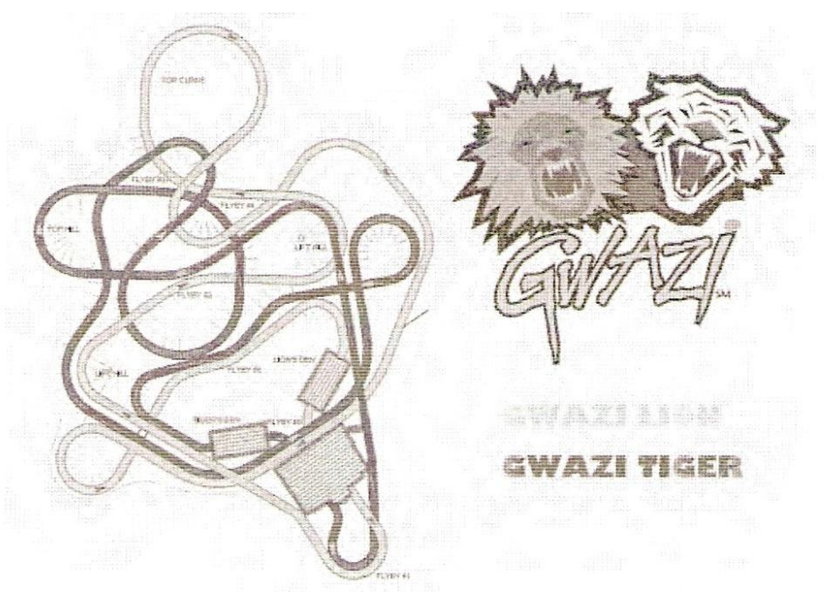
Gwazi Worksheet

INSTRUMENTS REQUIRED:
Stopwatch (No instruments allowed on the ride)



The Gwazi Lion and Tiger cross six times. The first time is just after leaving the station and before the lift hill. The second time is at the bottom of the first hill. The third time is at the bottom of the second hill. The fourth time is when banking at a 51-degree angle, making a sharp turn. The fifth time is next to the station, while going over a camelback hump. The sixth time is at the brakes at the end of the ride. See if you can manage to see all six crossings.

Prior To Physics Day

1. Problem: Find the speed of a coaster train whose length is 11m and which takes 0.63 seconds to pass a post.

   ____

2. Prediction: On the diagram above, the Lion track is gray and the Tiger track is black. The arrows indicate direction of motion. Up to the point in the ride where the white and black circles are placed on the diagram, both rides have been very similar except for what? (Look at the radius of the turns, and observe whether they are turns to the right or turns to the left.)

   ____

   ____

3. Prediction: After the white circles,

   a. How are the Lion and Tiger rides the same? ______________________________

   ____

   b. How are they different? ______________________________

   ____

4. Prediction: Where will you feel light on the ride?

	Tops of the hills		Bottom of the valleys

5. Prediction: Which car will experience the greatest g-force?

	Front car		Last car

What To Measure and Notice On The Ride

1. Where do you feel light? Do you ever leave your seat?
2. Notice where on the ride you felt heavy.
3. Sit in the third row, in view of the G-Force Meters, and record the g-force at the heaviest point. Record your value and that of two friends – or ride the Gwazi more than once.
4. Ride both the Gwazi Lion and the Gwazi Tiger and make note of the differences.

What To Measure and Notice Off The Ride

1. As you exit the ride, you will pass by the Photo Shop, which is indicated by a "P" on the diagram. Both the Tiger (further away and going to the right) and the Lion (closer and going to the left) pass by you at this point. Find the time for the Lion coaster to pass by one of the posts at the lowest point.

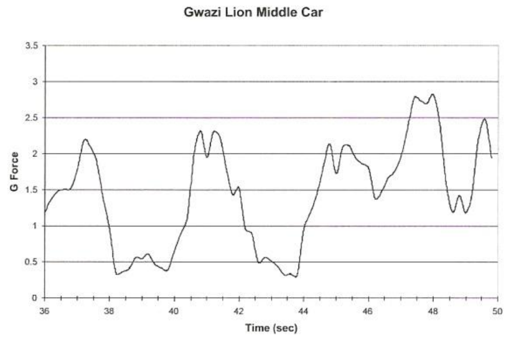
Data Table

	Trial #1	**Trial #2**	**Trial #3**	**Average**
Measured On The Ride				
Point of Highest G-Force				
Measured Off The Ride				
Time it takes the Lion to pass by a post at its lowest point				

Questions

1. After the Lion coaster (yellow) passes the low point by the Photo Shop, it will immediately go up over a hill. Draw a sketch of the shape of this hill. What is the mathematical name for this shape?

Mathematical Name: ___________________________________



2. On the Gwazi Lion Middle Car graph above, the hill in Question 1 starts about time = 42 seconds. What does the graph indicate that riders experience while on the hill? ____

3. In general, where did you feel light on this ride? ____

____

4. On the Gwazi Lion Middle Car graph above, the low point that you timed appears just after t=40 seconds. What is the g-force experienced by the riders at this point? How long do they feel heavy? ______________________________

____

5. At what points on the ride did you feel heavy? At which point did you feel the heaviest? ______________________

____

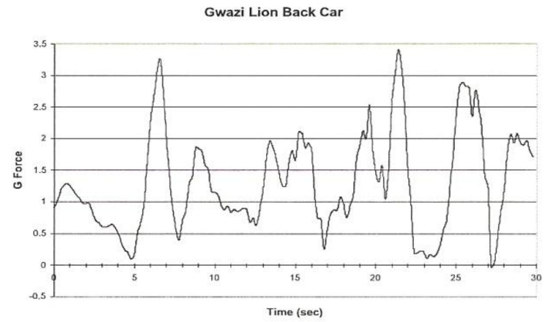
6. After riding both the Lion and the Tiger, indicate any differences in the two coasters. _______________________

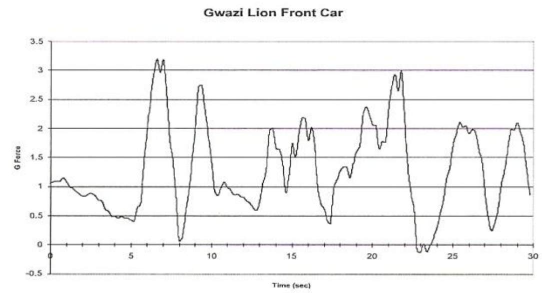
____

Problems

1. Compute the speed of the Gwazi Lion (by the Photo Shop) in m/s. The length of the coaster train is 12.9 meters.
____

2. Answer the following questions based on the graphs below. All of the graphs below start with the drop down the first hill. They show the first 30 seconds of an approximately 50-second long journey to the brakes at the end.





a. Using the graphs above, name two differences between the ride in the front car and the ride in the back car ________

____

b. Which ride would you consider more exciting? ______________________________________

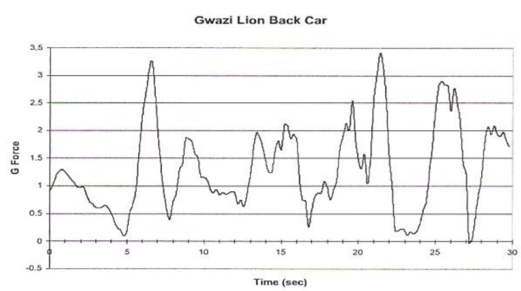
c. Which had the greatest g-forces? ____

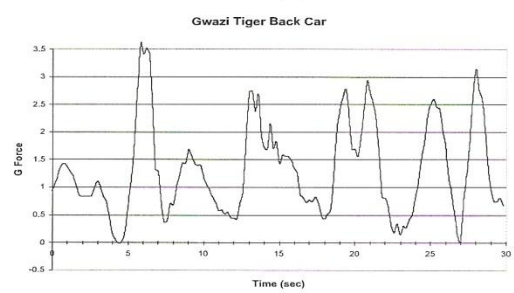
d. Compare the back car of the Lion (above) to the back car of the Tiger (below). What are the differences? ________

____

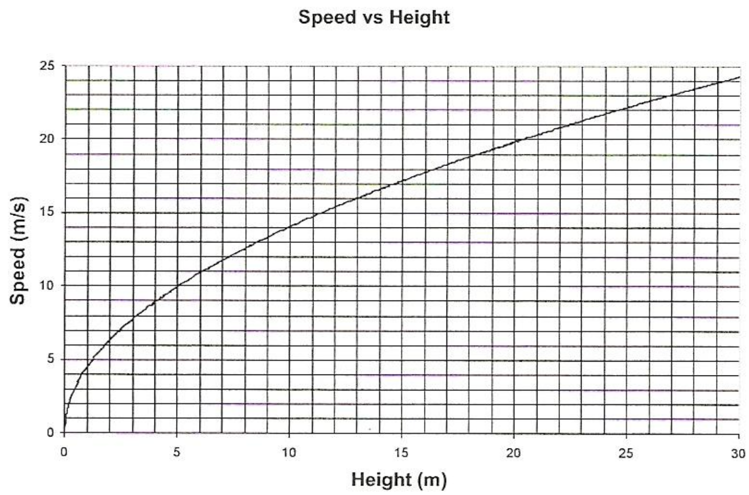
e. What are the similarities? ____

____





3. Using the Speed vs. Height graph below, find what height is required to produce a speed equal to the speed you computed near the Photo Shop. ____



Note: The actual height of the hill is 27.4m above the ground level. It is higher than your computed value because of the frictional losses along the way. Also, you are computing how high above this point in the track the highest hill would have to be, and the track at this point is not at ground level.

Sheikra Worksheet

INSTRUMENTS REQUIRED:
Stopwatch (No instruments allowed on the ride)

Prior To Physics Day

1. Problem: Given that the coaster takes 0.75 seconds to go from post A to post B, which are 20 meters apart, what is the speed of the coaster? ______________________________
2. Prediction: How long will you feel "weightless" on the big drop?

	0.5 sec		2.5 sec		5.0 sec

3. Prediction: Will you ever feel weightless when you are upside down?

	Yes		No

What To Notice On The Ride

1. Estimate the time you are "weightless" on the big drop. Estimate to the nearest ½ second. (Practice counting: One thousand one, one thousand two, etc.). Use your count and that of two friends, or ride three times.
2. There are at least two other places on the ride where you feel weightless. Where are they?

What To Measure Off The Ride

1. Measure the time for the coaster to "free fall" down the first hill. Start your stopwatch at the instant the coaster begins to fall (it will hang at the edge for approximately 4 seconds before falling), and stop your stopwatch when the coaster arrives at the top of the blue post that supports the track. The track begins to curve after this point.

Data Table

	Trial #1	Trial #2	Trial #3	Average
Measured On The Ride				
Estimated Time of Weightlessness on Big Drop				
Measured Off The Ride				
Time of Fall				

Questions

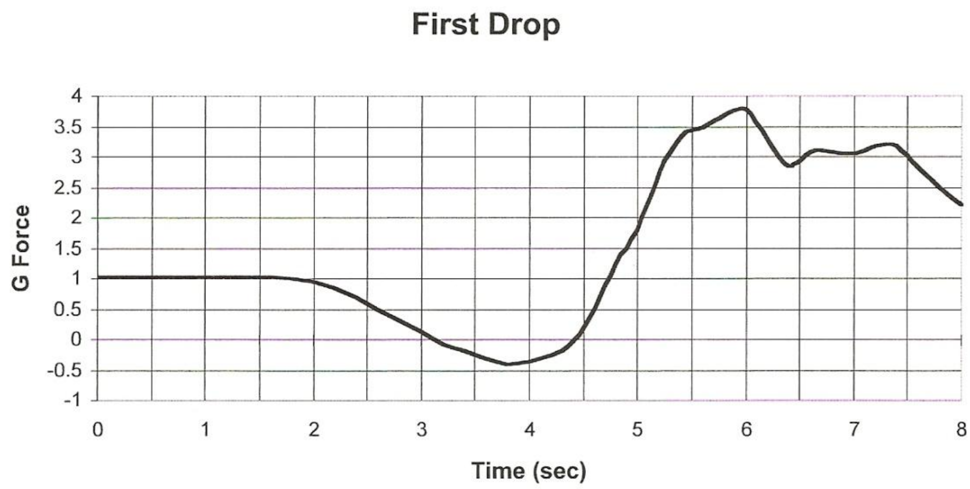
1. How does the time you estimated on the ride compare with the time you measured? ______________________________

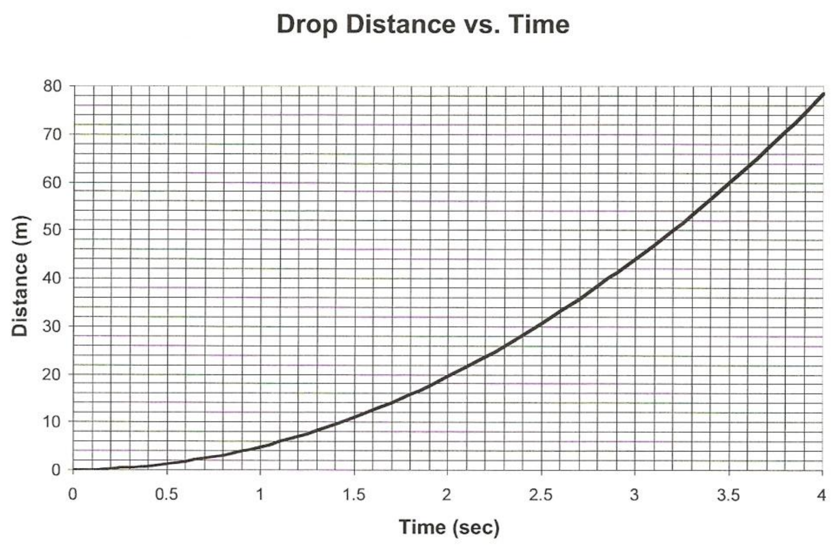
____

2. On the G-Force graph below, estimate the time of weightlessness by finding the time spent with a g-force of less than 1-g.

____

3. How long does it take for the g-force to increase from 1 to its highest level? ____________________________________





4. From the Drop Distance vs. Time graph above, determine how far the coaster dropped in the time measured with the stopwatch ___________________________

5. If the coaster dropped the entire 61 meters to the ground, how long would the falling time be? ______________________

6. Using the Drop Distance graph, what should the "free fall" time be if it is 32.7 meters from the top of the hill to the blue post? ____

7. From the Sheikra g-force graph in the PIB Physics Day Data Guide, find where else on the ride you are weightless.

____

8. Which weightless period is the longest? ____

9. How does this graph compare with your observations? ____

____

This data was collected (circle one) by myself / a team. I participated fully and equally in the collection of this data. The answers on this lab are a product of my own work and effort. Though I may have received some help in understanding the concepts and/or requirements, I did the work myself.

____

Student Signature (for electronic submission, type student number in lieu of signature)

APPLICABILITY:

In terms of the material covered thus far, this lab was given: ☐ too early in the course ☐ at the right time in the course ☐ too late in the course
In terms of degree of difficulty, this lab was: ☐ too easy ☐ just about right ☐ too hard
In terms of helping you understand the material presented in class, this lab was: ☐ not helpful ☐ somewhat helpful ☐ very helpful

IMPROVEMENT: This lab can be improved by:

When complete, E-mail to Mr. Smith @ smithky@pcsb.org
Ensure your filename is "LastnameFirstinitialPerXLabName"