PHYSICS EDUCATION SERIES

PREPARING THE WORKBOOK FOR YOUR STUDENTS

This workbook is designed as a review or teaching tool for an average first year physics student. The materials are designed to be modified to suit individual needs. This can generally be done by deleting sections from each activity.

1. The equations are in a column that is easily deleted if you want your students to use only the formula sheet or to work from memory.

2. For a conceptual class much of the calculation section can be modified or deleted.
   For more advanced students you may choose to eliminate some of the more detailed calculation instructions.

3. We strongly urge you to have your students do most of the calculations before going on the rides so that riding is an opportunity to verify the laws of physics. An important part of this experience is actually working through the activities while at the park, sharing frustrations and triumphs with classmates and students from other schools. Accurate predictions can be celebrated and reasons for poor results discovered immediately.

4. WARNING: Friction and air drag effects are generally ignored in this booklet in order to focus on fundamental physics principles. Although the speeds and forces calculated are somewhat larger than those experienced, they are usually well within the accuracy of our measuring devices.

   Past experience has shown that the calculations made and the force meter readings are close enough to give students the sense that physics really works.

5. In the answer key and on the student work sheets, the positive direction for circular motion is defined as toward the center of the circle. If you have defined up as ALWAYS positive or down as ALWAYS positive, you should point out this change to your students.

6. You may also want to review the ideas covered in Activity 1 before going to the park. The first section covers the idea of a force factor (**ff)** which is basically the g force being experienced. (We do not refer to it as g's to avoid confusion with acceleration.) The page titled Newton's Second Law and Circular Motion will help your students understand how the workbook approaches calculating forces experienced in circular motion.

7. Included in the teacher's section of the workbook are suggestions for applying amusement park physics to topics which are part of most standard courses. Also, in the teacher's section are problem sets, and laboratory exercises using amusement park examples. Please feel free to copy and use these in your class throughout the year.

School ________________________

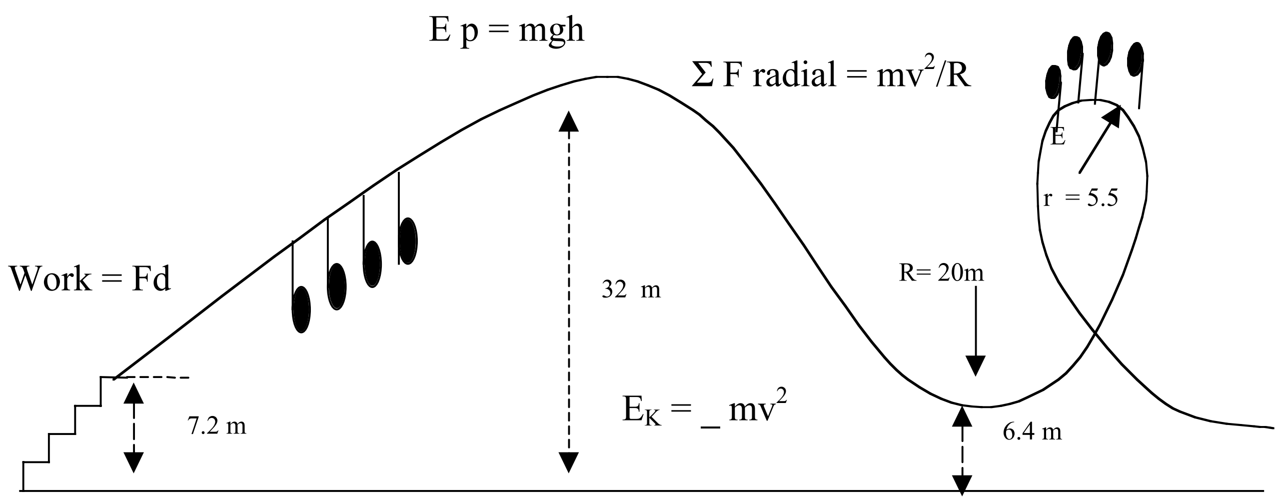
Teacher ________________________

Your Name ________________________

Partners: ________________________

____

____



STUDENT HANDBOOK FOR USE AT THE PARK

Your Weight = _________ lbs X 4.45 = ___________ newtons

Your Mass = $\dfrac{\text{Weight in Pounds}}{\text{2.21 pounds/kg}}$ = _________ kilograms

Symbols and formulas used in this handbook:

- d = Distance
- E_K = Kinetic Energy = $1/2\, mv^2$
- E_P = Potential Energy = mgh
- E_T = Total Mechanical Energy = Potential Energy + Kinetic Energy
- ΣF_r = Sum of the radial forces = mv^2/r
- F_c = Centripetal Force
- F_g = weight or gravitational force in newtons = mg
- p = momentum = mass x velocity

Speed Conversions

5 m/s	11 mph
10 m/s	22 mph
15 m/s	34 mph
20 m/s	45 mph
25 m/s	56 mph
30 m/s	67 mph
35 m/s	78 mph

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Some Materials adapted from student handbooks prepared by Columbia High School, Maplewood, NJ and the Amusement Park Physics Committee of the American Association of Physics Teachers

Equations Used in the Workbook

Distance: $d = v_{average}\, t$

$d = v_i t + 1/2\, at^2$

Speed: $v_{average} = \frac{\Delta d}{\Delta t}$

$v_{average} = \frac{v_i + v_f}{2}$

acceleration: $a = \frac{\Delta v}{\Delta t}$

Force: $\sum F = ma$

Weight: Weight = mg

Friction: $F_{fr} = \mu$Normal force

Force Factor: **ff** = $\frac{\text{force of seat}}{\text{weight}}$

Law of Inertia: In the absence of any unbalanced forces, an object at rest will stay at rest and an object in motion will continue to move in a straight line at a constant speed.

Circular Motion:

speed: $v_{tangential} = \frac{2\pi r}{T}$

Centripetal force:

$\sum F_{radial} = F_c = \frac{mv^2}{r}$

Work: $W = F\, d$

Power: Power = $\frac{\text{work}}{\text{time}}$

Momentum: $p = mv$

Impulse: $J = F\Delta t$

Relationship: Impulse = Change in Momentum

$F\Delta t = \Delta mv = m(v_f - v_i)$

Potential Energy: $E_p = mgh$

Kinetic Energy: $E_k = \frac{1}{2} mv^2$

Total Energy: $E_T = E_p + E_k$

CONCEPTS COVERED BY EACH RIDE

TO THE STUDENT: Be sure you complete Workbook Units for at least ______ activities at the park .

Be sure that you choose the rides so that you have covered all of the concepts checked across the top row.

REMEMBER - Most measurements are made **While Watching**, including **Times.**
The symbol for measurements that must be **Read On the Ride** is $^{R}O_{R}\Rightarrow$.

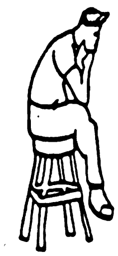
Read about the ride and take measurements before you ride. Usually, you can do this while in line.

Before you leave the ride make sure you have all the information you need.

Activity	Concepts Rides	Kinematics	Centripetal Force	Energy	Power	Friction	Vertical Circles*	Vectors	Electricity	Momentum
3	Scream Machine 1		X	X	X		X			
4	Scream Machine 2		X	X			XX			
5	Centrifuge		X					X		
6	Taz Twister		X			X		X		
7	Rolling Thunder		X	X	X		X			
8	Viper		X							
9	Runaway Train		X	X				X		
10	Saw Mill Log Flume	X								X
11	Carousel		X					X		
12	Spinmeister		X				X, XX			
13	Flying Wave		X					X		
14	Fantasy Fling		X				X,XX	X		
15	Batman The Ride 1		X	X	X		X			
16	Batman The Ride 2		X	X			XX			
17	Batman The Ride 3		X					X		
18	Stuntman's Freefall	X	X	X	X					X
19	Movietown Water Effect	X								X
20	Chiller Intro & Part 1	X			X					
21	Chiller Part 2	X			X				X	
22	Bumper Cars	X								X
Activity	Rides Concepts	Kinematics	Centripetal Force	Energy	Power	Friction	Vertical Circles*	Vectors	Electricity	Momentum

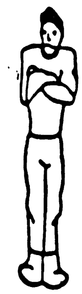
* In the Vertical Circles section, X means the Activity concerns forces on a rider at the bottom of a curve. XX means the Activity covers forces on a rider upside down at the top of a vertical circle.

ACTIVITY 1: SENSING SENSATIONS & FORCE FACTORS



1. Here you are in a chair. Use an arrow (vector) to show the size and direction of the force the **chair** is exerting on **you.**

   On what part of your body is this force exerted?



2. Here you are standing up. Show the size and direction of the force the **ground** is exerting **on you.**

   On what part of your body is the force exerted?

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

   On what part of your body is this force exerted?

4. Here you are **upside down** and **strapped** into a chair. The chair is NOT MOVING. Show the size and direction of the force that keeps you from falling out.

   a. What prevents you from falling out of the chair?

   b. Why is the hair hanging down?

5. Based on your answers to the previous questions, how could you tell what position you were in if your eyes were closed?

Force Factors

force factors (ff): A force factor enables you to express the size of a force you are experiencing as a multiple of your weight. Remember, your weight is the force, mg, that is exerted on you by gravity. (This is also referred to as the g force or simply how many "g's.")

To calculate a force factor: divide the force being applied to a person or object by the normal weight of that person or object.

$$\textbf{force factor} = \frac{\textbf{applied force}}{\textbf{weight}}$$

EXAMPLES OF HOW TO USE A FORCE FACTOR

When you are experiencing a force factor:

EQUAL to 1, you feel **NORMAL. RIGHT NOW** you feel a force on your seat exactly equal to your weight as the seat supports you.

GREATER than 1, you **FEEL HEAVIER** than normal and feel pressed into the chair. In reality, the chair is pressing up on you which you interpret as being pushed down.

LESS than 1, you **FEEL LIGHTER** than usual and can feel as if you are almost lifting out of the chair. This is how you feel when an elevator starts down suddenly.

At a given point on a ride, everyone, regardless of mass, experiences the same force factor.

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

(a) What force - factor is she experiencing?
If we round g off to 10 m/sec^2 she weighs 500 Newtons.

$$\textbf{force factor} = \frac{\textbf{applied force}}{\textbf{weight}} = \frac{1500 \text{ newtons}}{500 \text{ newtons}} = 3$$

(b) If her friend weighs 120 pounds, what force in pounds is her friend feeling?
They will feel the **same force factor**. This time, the number given is the person's weight. Her normal weight is 120 pounds, but she is experiencing a force factor of 3 and is therefore feeling a force of 3 times her normal weight. The force on her must be 3 x 120 pounds = 360 pounds.

YOUR TURN, SHOW YOUR WORK

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

(a) What force factor is he experiencing? force factor = ____________

(b) What force is his 500 newton girl friend feeling? Force felt = _______ newtons

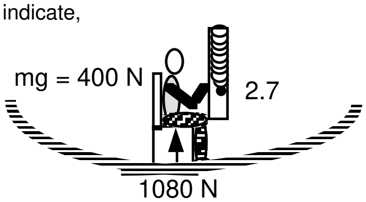
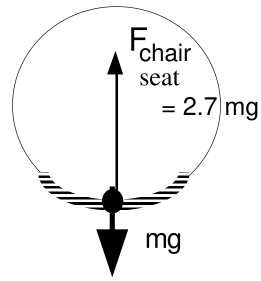
(If your answers were a force factor of 2.5 and 1250 newtons you've got it !!!)

USING THE FORCE METER

To make an object move in a circle an unbalanced force directed toward the center of the circle must be applied. The sum of the forces is fixed.

$$\Sigma F_r = F_c = \frac{mv^2}{r} \quad \text{with } F_r \text{ considered POSITIVE TOWARD THE CENTER OF THE CIRCLE}$$

When a person rides in a vertical circle, as on a roller coaster the centripetal force which controls the motion is the vector sum of the force of gravity and the force exerted on the rider by the chair.

<table>
<tr><th>RIDER AND METER</th><th>FREE BODY DIAGRAM</th><th>EQUATIONS</th></tr>
<tr>
<td>A 400 N student calculates that she will feel a force of 1080 N at the bottom of a roller coaster. What force factor will the meter indicate,

$ff = \frac{1080N}{400N} = 2.7$</td>
<td>RIDER AT THE BOTTOM
</td>
<td>$\Sigma F_r = \frac{mv^2}{r}$
$\Sigma F_r = F_{chair} - mg$
$F_{chair} - mg = \frac{mv^2}{r}$
$F_{chair} = mg + \frac{mv^2}{r}$
$ff = \text{force factor} = \frac{F_{chair}}{mg}$
Rider feels heavier than usual since F_{chair} is greater than mg.</td>
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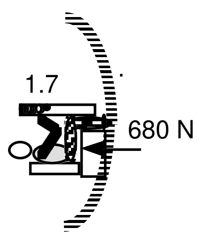
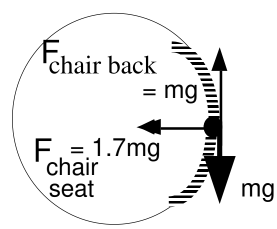
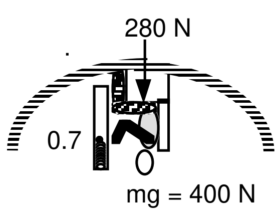
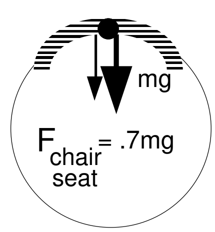
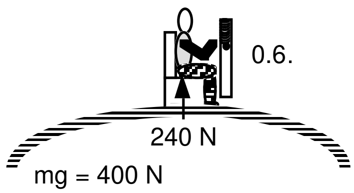
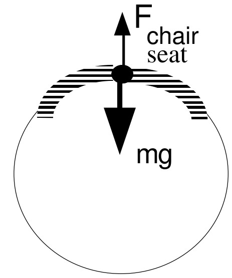
<tr>
<td>
$ff = \frac{680\ N}{400\ N} = 1.7$</td>
<td>RIDER AT THE SIDE
</td>
<td>$\Sigma F_r = \frac{mv^2}{r}$
Since mg is perpendicular to the radius it does not contribute to F_r
$\Sigma F_r = F_{chair}$
$F_{chair} = \frac{mv^2}{r}$
$ff = \text{force factor} = \frac{F_{chair}}{mg}$
Being at the sides feels like going up or down hill.</td>
</tr>
<tr>
<td>
$ff = \frac{280\ N}{400\ N} = 0.7$</td>
<td>RIDER AT TOP OF ARC
</td>
<td>$\Sigma F_r = \frac{mv^2}{r}$
$\Sigma F_r = F_{chair} + mg$
$F_{chair} + mg = \frac{mv^2}{r}$
$F_{chair} = \frac{mv^2}{r} - mg$
Rider will feel right side up as long as F_{chair} is positive. The force coming from the seat makes down seem up.</td>
</tr>
</table>



$ff = \frac{240N}{400N} = .6$

RIDER OVER TOP OF HILL



$\Sigma F_r = \frac{mv^2}{r}$

$\Sigma F_r = mg - F_{chair}$

$mg - F_{chair} = \frac{mv^2}{r}$

$F_{chair} = mg - \frac{mv^2}{r}$

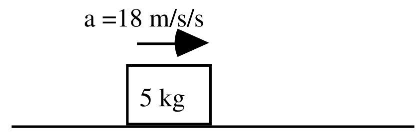
Rider feels lighter than usual and can even lift up off the seat. Then $F_{chair} < 0$ and a seat belt holds rider on.

Newton's Second Law and Circular Motion

Circular motion frequently causes problems in introductory physics courses because we think of centripetal force as an actual entity rather than just the sum of the radial forces. The following may help to emphasize that

$\Sigma F_{radial} = F_c = \frac{mv^2}{r}$. F_c is, in reality, just a net force.

One day, while watching the world go by, you notice a 5 kg object pulled along a surface you know to be frictionless accelerating at 18 m/s/s.

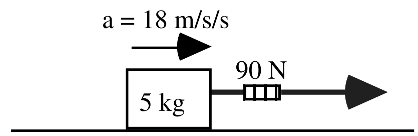


You immediately calculate the force needed to create this event. This force, given by Newton's second law is

$$F_{net} = \Sigma F = ma = 5\text{ kg }(18 \frac{m}{s^2})$$

$$\Sigma F = 90\text{ N}$$

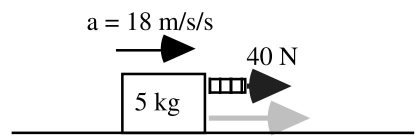
Checking the spring scale, you are delighted to see you are right.



A few moments later, an identical object goes by. You notice, however, that the spring scale is registering only 40 N. Because you trust Newton's 2nd law, you realize another force MUST now be acting.

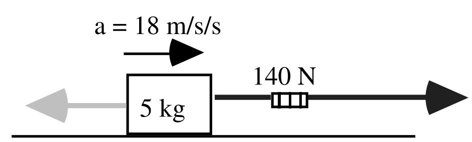
$$\Sigma F = 90\text{ N} = 40\text{ N} + F_{invisible}$$

From your calculations, you find this invisible force must have a magnitude of 50 N in the same direction as the spring force.



Another 5 kg object accelerates by at 18 m/s^2. This time, the spring scale pulling the object is reading 140 N. Again, you are certain that the net force, F_{net}, or the sum of the forces ΣF, must be 90 newtons.

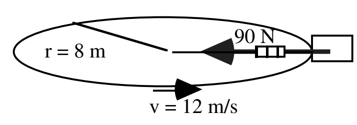
$$\Sigma F = 90\text{ N} = 40\text{ N} + F_{invisible}$$



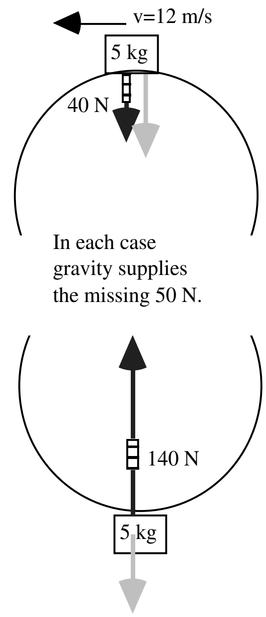
This time, the invisible force must be 50 N in the opposite direction.

A similar analysis applies to circular motion. When an object moves in a circle at a constant speed, there must be a **net force** toward the center of the circle which has a magnitude of exactly mv^2/R. Now:

$$\Sigma F_{radial} = ma = m\frac{v^2}{r}$$



Our 5 kg object is moving along on a horizontal circle of radius 8 meters at a speed of 12 m/s. Therefore, it must be tethered with a force of 90 N.



$$\Sigma F_{radial} = \frac{mv^2}{R} = 5\text{ kg}\ \frac{(12\text{ m/s})^2}{8\text{ m}} = 5\text{ kg}\ 18\,\frac{m}{s^s} = 90\text{ N}$$

When we have the object moving in a vertical circle, however, the force in the spring scale registers only 40 N when we are at the top of the circle. The net force toward the center of the circle must still be exactly 90 N. This time, the missing invisible force is being supplied by gravity. (mg ♠50 N)

$$\Sigma F_{radial} = 40\text{ N} + F_{invisible} = 90\text{ N toward center}$$

$$F_{invisible} = 50\text{ N toward center}$$

At the bottom of the circle, gravity will supply an invisible 50 N force away from the center of the circle. The net force toward the center of the circle must still be exactly 90 N. The force in the spring scale will read 140 N. A rider at an amusement park would feel heavier than normal.

$$F_{invisible} = 50\text{ N away from center}$$

$$\Sigma F_{radial} = F_{scale} + 50\text{ N away from center} = 90\text{ N toward center}$$

$$F_{scale} = 140\text{ N toward center}$$

ACTIVITY 2: CONSCIOUS COMMUTING

As you ride to Six Flags Great Adventure, be conscious of some of the PHYSICS on the way.

A. STARTING UP

THINGS TO MEASURE:

As the bus pulls away from a toll booth, record the time it takes to go from rest to 15 miles per hour.
You will have to put someone up front to help. t =_____ seconds

THINGS TO CALCULATE: SHOW ALL EQUATIONS AND SUBSTITUTIONS

1. Convert 15 miles per hour to meters per second. v_i = 0 m/s

   v_f = _______ m/s

2. Acceleration means how much the speed changes each second. Find the acceleration of the bus. Indicate units.

   a = _________

3. Using your mass in kilograms and Newton's Second Law, ($\Sigma F = ma$), find the forward force on you (in newtons) as the bus accelerates from rest.

   F = ________

4. Compare this force to the force gravity exerts on you (your weight).

much greater   slightly greater   equal   slightly less   much less

5. Calculate the force factor that you felt.

force factor = **ff** = $\dfrac{\text{force calculated(in Question \#3)}}{\text{weight in N}} = \dfrac{\_\_\_\ \text{N}}{\_\_\_\ \text{N}}$ **ff** = ________

PLEASE NOTE: When pilots or astronauts describe the "g" force they experience they are actually telling you the force factor! The force factor, like the "g" force, has **<u>no units</u>**.

6. Compare your **ff** with a neighbor whose mass is different from yours. Explain.

7. Close you eyes and listen. What can you tell about the motion of the bus by just listening?

THINGS TO NOTICE:

8. As you start up, which way do you FEEL thrown? (forward or backward)

9. If someone were watching from the side on the road, that person wouldn't see you move backward. What would that person see the seat doing to you?

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

B. GOING AT A CONSTANT SPEED - THINGS TO NOTICE

1. Describe the sensation of going at a constant speed. When the road is smooth, do you feel as if you are moving?

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

C. ROUNDING CURVES - THINGS TO NOTICE

1. If your eyes are closed :
   a. How can you tell when the bus is going around a curve?

   b. What do you feel when you are seated facing forward?

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

a. What is the direction of the force?

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

c. How is this force applied to your body:
(a) the friction of the seat, (b)your seat mate, (c)the wall,
(d) the arm of the seat, or (e) a combination of these? Explain.

3. Banked curves support coasters so that riders are not flung outward. Look for banked curves on roads and for the signs that give you the speed limit for the curve. What would happen if you went too fast through the banked curve?

D. OVER HILLS - THINGS TO NOTICE

1. If your eyes are closed, how can you tell when the bus is going over a hill?

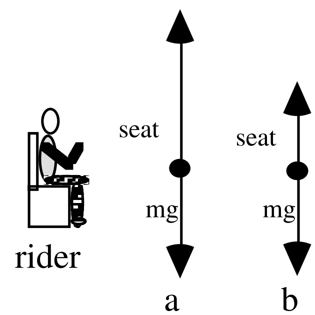
2. As the bus goes up and over hill concentrate on how you feel. Try to sense the forces that are affecting you.

   a. Compare the force you feel from seat when the bus is going over the top of the hill to the force you feel when the bus is standing still. The seat force seems:

      much greater   slightly greater   equal   slightly less   much less

   b. Circle the vector force diagram which best illustrates this situation?

   c. Most park rides are faster than the bus. What do you expect the seat force to be if you are over the top of a hill on a roller coaster?



3 . As the bus goes down into a valley and then goes up again, concentrate on how you feel. Try to sense the forces that are affecting you.

   a. Compare the force you feel from seat when the bus is going down into the valley to the force you feel when the bus is standing still. The seat force seems:

      much greater   slightly greater   equal   slightly less   much less

   b. Draw a force diagram for this situation.

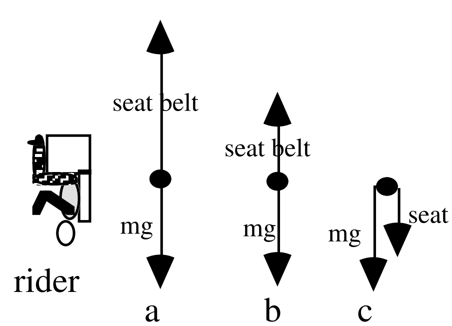
   c. If the bus were going faster, how would you feel?

E. IMAGINE BEING IN A COMMERCIAL - THINGS TO NOTICE

There was once a commercial where a real car went through a Hot Wheels loop configuration without falling down. Imagine you are in that car at the loop of the loop going very fast. You are upside down.

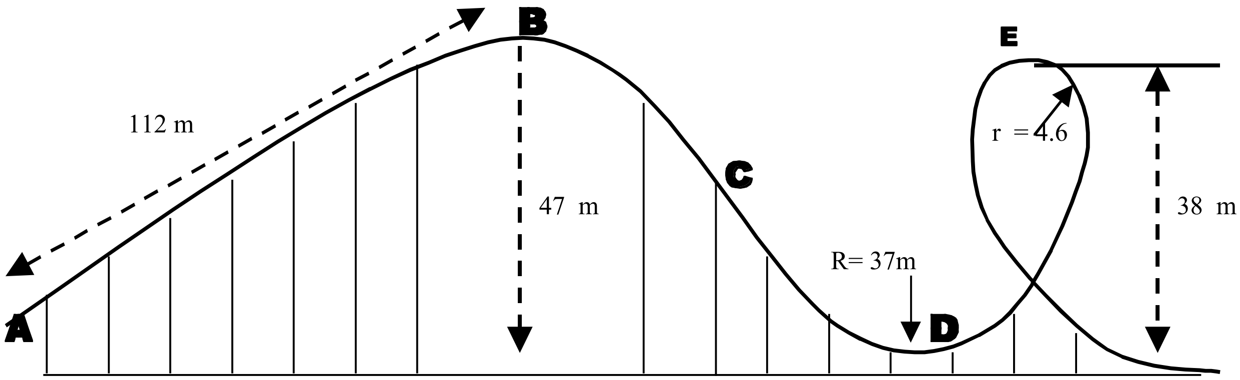
1. How would you feel (besides scared)?

2. If the car is moving fast enough to stay on the track, diagram c, at the right, correctly shows the forces acting on the rider. Why?



ACTIVITY 3 & 4 : THE GREAT AMERICAN SCREAM MACHINE
CONSOLIDATED DATA PAGE

Before Riding: **Measure required times**
Do all calculations and force factor predictions



<u>Measurements on the diagram are accurate.</u> Vertical measurements are taken relative to the station where h = 0

IMPORTANT: Hold force meter <u>parallel to track</u> on the way up the first incline (A to B). Change just before top

Hold meter <u>parallel to your back</u> after B. You can clutch meter and seat bar simultaneously.

Watching from the Ground

Time for first car to reach top of first hill
t_{uphill} = ________ s

Time for entire train, first car to last, to pass point E
$t_{past\ E}$ = ________ s

Length of train = 18 m

Force Meter Predictions and Verification Measurements
Calculate **ff** before riding so you know approximately what to expect

Where	Calculated **ff**	**ff** Measured on Ride	Sensation light, heavy, normal
Force on back going uphill (A to B) Meter pointed uphill		ROR⇒	
Force on seat at D, bottom of curve Meter parallel to back		ROR⇒	
At E, top of loop while upside down Meter parallel to back		ROR⇒	

Things To Notice While Watching and Questions To Have Riders Answer

1. Watch a rider with long hair. When the rider is upside down, is the hair hanging down as it would if the rider were stationary?

2. Did the rider feel upside down in the first loop?

3. Consider how the pressure from the seat and harness varied during the ride.
   a. Was there pressure on a rider's shoulders at any time during the ride? If so where?

   b. Where did the pressure from the seat seem greatest?

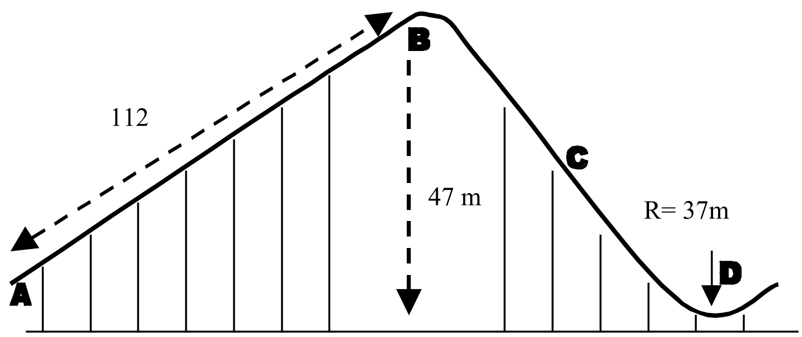
   c. Where did the pressure from the seat seem the least?

4. Describe the sensation of coming down a hill.

ACTIVITY 3 : THE GREAT AMERICAN SCREAM MACHINE
Part 1

Measurements to Use

Time for first car to reach top of first hill	t = ________
Height of first hill	h = ________
Length of first hill	l = ________
Radius at D	R = ________
Your Mass	m = ________
Your Weight in N	w = ________



Measurements on the diagram are accurate

OBSERVATIONS

1. In terms of forces, explain why most rides use a long shallow first incline?

2. If the time to go uphill were shorter, what would happen to the power needed?

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

4. Describe the way potential and kinetic energy are exchanged as the rider progresses.

5. Why is the first hill always the highest?

CALCULATIONS
(Show all substitutions)

FINDING YOUR TOTAL ENERGY

$E_p = mgh$

1. Your potential energy at B, the top of the first hill is the total energy you will have throughout the ride. If we can ignore friction, this total energy is the sum of your potential energy and kinetic energy at any given moment.
   Let potential energy be 0 when the train of cars in in the station. All vertical measurements are taken relative to the station (h = 0.) Calculate your potential energy at B. This is now your total energy for the ride.

Total Energy
E_T = _________

GETTING TO THE TOP - FORCES AND POWER

$\frac{\text{work}}{\text{length}} = \text{Force}$

2. The work done moving you up the hill from A to B is equal to the potential energy at B. The length of the first hill is 112 m. Calculate the force F_{AB} used on your back to push you to the top of the hill.

F_{AB} = __________

$\text{force factor} = \frac{\text{force felt}}{\text{weight}}$

3. Calculate the force factor on your back as you go up the hill and compare it to what you measured.

ff = __________

$\text{Power} = \frac{\text{work}}{\text{time}}$

4. Calculate the power used to get you from A to B.

Power = _________

ENERGY AND SPEEDS DOWN AT THE BOTTOM

$E_T = E_P + E_K$

5. During the ride you must account for your total energy as the sum of the potential energy and kinetic energy.
   At D the potential energy is 0. Fill in the chart at the right to find your KINETIC ENERGY at the bottom.

E_T = _________

E_P = _________

E_K = _________

$E_K = \frac{1}{2} mv^2$

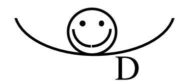
6. Use the value of your kinetic energy to calculate your speed at D. This is the maximum speed of the ride.

V_D = _________

NOTE: Friction on the first incline is low so it has very little effect on the speed at the bottom of the first hill.

FORCE FELT AT THE BOTTOM OF THE HILL

7. Going through the curve, the seat must exert enough force to both hold you in a circle and counteract gravity.



   a. At the right, draw a vector (free body)diagram showing the forces acting on you at point D.

   b. Write an equation that shows how to the sum of the forces, ΣF. (Let the center of the curve or up be the positive direction.)

   c. The sum of the forces, ΣF, is the net force that causes the centripetal acceleration, i.e.$\Sigma F = F_c$

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

   Calculate the net or centripetal force needed at D, the bottom of the loop to stay in the circular arc.

   F_c = _________

   d. Calculate the force the seat exerts on you at D, the bottom of the loop.

   $F_{seat\ at\ D} = F_c + mg$

   $F_{seat\ at\ D}$ = _______

8. Find the force factor at D.

force factor = $\frac{force_{seat}}{weight}$

ff = _________

9. Compare the calculated value to the reading you or a colleague experienced while riding. Suggest reasons for any differences.

Measured **ff** = _________

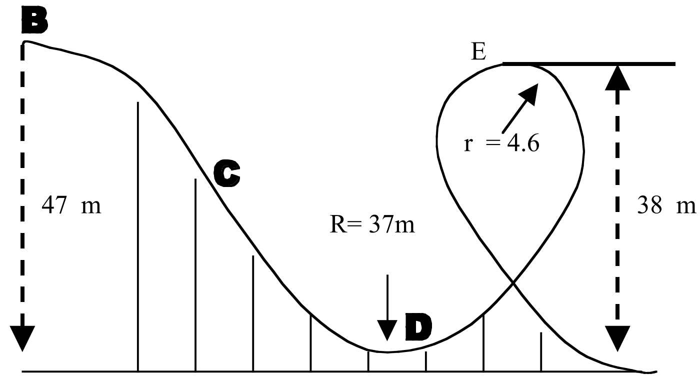
10. Based on your calculations, explain why it is important that the radius be large at point D. (Hint: If the radius were smaller, what would happen to the force factor and how would you feel?)

ACTIVITY 4: THE GREAT AMERICAN SCREAM MACHINE

Part 2

Measurements to Use

Time for train to pass point E, top of loop	t_E =	_______
Length of train	L =	18 m
Height of first hill	h_B =	_________
Height at E	h_E =	________
Radius at E	r =	_________
Your Mass	m =	________
Your Weight in N	w =	________



Measurements on the diagram are accurate

SENSATIONS (Normal, Heavier, Lighter)

At D, bottom of curve ________________________

At E, the top of the loop _____________________

METER READINGS

R_{OR}⇒ force meter D = _________

R_{OR}⇒ force meter E = _________

OBSERVATIONS

1. Did you ever feel upside down? Explain your answer.

2. Where does the coaster have
   a. Maximum potential energy?

   b. Maximum kinetic energy?

   c. Maximum speed?

3. Observe the heights of successive hills and loops along the track. What happens to the heights? Explain.

4. If the loop radius of the loop at E were made larger but the height remained the same, would the speed at E be any different?
   Explain in terms of energy considerations.

CALCULATIONS

(Show all substitutions)

Finding Your Total Energy

$E_p = mgh$

1. Your potential energy at B, the top of the first hill is the ideal total energy you will have throughout the ride. If we ignore friction, this total energy is the sum of your potential energy and kinetic energy at any given moment. Let potential energy be 0 on the ground and calculate your potential energy at B. This is now your total energy for the ride.

Total Energy
E_T = ______

IDEAL VERSUS ACTUAL SPEED AND ENERGY AT THE TOP OF THE LOOP

$E_p = mgh$

2. During the ride you must account for your total energy. At E your total energy is partially potential and partially kinetic. Calculate your potential energy at E, the top of the loop.

E_P = ___________

$E_T = E_p + E_k$

3. Calculate your IDEAL KINETIC ENERGY at the top of the loop. We are assuming that the total energy is still the same. What factors affect the validity of this assumption? Explain.

E_K = ___________

$E_k = \frac{1}{2} mv^2$

4. Calculate your IDEAL speed at E, the top of the loop.

Ideal
$V_{\text{at } E}$ = ________

$v = \frac{L}{t_E}$

5. Calculate your EXPERIMENTAL speed by using the time it took the entire train of cars to pass point E at the top of the loop.

Experimental
$V_{\text{at } E}$= ________

$E_k = \frac{1}{2} mv^2$

6. Calculate the value of the kinetic energy using the experimental velocity at point E.

Experimental
E_K =
____

$E_T = E_k + E_p$

7. Calculate the experimental value of the total energy at this point. Note: you still have the same potential energy as you did in # 2.

Experimental
E_T = ________

8. Find the difference between your experimental value of total energy and the ideal value you calculated in #1.

Difference = _____

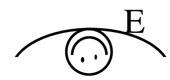
$\% = \frac{\text{Difference}}{\text{Original } E_T}$
X100

9. Find the percent deviation between your experimental value found in #7 and the ideal value found in #1.

Percent = ______

10. How would you account for the energy difference you found?

FORCES FELT AT THE TOP OF THE LOOP



11. At the top of the loop, E, gravity works with the seat to hold you in a circle. The seat can exert less force.

a. At the right, draw a vector (free body)diagram showing the forces acting on you at point E.

b. Write an equation that shows how to the sum of the forces, ΣF. (Let the center of the curve or down be the positive direction.)

c. The sum of the forces, ΣF, is the net force that causes the centripetal acceleration, i.e. $\Sigma F = F_c$

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

Using the EXPERIMENTAL velocity, calculate the net or centripetal force used to hold you in the circle at E.

d. Calculate the force the seat exerts on you. Remember, gravity is helping hold you in the arc, therefore the seat can exert less force than F_c.

F_c = ___________

$F_{seat\ at\ E} = F_c - mg$

$F_{seat\ at\ E}$ = _______

12. Calculate the force factor at the top of the loop, point E.

ff $= \frac{force_{seat}}{weight}$

ff = _________

13. Compare your calculated value to the reading you or any other person found when riding.

Measured **ff** = _________

14. Your calculations should show that you need quite a bit of force from the seat to make you follow the arc of the track. Use this fact to explain why riders do not feel upside down at E.

15. For safety and comfort, coasters are designed so that people always feel a force from the seat. How does this account for the need to make the upper radius small? (Suggestion: calculate the ff for r_E = 20 m)

16. The first looping coaster, which had a circular loop, was quickly abandoned because the speed needed to have a significant seat force when the coaster was upside down made most people pass out. The circular loop was replaced by clothoid loops which have a large radius at the bottom and a small one at the top. Explain what happened to the force factor when the radius of the bottom loop was increased and the radius of the top loop decreased?

17. OPTIONAL: Put some numbers on #16. Imagine that the coaster was constructed so that at both D and E the radius was 19 m. The loop would be circular but the height at E, h_E= 38m, would be the same.

a. Why would this NOT affect the speeds?

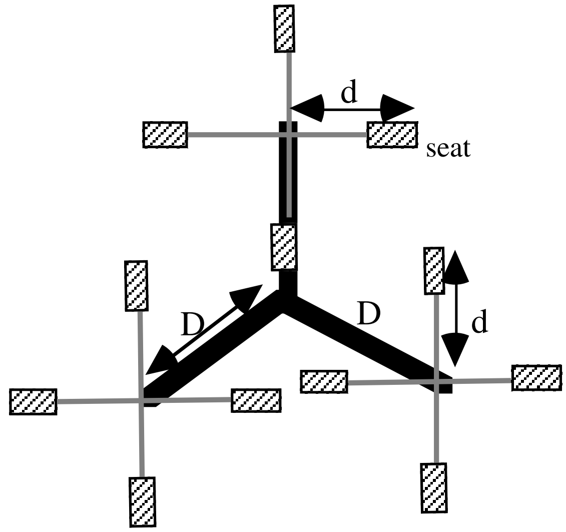
b. Calculate what would happen to the force factor at D.

c. Calculate what would happen to the force factor at E.

ACTIVITY 5: CENTRIFUGE G FORCE

MEASUREMENTS

Distance from main axis to secondary axis, D = 4.42 m
Distance from secondary axis to rider in outer most seat
d = 3.28 m



WHILE WAITING IN LINE OBSERVE

1. Record the direction of motion.

a. Observe the center of the ride (the primary axis) and the three main arms that come out from the center of the ride. Imagine you are suspended above the ride. Circle the way the primary axis turns.

clockwise counter clockwise.

b. Observe the motion of the individual seats as they move around their center, the secondary axis. Imagine you are suspended above the ride. Circle the way the secondary axis turns.

clockwise counter clockwise.

c. Indicate the direction of these motions on the diagram at the right.

2. Time the motions

a. Carefully watch one of the main arms rotating about the primary axis. Measure the time it takes for the arm to make 3 revolutions at full speed.

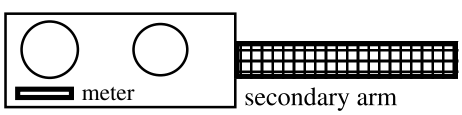
time for 3 revs = _________

2 b. Now observe the motion of a rider in one of the cars. To find the period of the car around the secondary axis, find the time it takes for the rider to travel in a complete circle relative to the ground. For example this would be the time it takes for a rider to go from facing west to the next time the rider is facing west.

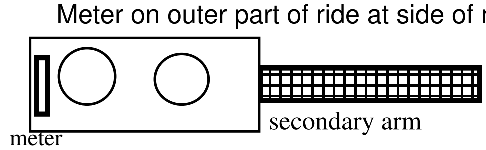
time for 1 rev = _________

READINGS ON RIDE

Meter held in front of rider



Meter on outer part of ride at side of rider



On this ride the horizontal meter is held in two different orientations by a person in the outermost seat. Two people in different cars can take the readings or a single rider can ride twice.

For both the largest and smallest meter readings record where it occurred, its magnitude and the forces you are feeling at that time. Record in the chart below.

	Reading in degrees	where on ride	size of force felt (large, small, none)	force felt on what part of body (back, side..)
meter in front largest reading				
meter in front smallest reading				
meter at side largest reading				
meter at side smallest reading				

OBSERVATIONS

1. Try to focus on only the movement of the center of the ride as it rotates around the primary axis. When the ride is up to speed, the rotation rate of the primary axis (circle one):

   decreases   increases   remains the same

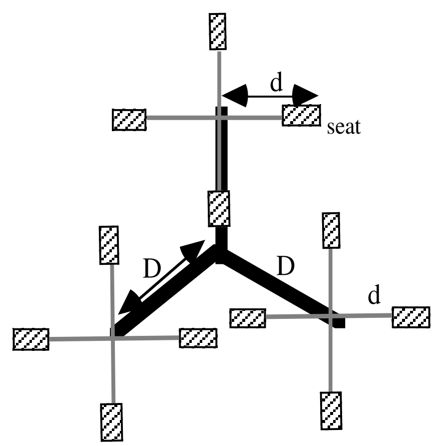
2. Try to focus on only the movement of the center of the of one of the smaller or secondary arms as it rotates around the secondary axis. When the ride is up to speed, the rotation rate of the secondary axis:

   decreases   increases   remains the same

3. Try to follow the motion of a single rider through one complete rotation of the primary axis. Sketch the path the rider would take if viewed from above.P

4. The motion of the rider is a combination of motions around the primary axis and the secondary axis. When an object moves in a circle with a constant speed, the velocity vector is tangent to the circle at the point where the object is located. Each circular movement has a tangential velocity.

   a. On the diagram to the right show where on the ride are the tangential velocities additive to produce the greatest speed. Use the following symbols on your vectors.
   v_p = tangential velocity due to primary axis rotation
   v_s = tangential velocity due to secondary axis rotation
   Explain.



   b. Where on the ride are these velocities subtracted to produce the smallest speed? Show the tangential velocity vectors. Explain.

5. By observing the riders or actually riding the ride, determine where on the ride the change in velocity is the greatest.

6. Do you feel the greatest force at the location where you have the greatest speed? Explain why or why not.

7. Explain what would happen if both the primary and the secondary rotation were in the same direction.

CALCULATIONS

(Show all substitutions)

ff = tan θ

1. Convert the degrees read on the meter to force factors
2.

   a. meter in front Largest reading **ff** = ____________

   b. meter in front Smallest reading **ff** = ____________

   c. meter at side of rider Largest reading **ff** = ____________

   d. meter at side of rider Smallest reading **ff** = ____________

2. How do these force factors compare to those experienced on other rides?

3. When the ride is at full speed the secondary axis rotation rate is constant. If only the secondary axis were to rotate and the rider was at a position furthest from the hub of the secondary axis:

   a. Give the rider's distance from the secondary axis of the ride

$r = d$ d = __________

   b. Based only on the rotation of the secondary axis what is the speed and direction the rider. (Use the period of rotation of the secondary axis.)

$v_{secondary} = \frac{2\pi d}{T}$ v= ____________

$R_1 = D + d$

4. When the ride is at full speed, the primary axis rotation rate is constant. A rider's speed will depend on how far he/she is from the center of rotation. If only the primary axis were to rotate and the rider was at a position <u>furthest</u> from the hub of the primary axis:

R_1= __________

   a. What is the distance of the rider from the center of the ride?

$v_{primary1} = \frac{2\pi R_1}{T}$ v= ____________

   b. Based only on the rotation of the primary axis what is the speed and direction of the rider. (Use the period of rotation of the primary axis.)

$R_2 = D - d$

5. When the ride is at full speed the primary axis rotation rate is constant. A rider's speed will depend on how far he/she is from the center of rotation. If only the primary axis were to rotate and the rider was at a position closest to the hub of the primary axis:

   a. What is the distance of the rider from the center of the ride

$v_{primary\ 2} = \frac{2\pi R_2}{T}$

$R_2 =$ __________

   b. Based only on the rotation of the primary axis what is the speed and direction of the rider. (Use the period of rotation of the primary axis.)

v= ____________

6. Using vector addition combine the appropriate individual velocities to find the velocity of the rider at a position furthest from the primary axis. Show your vector diagram and the math at the right. Does this calculated value agree with what you felt on the ride?

7. Using vector addition combine the appropriate individual velocities to find the velocity of the rider at a position closest to the primary axis. Show your vector diagram and the math at the right. Does this calculated value agree with what you felt on the ride?

8. When the rider is at a position halfway between the outermost and the closest point to the primary axis and the rider is headed in toward the center of the ride

$r = D$

   a. What is the distance from the center of the ride

r = __________

   b. Based only on the rotation of the primary axis what is the speed and direction of the rider. (This is the one that varies.)

$V_{mid\ /\ prim} = \frac{2\pi D}{T}$

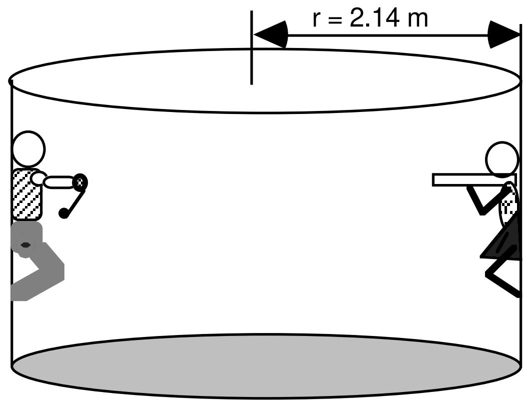
v= ____________

9. Using vector addition, combine the appropriate individual velocities to find the resultant velocity when the rider at a position halfway between the outermost and the innermost point and is headed in.
   Show your vector diagram and the math below.
   Does this calculated value agree with what you felt on the ride?

ACTIVITY 6: TAZ TWISTER

MEASUREMENTS

Time for 5 Revolutions at top speed	t =	_______
ROR⇒ TUBE FORCE METER at top speed	**ff =**	________
ROR⇒ HORIZONTAL METER in degrees at top speed (ß)	**ß =**	________
Radius	r =	2.14 m
Your Mass	m =	_______
Your Weight in newtons	w =	________



NOTE: This ride requires three partners. One with tube, one with string as shown.
The **Third Partner** must hold the **horizontal meter** as shown in number 4 below.

OBSERVATIONS

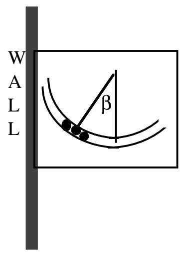
1. Describe how the wall feels and explain why it was constructed this way.

2. Describe how the force against your back changes as the speed increases.

3. Have someone on the ride hold an object hanging from a string. Sketch and describe how the angle the string makes with the vertical changes as the speed increases.

Start	Slow	Fast	Description

4.

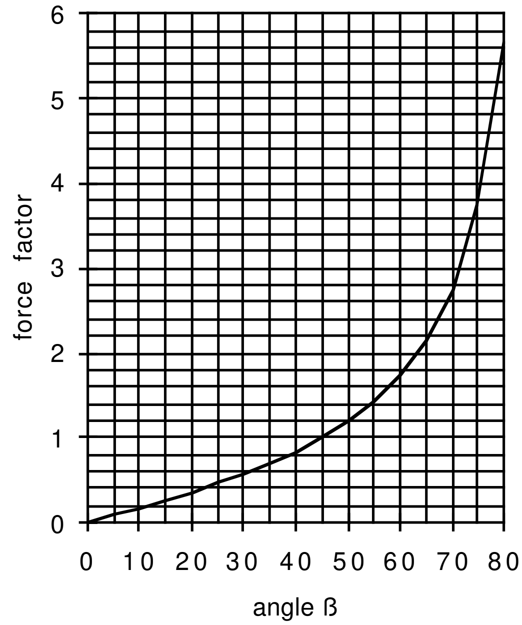


a. Hold the horizontal meter next to the wall at eye level as shown in the diagram at the left. Turn your head slightly to the side to read the meter.

b. Use the graph and the angle ß recorded on the ride to determine the horizontal force factor.

force factor = ________

c. Compare this force factor to the reading on the tube meter.



CALCULATIONS
(Show all substitutions)

$T = \frac{t}{\# \text{ of rev}}$

1. Calculate the period of the ride.

T = _________

2. Calculate the maximum speed of the ride.

V_{max} = _________

$v = \frac{2\pi r}{T}$

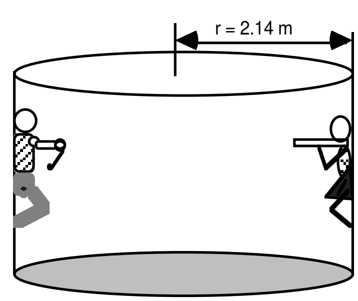
$\Sigma F_r = F_c = \frac{mv^2}{r}$

3. Calculate the net radial force F_c which the wall exerts on your back to keep you moving in a circle when at top speed. This force on your back is the NORMAL FORCE.

F_c = __________

4. While you are spinning three forces are acting on you: *gravity*, *friction* and the *inward push of the wall*.

Show the forces acting on one of the figures at the right.



$F_{friction} = mg$

5. You do not slide down the wall when the ride is at top speed. Which force must have the same magnitude as the frictional force ?

$F_{friction}$ = _______

$F_{friction} = \mu F_{normal}$

6. Compute the minimum coefficient of friction, μ, necessary for this ride to operate safely.
Remember, in this case the normal force is exerted by the wall while the frictional forces are what hold you up.

μ = ________

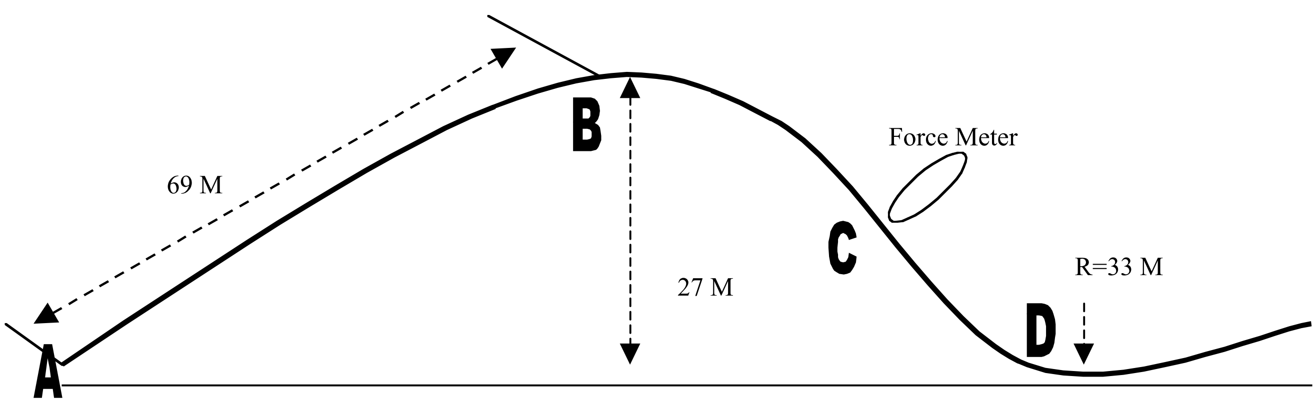
force factor = $\frac{\text{force on back}}{\text{weight}}$

7. The force you felt was the force exerted by the wall on your back, F_C. Calculate the force factor exerted on a rider's back when the ride is at top speed.

ff = ________

How does this calculated value compare to the readings you got on the ride?

ACTIVITY 7 : ROLLING THUNDER



Measurements on the diagram are accurate

MEASUREMENTS

IMPORTANT: Force meter is held parallel to track on the way up the first incline and then is held parallel to the rider's back. Clutch meter and seat bar simultaneously.

While Watching

Time for first car to reach top top of first hill t = ________

Your Mass m = ________

Your Weight w = ________

Read On Ride

ROR ⇒ Collect this information on the ride.	Sensation (heavier, lighter, normal, weightless)	Force Meter
Going uphill A to B		
At B, just before descending		
At C, half way down		
At D, bottom of curve		
At E, top of second hill		

OBSERVATIONS

1. In terms of forces, explain why most rides use a long shallow first incline?

2. If the time to go uphill were shorter, what would happen to the power needed?

3. Where does the meter give a maximum reading? Why is it maximum there?

4. Did you ever feel as if you were lifting out of you seat? Where? Why?

5. Describe the way potential and kinetic energy are exchanged as the rider progresses.

6. Why is the first hill always the highest?

CALCULATIONS

(Show all substitutions)

FINDING YOUR TOTAL ENERGY

$E_P = mgh$

1. Your potential energy at B, the top of the first hill is the total energy you will have throughout the ride. If we ignore friction, this total energy is the sum of your potential energy and kinetic energy at any given moment. Let potential energy be 0 on the ground and calculate your potential energy at B. This is now your total energy for the ride.

Total Energy
E_T = _________

GETTING TO THE TOP - FORCES AND POWER

$\text{Force} = \frac{\text{work}}{L}$

2. The work done moving you up the hill from A to B is equal to the potential energy at B. The length of the first hill is 69 m. Calculate the force F_{AB} used on your back to push you to the top of the hill.

F_{AB} = _________

$\text{force factor} = \frac{\text{force felt}}{\text{weight}}$

3. Calculate the force factor on your back as you go up the hill and compare it to what you measured.

ff = _________
.

$\text{Power} = \frac{W}{t}$

4. Calculate the power used to get you from A to B.

Power = _________

ENERGY AND SPEEDS DOWN AT THE BOTTOM

$E_T = E_P + E_K$

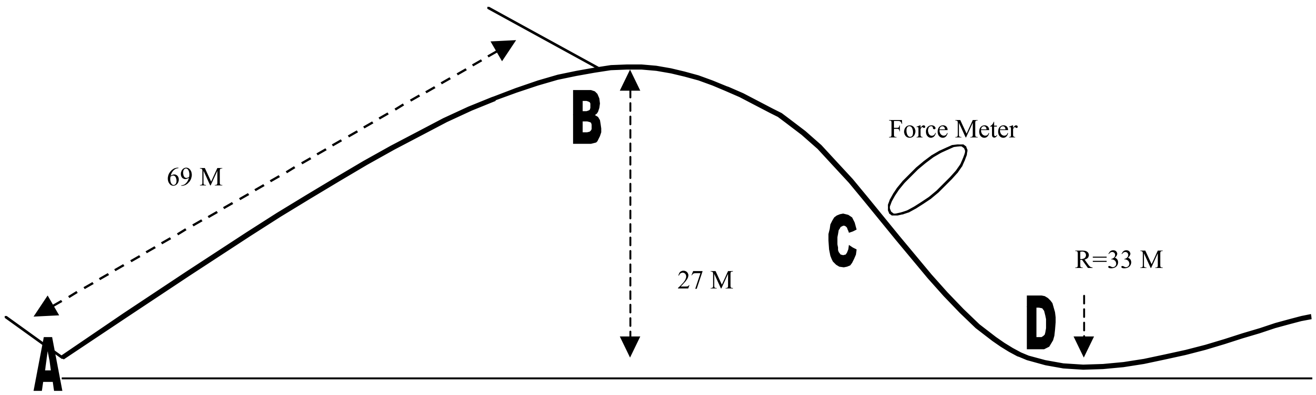
5. During the ride you must account for your total energy as the sum of the potential energy and kinetic energy.
At D the potential energy is 0. Fill in the chart at the right to find your KINETIC ENERGY at the bottom.

E_T = _________
E_P = _________
E_K = _________

$E_K = \frac{1}{2} mv^2$

6. Use the value of your kinetic energy to calculate your speed at D. This is the maximum speed of the ride.

V_D = ___________



FORCE FELT AT THE BOTTOM OF THE HILL

7. Going through the curve, the seat must exert enough force to both hold you in a circle and counteract gravity.

$F_{centripetal} = \frac{mv^2}{r}$

a. Calculate the centripetal force needed at D, the bottom of the loop to stay in the circular arc.

F_C = ___________

$F_{seat\ at\ D} = F_C + mg$

b. Calculate the force the seat exerted on you at D, the bottom of the loop.

$F_{seat\ at\ D}$ = ________

force factor = $\frac{\text{force felt}}{\text{weight}}$

8. To describe the force you are feeling in terms of your own weight find the force factor at D. (force felt = $F_{seat\ at\ D}$)

ff = _________

9. Compare the calculated value to the reading you or a colleague experienced while riding. Suggest reasons for any differences.

Measured
ff = _________

10. Based on your calculations, explain why it is important that the radius be large at point D.

ACTIVITY 8: THE VIPER

MEASURE ON RIDE | **MEASURE WHILE WATCHING**

Force Meter reading while on the first incline ROR⇒ **ff = _____**

Time for first car to reach top of first hill t = _________

IMPORTANT: **Hold the force meter parallel to track on the way up the first incline. After that, just notice variations in forces on your back, seat and shoulders.**

SENSATIONS (Circle your answer)

Sensation during first drop	heavier than normal	lighter than normal	losing contact with seat
At bottom of first drop	heavier than normal	lighter than normal	losing contact with seat
Going through heart line roll	heavier than normal	lighter than normal	losing contact with seat
Other observations	____		

Things to Notice While Watching and Questions To Have Riders Answer

The Viper starts out much the same way as Batman or Scream Machine but then, instead of going through a vertical loop, it sends the rider through two “heart line” rolls.

1. Watch riders with long hair. When the ride is upside down in the heart line rolls, can you see the hair hanging down?

2. Does a rider ever feel upside down?

3. The first incline of the Viper is much steeper than that of any other ride. How does this affect the force on the rider’s back?

4. Describe the path of the ride during the first part of the first drop.

5. Viper then sends the rider through a steep “tunnel” created by a set of rings. Why do the rings make the ride seem to move at higher speed?

6. How does a rider feel going through the curve at the bottom of the first drop?

7. Compare and contrast the sensations of the two heart line rolls.
   a. First roll - open air

   b. Second roll - inside red rings

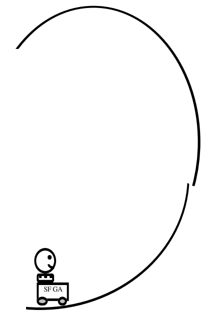
8. Describe the harness system. Why should it alert you that the seat force will at times be zero?

9. Why the Viper is called a “heart line” coaster?

COMPARE AND CONTRAST VIPER AND OTHER COASTERS

Viper's heart line roll is a sensation unlike anything you have ever experienced.

The diagram at the right represents a rider on an ordinary coaster.



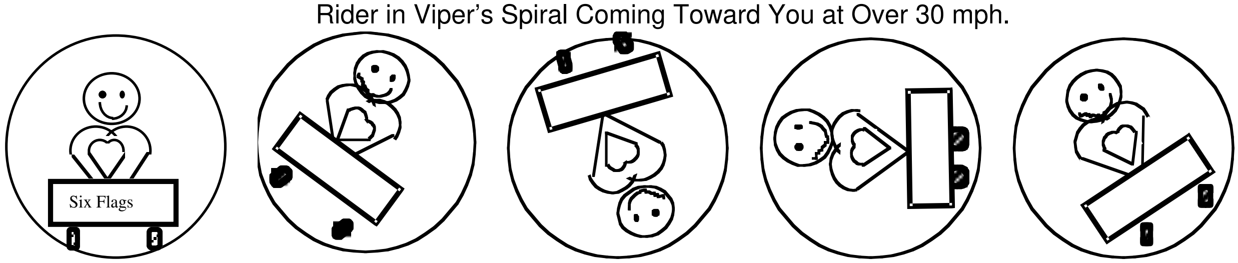
DO THIS: On the diagram to the right, draw lines to represent the paths taken by the top of your head, your heart, and your feet .

head (dashed) - - - - - - -

heart (dotted) ....

feet (solid) ________

Rider in Viper's Spiral Coming Toward You at Over 30 mph.



1 2 3 (head) 4 (heart) 5 (feet)

Although you are going very fast in the forward direction, the speed at which each part of your body completes its circle is very small. One complete rotation takes about 2.5 seconds . To make things even stranger, the plane of rotation is perpendicular to the direction in which you are facing.

DO THIS: On diagram 3 draw a dashed line representing the path taken by the top of your head
On diagram 4 draw a dotted line representing the path taken by your heart
On diagram 5 draw a solid line representing the path taken by your feet

	Description - Check which ride or rides each description fits.	Viper	Ordinary coasters
1	Going down hill and through the bottom of the curve is like riding very fast on a mountain road or pumping your swing until it goes super fast.		
2	When your body makes a loop, your body is both going in the forward direction and along the tangent of the arc at the same time.		
3	When your body makes a circle, the radius of the circle is large compared to your body. The speed and radius for your seat and head are similar. If the force of the seat on you is 2 x normal, the force your neck is exerting on your head is also 2 x normal.		
4	When your body rotates, the center is actually between your head and waist. The speed for each part of your body is very different. Some parts are going twice as fast as others. Each part of your body needs a different force factor.		
5	When you are in the vertical loops the support force from your seat is still very strong and so you feel very secure. The ride confuses you because, while you see that you are upside down, you actually feel right side up and lighter than normal. (Check that out by riding with your eyes closed.)		
6	When you are rotating it feels a little like doing a cartwheel.		

7. Compare and contrast the paths made by your head, heart and feet on the two coasters.

8. Use these diagrams to explain why the spiral section of the Viper is called a heart line roll.

CALCULATIONS

$v = \frac{2\pi r}{T}$

1. Calculate the speed at which your head makes a circle. The radius of the circle made by most riders' heads appears to be about 0.3 m. It takes 2.5 seconds for your body through its full rotation.

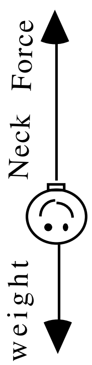
v_{head} = ________

ΣF_{radial} =

$F_c = \frac{m v^2}{r}$

2. Assuming that your head has a mass of about 4 kg, calculate the force needed to keep your head in its 0.3 m circle.

ΣF = ________



3. When you are upside down the combination of the forces exerted by your neck and gravity must combine and equal the force calculated in #2. The combination must be toward the center of the circle made by your head. How much force must your neck provide?

   $\Sigma F_{radial} = F_{neck} - \text{weight}_{head}$ $\text{weight}_{head} = m_{head}\,g$

F_{neck} = ________

You should find that your neck has to pull your head towards your shoulders with a little more force than it does when you are just hanging upside down.

$v = \frac{2\pi r}{T}$

4. Calculate the speed at which your feet make a circle. The radius of the circle your feet make around the axis of rotation is about 0.7 m.

v_{feet} = ________

ACTIVITY 9 : RUNAWAY TRAIN

MEASUREMENTS

Your mass m = ________

Your Weight w = ________

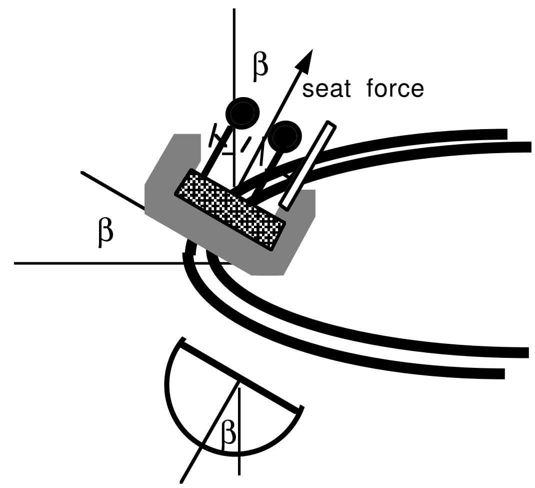
Watch the train from across the water. Choose one of the track supports as a reference find the time for entire train to pass that support t = ________

Angle ß, between vertical and seat force ß = ________°

Length of train L = 15.5 m

Radius of Horizontal Curve R = 26 m

$^{R}O_{R}$⇒ force factor **ff** = ________



Don't forget: Read the tube force meter as you round the curve when going over the water !!

Sensations (Normal, Heavier, Lighter)

As the train rounds the horizontal curve ______________________

Easy Angle Measure Instructions

Align protractor meter as shown

Determine angle ß by counting degrees. (The location of your 0 may make the apparent measurement the complement

OBSERVATIONS

1. On what part of your body did you feel forces being exerted as you rounded the curve?

2. Explain the advantage of using a banked turn in terms of the forces needed to make an object move in a circle. (Think about a car going around a curve on a level road. What is the only force available to keep it from skidding?)

3. Sketch how the banking angle of the train would look if the train were moving faster.

4. Sketch what would happen to the banking angle of the train if the radius were larger.

5. Even though the train was at an angle as it came around the curve, did you ever feel as if you were falling to the side? Which way seemed to be up?

CALCULATIONS

(Show all substitutions)

FINDING YOUR TOTAL ENERGY

$E_p = mgh$

1. Your potential energy at the top of the first hill which has a height of 20 m, is the ideal total energy you will have throughout the ride. Let potential energy be 0 on the ground and calculate your potential energy at the top of the first rise. This is your ideal total energy for the ride.

Total Energy
E_T = _____

IDEAL VERSUS ACTUAL SPEED AND ENERGY GOING AROUND THE CURVE

$v = \frac{L}{t}$

2. Calculate your EXPERIMENTAL speed going around the curve by using the time it took the entire train of cars to pass your chosen support point.

v = ________

$E_K = \frac{1}{2} mv^2$

3. Calculate the value of the kinetic energy using the experimental velocity as you go around the curve.

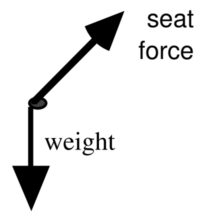
Experimental E_K = _______

4. Calculate the difference between the kinetic energy at this point and the ideal total energy for the ride.

Difference = ________

5. How can you account for the difference?

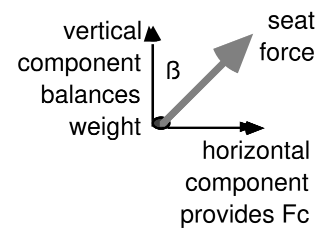
ROUNDING THE CURVE



Two forces act on you as you ride **weight** and the **seat force.** They are shown at the left in bold.

The **seat force** has two components shown at the right
- •The <u>vertical component</u> balances your weight.
- •The <u>horizontal component</u> provides the centripetal force needed to make you follow the arc of the turn.

Combined as vectors they give the force you were feeling.



6. Find the centripetal force on you as you round the curve..

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

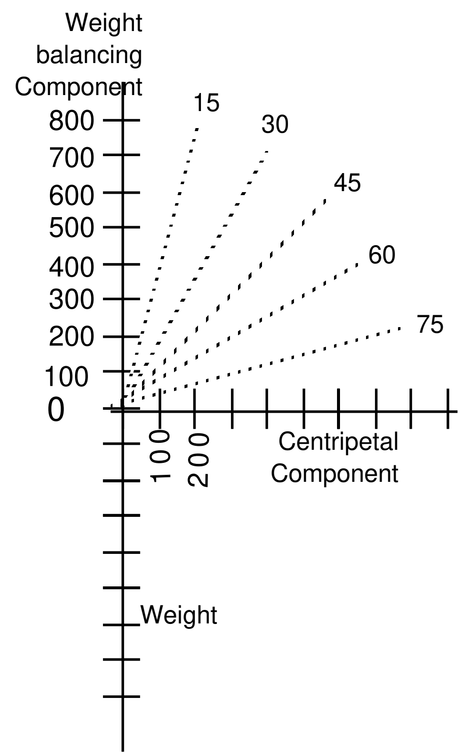
$F_{centripetal}$ = ________

Combining the vectors

7. **List** the facts you need
   a. Write your weight in newtons _______ N

   b. Write the centripetal force you calculated in # 6. _________ N

8. **Draw to scale** on the diagram at the right
   a. your weight in newtons pointing down
   b. the vertical component of the seat force pointing up (it is the same size as your weight)
   c. the horizontal component which is the centripetal force you calculated in #6.



9. **Complete the vector diagram** and **Find the resultant**
   a. By approximating the length and angle on the diagram
   and/or
   b. Mathematically from the Pythagorean Theorem

   and $ß = \tan^{-1} \frac{\text{horizontal component}}{\text{vertical component}}$

x

Seat Force = ________ angle ß = _______°

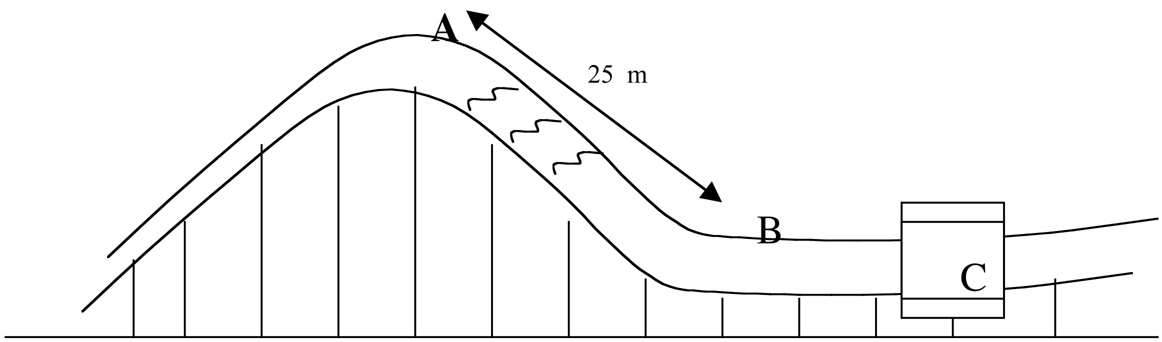
10. **Calculate the force factor you felt on the ride**

    force factor = $\frac{\text{seat force}}{\text{normal weight}}$ = __________

11. The angle the seat force makes with the normal is the same angle the train makes with the ground. Compare your calculated angle to the angle you measured.

12. Compare your calculated force factor to the force factor you measured?

ACTIVITY 10: LOG FLUME



MEASUREMENTS Measurements on the diagram are accurate

Length of a boat L = 3.4 m

Your Mass m = ________

Your Weight w = ________

Time to come down slide t_{AB} = ________

Duration of the splash t_{splash} = ________

Time needed for whole boat to pass under the front edge of the bridge point C. t_C = ________

OBSERVATIONS

1. Why is there water on the slide and not just at the bottom?

2. If there is a lot of mass up front, is the splash larger or smaller? Explain why this is so.

3. Does the distribution of mass influence the duration of the splash? Describe your observation.

4. Where on the ride do the riders lunge forward? Explain why this is so.

CALCULATIONS

(Show all substitutions)

$V_{av} = \frac{\text{slide length}}{t_{AB}}$

1. Calculate your average speed down the slide.

$V_{average}$ = ___________

$\frac{V_i + V_f}{2} = V_{av}$

2. Assuming constant acceleration starting from rest, calculate your speed at point B, the bottom of the slide.

$V_{at\ B}$ =_________

$V_c = \frac{L}{t_c}$

3. Calculate your speed after the splash as the boat passes point C.

$V_{at\ C}$ = _________

$p_B = mv_B$

4. Calculate your momentum (p_B) at point B.

p_B = __________

$p_C = mv_c$

5. Calculate your momentum (p_C) at point C.

p_C = __________

$\Delta p = p_C - p_B$

6. Calculate your momentum change.

Δp = _________

$\Delta p = F\Delta t$

7. Using the time of the splash as the time needed to change the momentum, calculate the average force that you experience during the splash.

F_{splash} = _________

force factor = $\frac{\text{force felt}}{\text{normal weight}}$

8. Calculate the force factor for the stopping force.

ff = _________

ACTIVITY 11: CAROUSEL

MEASUREMENTS
While Watching
Period of ride T_{ride} = __________s

	Inner Ring	Outer Ring
Number of horses		
ROR ⇒ Space between horses		
ROR ⇒ Time for three complete up and down motions		
ROR ⇒ Distance horse moves from highest to lowest point		

OBSERVATIONS

1. Is the floor level? _______ If not, which way does it tilt? __________

   Why?

2. How does the linear velocity of the outer horse compare to the linear velocity inner horse?

3. How does the angular velocity of the outer horse compare to the angular velocity of the inner horse? (Remember, units for angular velocity may be radians/second, degrees/second or revolutions/minute)

4. Describe the mechanism that causes the horses to go up and down.

5. Do the inner and outer horses have the same period of up and down motion?

6. When you are at the highest point on your animal, what is the position of the one in front of you?

   Is the motion of the animal in front of you in phase or out of phase with yours?

7. When you are at the highest point on your animal, what is the position of the one next to you?

   Is the motion of the animal next to you in phase or out of phase with yours?

8. Imagine the carousel inside a circular building. Holding a felt marker at arm's length you can just touch the wall. When the carousel is at full speed you begin to mark the wall. Sketch the pattern the ink makes on the wall.

CALCULATIONS

(Show all substitutions)

COMPARING SPEEDS OF THE HORSES

1. Calculate the circumference of the outer ring.
   (distance between horses • number of horses)

C_{outer} = ________

$C = 2 \pi R$

2. Find the radius of the outer ring.

R_{outer} = ________

$v = \frac{C}{T}$

3. Calculate the linear speed of an outer horse.

V_{outer} = _______

$\omega = \frac{360°}{T}$ or $\omega = \frac{2\pi}{T}$

4. Calculate the angular velocity of an outer horse.
   One revolution is 360° or 2π radians.

ω = _________

5. Calculate the circumference of the inner ring and its radius as you did for the outer ring in 1 and 2.

C_{inner} = ________

r_{inner}= _________

$v = \frac{C}{T}$

6. Calculate the linear speed of an inner horse.

V_{inner} = _______

$\omega = \frac{360°}{T}$ or $\omega = \frac{2\pi}{T}$

7. Calculate the angular velocity of an inner horse. One revolution is 360° or 2π radians.

ω = _________

8. Explain why the angular speeds are the same even though the linear speeds are different.

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

9. Calculate the centripetal force that must act on you when you ride an outer horse

F_{outer} = _________

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

10. Calculate the centripetal force that must act on you when you ride an inner horse.

F_{inner} = _________

11. The floor of the carousel is tilted slightly inward. Why is this more important for an outer horse than an inner one?

TRACING THE PATH OF A SINGLE HORSE

$T = \frac{time}{3}$

12. Using the time it takes to make three complete up and downs, calculate the period of the vertical motion of an outer horse.

T = ________

$f = \frac{1}{T}$

13. Find the frequency of the motion of an outer horse.

f = ________

$\lambda = \frac{v}{f}$
or
$\Delta d = \lambda = vT$

14. How far does the outer horse travel in one cycle.

λ = ________

15. The distance calculated in #5 is the wave length of this wave form. How many waves will the outer horse make as the carousel makes one complete circuit.

= ________

16. Find the amplitude of the wave form.

A = ________

17. Sketch the sine wave of an outer horse's motion along the line below. Label both the amplitude and wave length.

____

18. How far does the inner horse travel in one cycle.

λ = ________

19. How many waves will the inner horse make as the carousel makes one complete circuit.

= ________

20. Fill in the chart below.

	Inner	Outer
Circumference		
Radius		
Linear Speed		
Angular Speed		
Centripetal Force		
Wavelength of horse's motion		
Frequency of horse's motion		
Number of horse wavelengths per carousel revolution		

Write a paragraph comparing and contrasting the motions, forces and wave patterns of the inner and outer horses.

ACTIVITY 12:   SPIN MEISTER

MEASUREMENT

Time for 4 revolutions at top speed	t = ________
ROR⇒Force meter reading just before tilt	**ff = ______**
ROR⇒Force meter reading at BOTTOM	**ff = ______**
ROR⇒Force meter reading at TOP	**ff = ______**
Radius of rider's seat at top speed	R = 7.9 m
Your Mass	m = ________
Your Weight in newtons	w = ________

OBSERVATIONS

While the Wheel is Horizontal

1. Watch the ride as it starts up and sketch what happens to the angle of the cars.

Stationary | Slow | Just before lift

2. DESCRIBE the sensations the riders have on the ride as it is speeding up.

3. a. As the speed of the ride increases the centripetal force on the rider:
   1. decreases   2. increases   3. remains the same

   b. As the speed of the ride increases the gravitational force on the rider:
   1. decreases   2. increases   3. remains the same

   c. Use your answer to a and b to explain why the angle changes as the speed increases.

While the Wheel is Vertical

4. a. Where do riders feel the heaviest?

   b. Where do riders feel the lightest?

   c. Do riders ever feel upside down?

CALCULATIONS

(Show all substitutions)

$T = \frac{t}{\# \text{ of rev}}$

1. Calculate the period of the ride.

T = ________

$v = \frac{2\pi R}{T}$

2. Calculate the speed of the car when the ride is vertical.

v_{max} = ______

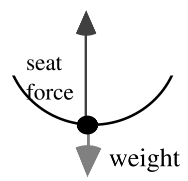
$F_c = \frac{m\ v^2}{R}$

3. Find the centripetal force needed to make YOU move in a circle when the ride is at top speed.

F_c = ________

$\Sigma F = F_c$

$F_{seat} - mg = F_c$



4. At the bottom of the circle, gravity works against the force exerted on you by the seat as it forces you to go in a circle. Calculate the force the seat exerts on you at the bottom of the loop.

$F_{\text{seat at bottom}}$

= ________

force factor = $\frac{\text{force}}{\text{weight}}$

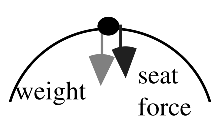
5. Calculate the force factor you would experience at the at the bottom of the ride.

ff$_{\text{bottom}}$ = ________

6. How well does this calculated force factor compare to the one measured on the ride?

$\Sigma F = F_c$

$F_{seat} + mg = F_c$



7. At the top of the loop, gravity works with the seat to hold you in a circle making the seat force lower Calculate the force the seat exerts on you when the car is at the top of the ride

$F_{\text{seat at top}}$

=__________

force factor = $\frac{\text{force}}{\text{weight}}$

8. CALCULATE the force factor you would experience at the top of the ride.

ff$_{\text{top}}$ = ________

9. How well does this calculated force factor compare to the one measured on the ride?

10. When you are stationary, a seat exerts a force on you equal to your weight. You experience a force-factor of 1. Based on the force factor when you are at the top of the ride, EXPLAIN why riders do not FEEL upside down.

11. Compare the force factor experienced during the same ride by people of different masses. Explain why they should be the same.

ACTIVITY 13: FLYING WAVE

MEASUREMENTS

Time for 2 revolutions at top speed t = __________

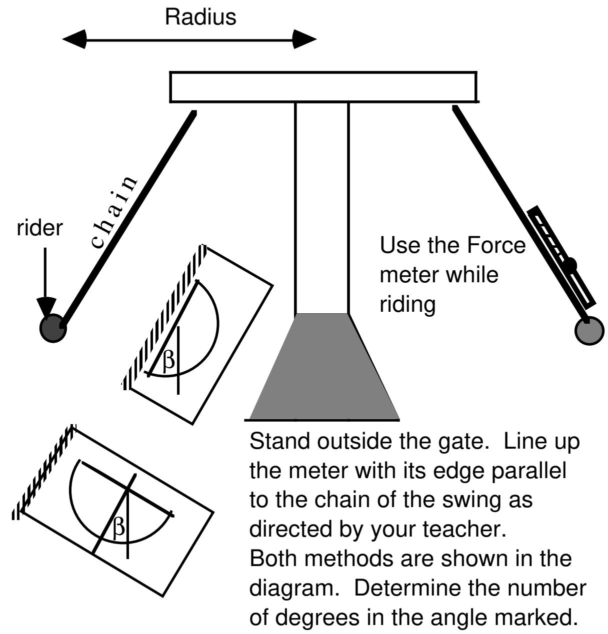
Maximum angle chain makes with the vertical ß = __________

ROR ⇒ Force meter reading along the chain at top speed **ff =** _______

Radius of rider at top speed R = 7.6 m

Your Mass m = _________

Your Weight in newtons w = _________



OBSERVATIONS

As you are waiting in line:

1. Sketch what happens to the swings as the ride speeds up.

Start Slow Fast

2. Compare the angle to the vertical of the chain on an empty swing with that of an occupied one at the same radius?

More Less The Same

3. Observe and describe the change in the motion of the swings after the top tilts.

While you ride, focus on the forces being exerted on your body.

4. When the ride is at rest, you feel the seat pushing up to balance gravity. Compare the forces you feel when the ride is standing still to the forces you feel as the ride speeds up.

5. What happens to the meter reading as the ride gets faster? Relate this to the forces experienced.

6. What physical sensations tell you that the ride has tilted?

7. What happened to the meter readings after the ride tilted?

CALCULATIONS - FINDING THE ANGLE AND THE NET FORCE

(Show all substitutions)

$T = \frac{\text{time}}{\text{\# of revs}}$

1. Calculate the period of revolution of the swing ride.

T = ____________

$v = \frac{2\pi R}{T}$

2. Calculate the maximum speed of an outer swing

v_{max} = __________

3. Calculate the centripetal force acting on you .

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

F_c = ____________

Weight = mg

4. Record your **weight in newtons** at the right.

Weight = ________

5. Multiply the force meter reading by your weight. This gives the *measured* seat force.

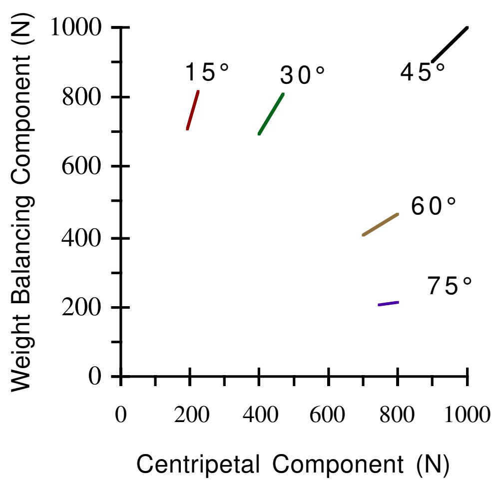
Measured Seat force = __________

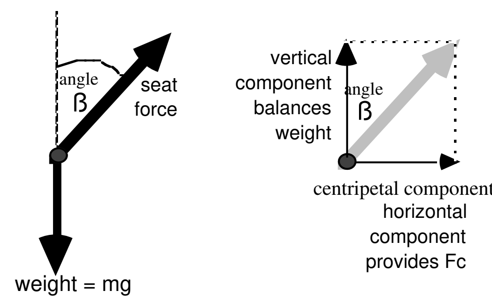
6. Two forces act on you as you ride, your weight and the seat force. The seat force has two components. Combine them to find the force you were feeling as you rode and compare it to the measured value.

Scale Drawing

a. Draw to scale the components of the seat force:
   (1) vertical vector equal in magnitude to your weight but directed upwards.
   (2) horizontal vector representing the centripetal force calculated in part 3.

b. Draw the resultant force vector (seat force) and estimate its direction using angle markings shown





Mathematical Solution

a. Find the magnitude of the seat force using the Pythagorean theorem. Show work here.

b. Find the angle ß by calculation.

$\text{tangent } ß = \frac{\text{centripetal component}}{\text{vertical component}} =$

RECORD ANSWERS HERE
Seat Force = ____________
angle ß = ____________

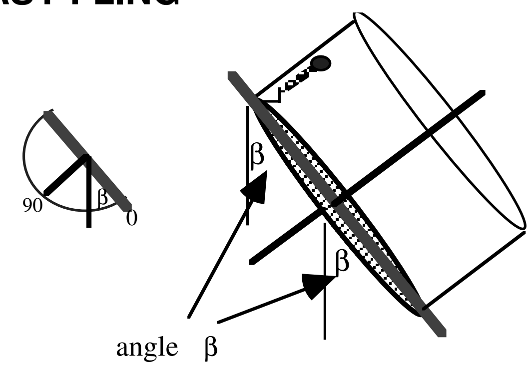
% difference = $\frac{\text{meas-calc}}{\text{calc}}$ *100

7. What is the % difference between the measured and calculated seat forces?

8. Compare the angle ß found above to the angle measured while observing the ride.

ACTIVITY 14: FANTASY FLING

Measurements *Watching From the Ground*



Time for three (3)revolutions at top speed t = ________

Period = T = $\frac{t}{3}$ T = _______

Angle of Ride to vertical at full tilt (Should be under 40°) β = _______°

Radius r = 7.8 m .

Your Mass m = _______

Your weight w = _______

$^{R}_{OR}$⇒ READINGS ON RIDE

FORCE METER READINGS
(tube horizontal next to your eyes)

Easy Angle Measure Instructions

Align protractor meter as shown

Determine angle ß by counting degrees. (The location of your 0° mark may make the apparent measurement a complement

$^{R}_{OR}$⇒ Before lift at top speed ____

$^{R}_{OR}$⇒ After Lift Highest Point _____

$^{R}_{OR}$⇒ After Lift Lowest Point _____

On a scale of 0 to 10 with 10 representing the strongest force, rank the forces you felt on your back in each of the following situations

1. At top speed before lift when near operator's booth ! - - - - ! - - - - ! 0 5 10
2. At top speed before lift when opposite operator's booth ! - - - - ! - - - - ! 0 5 10
3. At highest point of ride after lift ! - - - - ! - - - - ! 0 5 10
4. At lowest point of ride after lift ! - - - - ! - - - - ! 0 5 10

OBSERVATIONS

1. Describe how the force against your back changes as the ride speeds up.

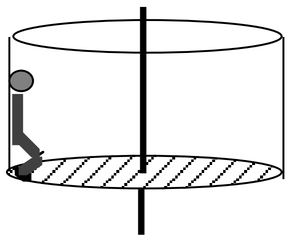
2. If your eyes were closed, describe the physical sensations that would tell you the ride had tilted. Include a discussion of the force on your back at various points in the rotation.

3. Did you ever feel as if you were going to fall into the center of the ride? Explain your answer.

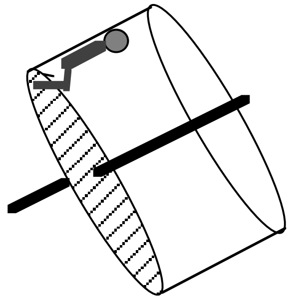
PICTURING THE SITUATION

(ANSWER ALL QUESTIONS)

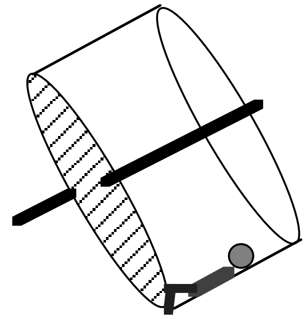
On the diagrams below draw vectors showing the relative size of the force the wall exerted on your back pushing you toward the center of the ride.



A: ride horizontal
and at top speed



B: Ride tilted
rider at highest point



C: Ride tilted
rider at lowest point

Since the ride was moving at the same speed in all the pictures above, the total force pushing you toward the center is the same.

a. The force of the wall in case B is clearly less that in diagram A. What provides the rest of the force needed ? Hint: what is the gravitational force doing?

b. In picture C you should have showed the wall exerting a very large force on your back. Why do you need so much more force when you are in this position?

CALCULATIONS

(Show all substitutions)

$v = \frac{2\pi r}{T}$

1. Calculate the top speed of the ride

$v =$ _________ $\frac{m}{s}$

$\Sigma F_{radial} =$

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

2. Calculate the net radial force needed to hold you in the circle of the ride at this speed. This centripetal force will be the same no matter what angle the ride is at. (That is why it is boxed right.)

$\boxed{F_c = \_\_\_\_\_\_\_\_\_}$

ff $= \frac{\text{Force felt}}{\text{weight}}$

3. When the ride is horizontal the entire ΣF_{radial} or Fc is exerted by the wall on your back. Using the F_C from above, calculate the force factor when the ride is horizontal and moving at top speed.

calculated
ff = _________

Compare it to the force meter reading measured on the ride.

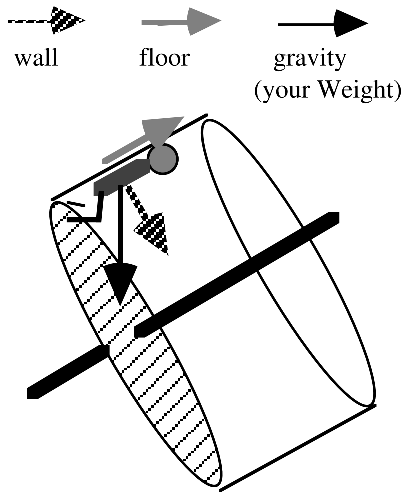
measured
ff = _________

Using Vectors to Check the Numbers

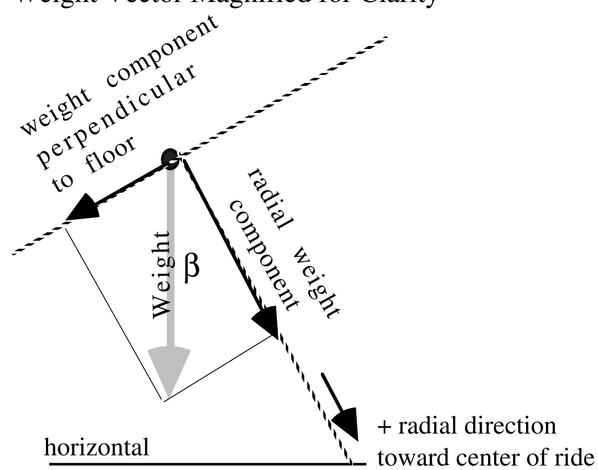
When the ride tilts, the force gravity exerts on you, your weight, W, has a component in the radial direction. Now, the force the wall exerts on you and the radial component of your weight (the force gravity exerts along the radius of the circle either toward or away from the center) combine to create the force holding you in circular motion.

$$F_{\text{wall}} + F_{\text{gravity radial}} = \frac{mv^2}{r}$$

1. Look at the figure showing the forces on you when you are at the highest point on the ride at full tilt. To the right slender arrows show the components of the force of gravity(your weight) parallel to and perpendicular to the floor.



Weight Vector Magnified for Clarity



B: Ride tilted and rider at the highest point.

a. Record your value for the angle of full tilt β .

$\beta =$ ___________

b. Calculate the component of your weight that helps you to move in a circle. This is called the *radial* component of your weight.

$$\text{weight}_{\text{radial}} = \text{weight} \times \cos\beta$$

Radial component of your weight

w_{radial} = ________

c. On the previous page you calculated the total force needed to hold you in a circle at top speed. Rewrite it at the right.

$\boxed{F_c = \text{\_\_\_\_\_\_\_\_\_\_}}$

d. Find the force the wall must contribute using

$$F_{wall} + w_{radial} = F_c = \frac{mv^2}{r}$$

$\mathbf{ff} = \dfrac{F\ \text{wall}}{\text{weight}}$

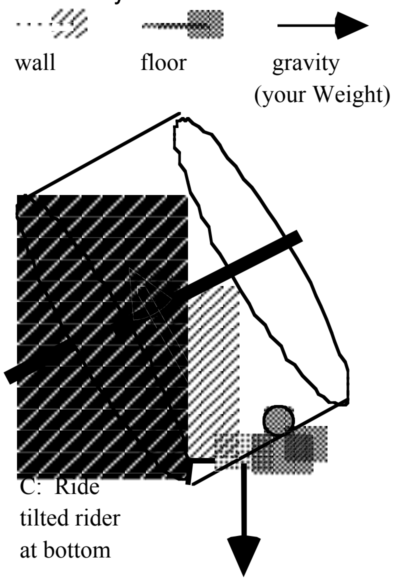
F_{wall} = ___________

e. Calculate the force factor and compare it to the meter reading from the ride.

calculated
ff = _________

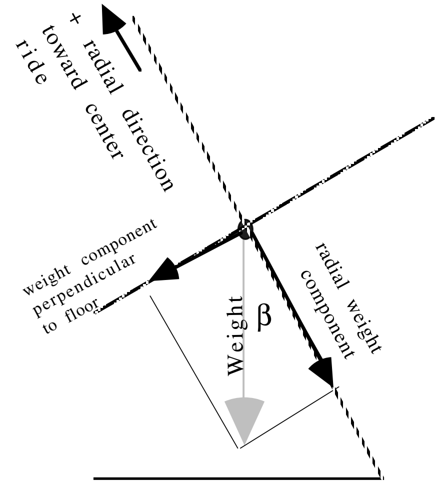
measured
ff = _________

2. Diagram C shows the forces on you when you are at the lowest point of the ride. Now, the component of your weight which acts in the radial direction is in the “wrong” direction for circular motion. To compensate, the wall force increases so that the sum of the radial forces stays the same.



C: Ride tilted rider at bottom

Weight Vector Magnified for Clarity



Angle β will be under 40°

a. Record your value for the angle of full tilt β .

β = __________

b. Calculate the component of your weight that pulls you away from the center of the circle. This is still called the *radial* component of your weight. (This number should look familiar!)

weight $_{radial}$ = weight x cosß

Radial component of your weight =
w_{radial} = ________

c. On a previous page you calculated the total force needed to hold you in a circle at top speed. Rewrite it at the right.

F_c = _________

d. Calculate the force the wall must contribute now that gravity is a pulling away from the center. The equation is:

$$\sum F_{radial} = F_{wall} - w_{radial} = F_c = \frac{mv^2}{r}$$

F_{wall} = __________

$$\textbf{ff} = \frac{\text{F wall}}{\text{weight}}$$

e. Calculate the force factor and compare it to the meter reading from the ride.

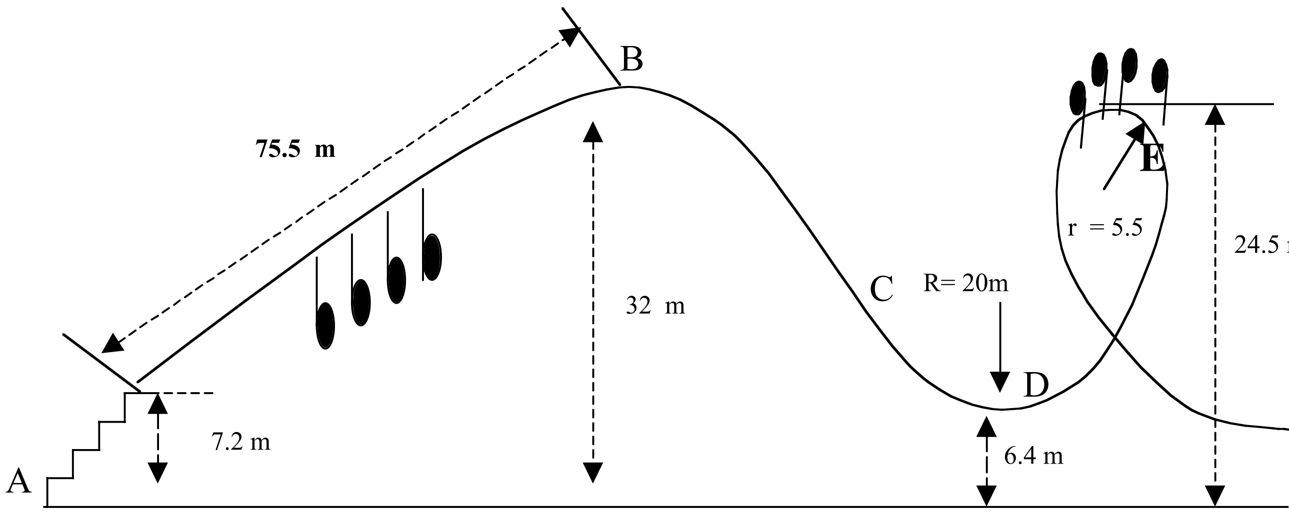
calculated
ff = ________

measured
ff = ________

f. Explain why, when the rider is at the bottom of the ride, the radial weight component is considered negative and the wall force becomes so very large.

ACTIVITY 15: BATMAN THE RIDE - Part 1

If you intend to do the other Batman Activities check to see what additional data is needed before going on the ride.



MEASUREMENTS Measurements on the diagram are accurate and go from reference point to rider. The turns in the ride have been "straightened" to make the ride easier to visualize.

All measurements, except force meter, are taken while watching

Your Mass m = ________

Your Weight w = ________

time for first car to reach top of first hill t = ________

Sensations (Normal, Heavier, Lighter)	Meter Readings
At B, just before descending ________________	$\vec{R}_{OR}$ force meter = ________
At D, bottom of curve ________________________	$\vec{R}_{OR}$ force meter = ________
At E, the top of the loop ___________________	$\vec{R}_{OR}$ force meter = ________

OBSERVATIONS

1. In terms of forces, explain why most rides use a long shallow first incline.

2. What is the advantage to the park of having you walk up the first 7.2 meters to get on?

3. If the time to go uphill were shorter, what would happen to the power needed?

4. Why is the first hill always the highest?

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

CALCULATIONS

(Show all substitutions)

FINDING YOUR TOTAL ENERGY

$E_p = mgh$

1. Your potential energy at B, the top of the first hill is the total energy you will have throughout the ride. If we ignore friction, this total energy is the sum of your potential energy and kinetic energy at any given moment. Let potential energy be 0 on the ground and calculate your potential energy at B. This is now your total energy for the ride.

Total Energy

E_T = _________

GETTING TO THE TOP - WORK AND POWER

2. The potential energy at B is a combination of the work you did to get to A and work the coaster did to get you from A to B.
   a. Find the work you did climbing the stairs which have a height of 7.2 m.

$\text{work} = mgh_A$

Work $_{\text{on stairs}}$ = _________

   b. Subtract the work you did from the total energy to find the work the coaster did to pull you to the top.

Work_{AB} = ________

$\text{Power} = \frac{\text{work}}{\text{time}}$

3. Calculate the power the ride used to get you from A to B.

Power = _________

ENERGY AND SPEEDS DOWN AT THE BOTTOM

$E_P = mgh$

$E_T = E_P + E_K$

4. During the ride you must account for your total energy as the sum of the potential energy and kinetic energy. At D the potential energy is not 0. (At this point h = 6.4 m) Fill in the chart at the right to find your KINETIC ENERGY at the bottom.

E_T = _________

E_P = _________

E_K = _________

$E_K = \frac{1}{2}mv^2$

5. Use your kinetic energy to calculate your speed at D. This is the maximum speed of the ride.

V_D = _________

FORCE FELT AT THE BOTTOM OF THE HILL

6. Going through the bottom of the curve before the first loop, the seat must exert enough force to both hold you in a circle and counteract gravity.

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

a. Calculate the net or centripetal force needed at D, the bottom of the loop, to stay in the circular arc.

F_c = ________

$\Sigma F_r = F_c$

$\Sigma F = F_{seat} - mg$

$F_{seat\ at\ D} = F_c + mg$

b. Calculate the force the seat exerts on you at D, the bottom of the loop.

$F_{seat\ at\ D}$ = _____

force factor = $\frac{force_{seat}}{weight}$

7. To describe the force you are feeling in terms of your own weight find the force factor at D. (force felt = $F_{seat\ at\ D}$)

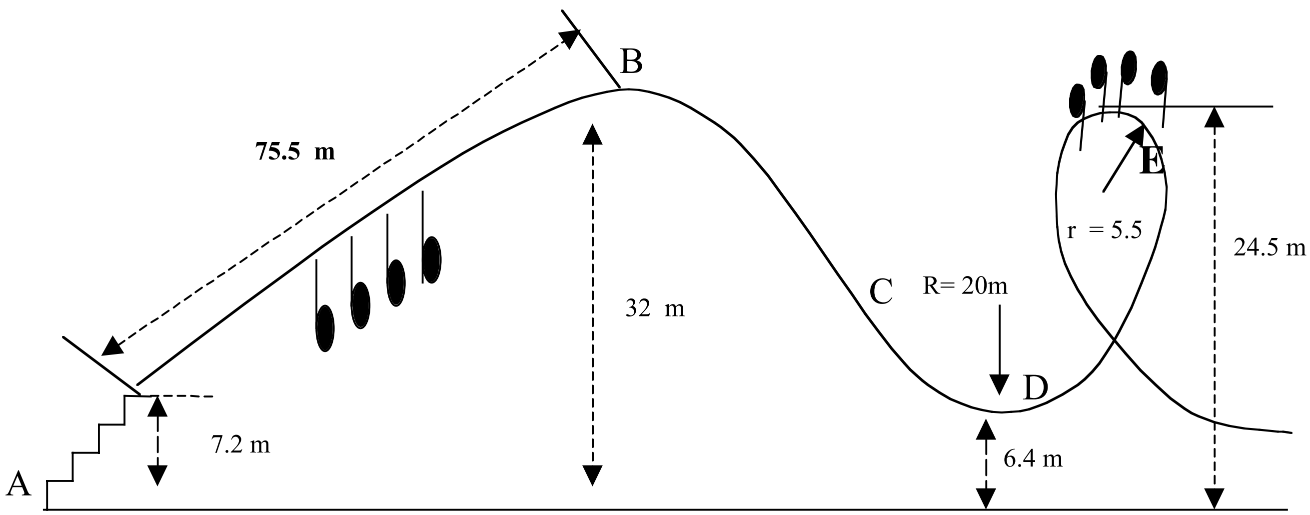
ff = ________

8. Compare the calculated value to the reading you or a colleague experienced while riding. Suggest reasons for any differences.

Measured **ff** = ________

9. Based on your calculations, explain why it is important that the radius be large at point D.

ACTIVITY 16: BATMAN THE RIDE - Part 2



MEASUREMENTS <u>Measurements on the diagram are accurate and go from reference point to rider.</u>
The turns in the ride have been "straightened" to make the ride easier to visualize.

Your Mass m = ________

Your Weight w = ________

time for entire train to pass point E at the top of the loop t = _______

length of train L = 12 m

SENSATIONS (Normal, Heavier, Lighter)

At B, just before descending ________________

At D, bottom of curve________________________

At E, the top of the loop ____________________

METER READINGS

$^{R}O_{R}\Rightarrow$ force meter = ________

$^{R}O_{R}\Rightarrow$ force meter = ________

$^{R}O_{R}\Rightarrow$ force meter = ________

OBSERVATIONS

1. Did you ever feel upside down? Explain your answer.

2. Describe the way potential and kinetic energy are exchanged as the rider progresses.

3. Where and why does the coaster have:
   a. Maximum potential energy?
   b. Maximum kinetic energy?
   c. Maximum speed?

CALCULATIONS

(Show all substitutions)

FINDING YOUR TOTAL ENERGY

$E_p = mgh$

1. Your potential energy at B, the top of the first hill is the ideal total energy you will have throughout the ride. If we ignore friction, this total energy is the sum of your potential energy and kinetic energy at any given moment. Let potential energy be 0 on the ground and calculate your potential energy at B. This is now your total energy for the ride.

Total Energy
E_T = ______

IDEAL VERSUS ACTUAL SPEED AND ENERGY AT THE TOP OF THE LOOP

$E_p = mgh$

2. During the ride you must account for your total energy.At E your total energy is partially potential and partially kinetic. Calculate your potential energy at E, the top of the loop.

E_P = ___________

$E_T = E_P + E_K$

3. Calculate your IDEAL KINETIC ENERGY at the top of the loop. We are assuming that the total energy is still the same.

E_K = ___________

$E_K = \frac{1}{2}mv^2$

4. Calculate your IDEAL speed at E, the top of the loop.

Ideal
$V_{\text{at E}}$ = ________

$v = \frac{L}{t}$

5. Calculate your EXPERIMENTAL speed by using the time it took the entire train of cars to pass point E at the top of the loop.

Experimental $V_{\text{at E}}$ = ________

$E_K = \frac{1}{2}mv^2$

6. Calculate the value of the kinetic energy using the experimental velocity at point E.

Experimental E_K = ________

$E_T = E_K + E_P$

7. Calculate the experimental value of the total energy at this point. Remember you still have the same potential energy as you did in question 2.

Experimental E_T = ________

8. Find the difference between your experimental value of total energy (#7) and the ideal value you calculated in #1.

Difference = _____

9. Find the percent deviation between your experimental value and the ideal value (the original total energy)

$\% = \frac{\text{Diff}}{\text{Ideal } E_T}$ X100

How do you account for any difference <u>you</u> found?

Percent deviation = ______

FORCES FELT AT THE TOP OF THE LOOP

10. At the top of the loop, E, gravity works with the seat to hold you in a circle. The seat can exert less force.

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

a. Using the EXPERIMENTAL velocity, calculate the centripetal force used to hold you in the circle at E. (NOTE: Both v and r are smaller than at D.)

F_c = ___________

$\Sigma F = F_c$

$\Sigma F = F_{seat} + mg$

$F_{seat} = F_c - mg$

b. Calculate the force the seat exerts on you. Remember, gravity is helping hold you in the arc., therefore the seat can exert less force.

$F_{seat\ at\ E}$ = _______

force factor = $\frac{force_{seat}}{weight}$

11. Calculate the force factor for the top of the loop.

Calculated
ff = _________

12. Compare your calculated value to the force factor read on ride.

Measured
ff = _________

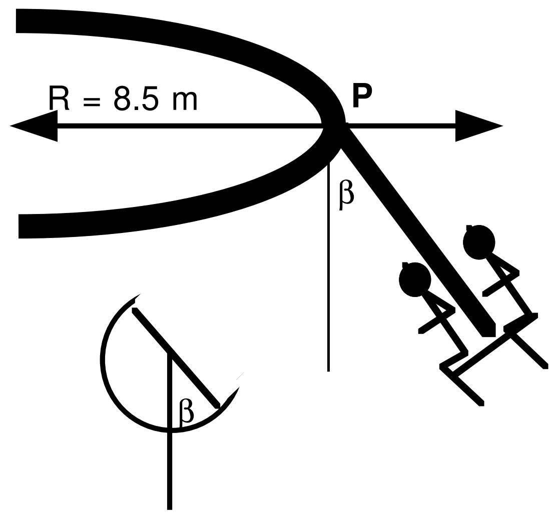
13. Your calculations should show that you need quite a bit of force from the seat to make you follow the arc of the track. Use this fact to explain why riders do not feel upside down at E.

14. Why is the radius of the curve at the bottom of a loop much larger than the radius of the curve at the top?

ACTIVITY 17: BATMAN THE RIDE - Part 3

MEASUREMENTS

Measurements on the diagram are accurate



time for entire train to pass point P at the SIDE of the loop t = ________

Angle of train to the vertical ß = ________°

length of train L = 12 m

Your Mass m = ________

Your Weight W = ________

$^{R}O_{R}$⇒ force factor at P **ff** = ________

Sensations (Normal, Heavier, Lighter)

At F, along the horizontal curve ________________________

Easy Angle Measure Instructions

Align protractor meter as shown

Determine angle ß by counting degrees. (The location of your 0 may make the apparent measurement the complement of the angle you want)

OBSERVATIONS

1. On what part of your body did you feel forces being exerted as you rounded the curve?

2. Sketch what would happen to the angle of the train if it were moving faster.

3. Sketch what would happen to the angle of the train if the radius were larger.

4. Even though the train was at such a great angle as it came around the curve, did you ever feel as if you were falling out? Explain.

CALCULATIONS

ROUNDING THE FAR TURN

$v = \frac{L}{t}$

1. Use the length of the coaster and the time it took to pass point P to calculate the speed of the coaster as it rounds the far turn.

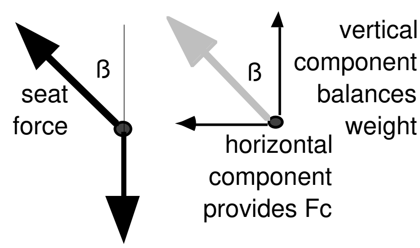
v = _________

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

2. Find the centripetal force on you.

F_c = __________

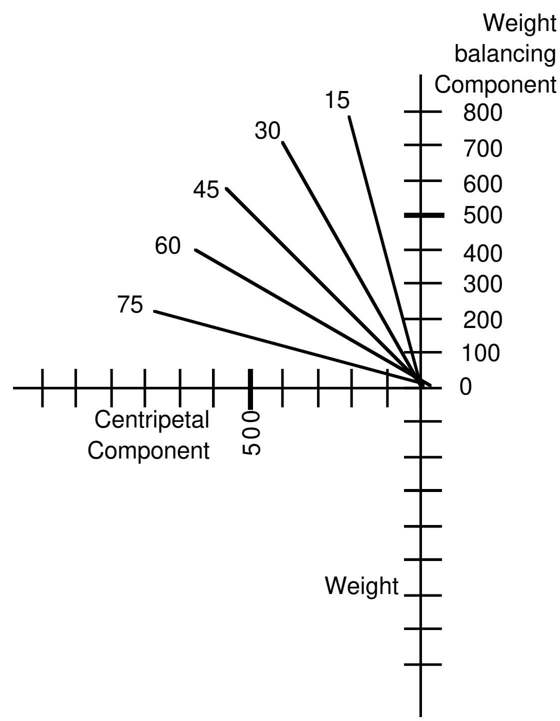
3. The two forces acting on you as you ride are shown at the right in bold. They are your weight and the seat force.



The seat force has two components

- The vertical component balances your weight.
- The horizontal component provides the centripetal force needed to make you follow the arc of the turn. Combined as vectors they give the force you were feeling.

COMBINING THE VECTORS



4. Draw to scale on the diagram given
   a. your weight in newtons pointing down
   b. the vertical component of the seat force pointing up (it is the same size as your weight)
   c. the horizontal component which provides the centripetal force you calculated in #2

5. Complete the vector diagram
   Find the resultant
   a. Graphically and/or
   b. Mathematically (using Pythagorean Theorem and tanß)

Seat Force = _________ angle ß = _______°

6. Calculate the force factor you experience

$$\text{force factor} = \frac{\text{seat force}}{\text{normal weight}}$$

ff = _________

7. How do your calculated angle and force factor compare to the angle and force factor you measured?

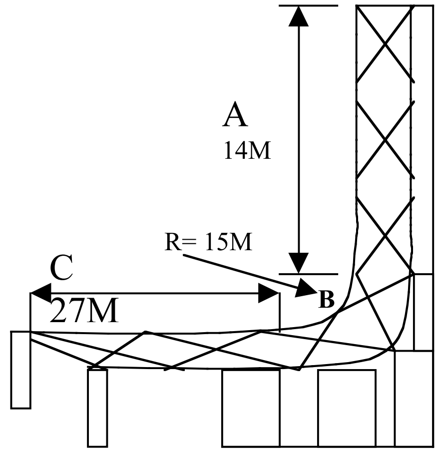
How can you account for discrepancies?

ACTIVITY 18:   STUNTMAN'S FREEFALL

If you do not go on this ride ask someone who has for the necessary information.

MEASUREMENTS

While Watching Time several drops and record the average time



Section of Ride	Measured Times	Average
Elevator Going Up	_____, _____, _____	t_{up} = ______
Region A - Free Fall Section	_____, _____, _____	t_A = ______
Region C - Stopping Track	_____, _____, _____	t_C = ______

Readings On Ride Force Meter Readings

Elevator going up $^{R}O_{R}\Rightarrow ff_{up}$ = _____

Free Fall Section $^{R}O_{R}\Rightarrow ff_{A}$ = _____

Stopping Track $^{R}O_{R}\Rightarrow ff_{C}$ = _____

OBSERVATIONS

1. For each portion of the ride, describe the FORCES THE RIDER actually FEELS. Be sure to note on what part of the body the force acts (back, seat shoulders...)

Where on Ride	Where on Rider's Body (back, bottom, shoulders...)	Sensation compared to normal weight (normal, larger, smaller, none)
Going up	__________________	____________________
Waiting to Drop	__________________	____________________
Free fall region A	__________________	____________________
Changing Direction Region B	__________________	____________________
Stopping Region C	__________________	____________________

2. On the way down, how can you tell when the direction is changing?

3. Where did your force meter read closest to zero? Why does this make sense?

4. Where did you experience the greatest force?

5. In the braking portion of the ride:
   a. how was your body oriented ?
   b. on what portion of your body was the stopping force exerted?
   c. why did the engineers design the ride this way?

CALCULATIONS

(Show all substitutions)

GETTING TO THE TOP - POWER

$W = F\,d$

1. Find the work done in lifting you to the top. The average lifting force is the upward force needed to lift your weight. The full distance from the ground to top is 30 m.

Work = ________

$P = \frac{W}{t}$

2. Find the power used getting you to the top.

Power = _______

3. Calculate the power used in horsepower
(1 horsepower = 746 watts)

Power = _____ hp

COMING DOWN - CHECKING THE FREE FALL

$d = \frac{1}{2}\,gt^2$

4. Calculate the time it should take for the free fall drop of 14 m (region A) if the track were frictionless.

time = ________

5. Compare the time of free fall you measured with the time you calculated in #4.
Within experimental error is section A really free fall?

6. Did the force meter and sensations during the drop support this conclusion? Explain.

7. A typical description of free fall is “My stomach jumped into my throat.” Relate this to what happens to the mass in the vertical force meter.

COMING DOWN - THE SPEED IN THE CURVE

$\Delta E_p = mg\Delta h$

$\Delta E_p = \Delta E_k$

$E_k = \frac{1}{2} mv^2$

$v_f^2 - v_i^2 = 2ad$

8. Calculate the instantaneous speed after a drop of 20 meters assuming the ride is frictionless. Without friction the curved track changes the direction of the car without affecting speed. You can do this calculation using either energy or kinematics.

v = ________

COMING DOWN - THE FORCE IN THE CURVE

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

9. The 20 meter point is on the curve which has a radius of 15 m. Calculate the centripetal force needed to make you follow the curve of the ride at this point.

F_c = ______

force factor = $\frac{F_{centripetal}}{weight}$

10. Calculate the force factor experienced at this point.

ff = ________

11. You probably couldn't read the meter at this moment but does this force factor seem reasonable compared to your experience

STOPPING - MOMENTUM AND IMPULSE

$\Delta E_p = \Delta E_k$

$mg\Delta h = \frac{1}{2} mv^2$

12. The drop to the start of the braking track is 25 meters. Find the speed assuming all of the potential energy lost becomes kinetic energy. (In mph this is _________)

v = ______ m/s

$P_i = mv_i$

13. Calculate your momentum (P_i) as you enter the stopping track.

P_i = ________

$F\Delta t = P_f - P_i$
or
$F\Delta t = 0 - mv_i$

14. Your momentum after stopping, (P_f) is 0. Use the concepts of impulse and momentum to calculate the average force on you while stopping. You measured the time used to stop the car.

F = ________

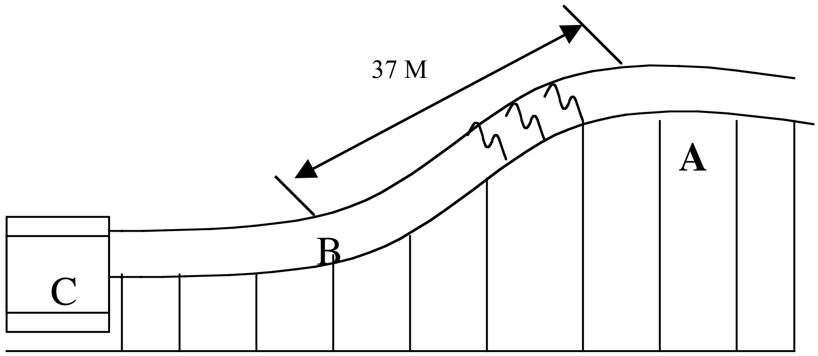
force factor = $\frac{\text{braking force}}{\text{weight}}$

15. Relate the braking force to your normal weight by find the force factor.

ff = ________

16. Discuss the agreement between calculated and experienced forces.

ACTIVITY 19: MOVIETOWN WATER EFFECT



MEASUREMENTS Measurements on the diagram are accurate

Length of a boat L = 7.0 m	**Time Measurements**
Your Mass m = ________	Time to Pass Point A, at top of last drop T_A = ________
Your Weight w = ________	Time to come down slide T_{AtoB} = ________
	Duration of the splash T_{splash} = ________
	Time needed for whole barge to pass under the front edge of the bridge, point C. T_C = ________

OBSERVATIONS

1. Why is there water on the slide and not just at the bottom?

2. If there is a lot of mass up front, is the splash larger or smaller?
   Explain why this is so.

3. Does the distribution of mass influence the duration of the splash? Describe your observation.

4. Where on the ride do the riders lunge forward?
   Explain why this is so.

CALCULATIONS

(Show all substitutions)

FINDING SPEEDS DURING THE RIDE

$V_A = \frac{L}{T_A}$

1. Calculate your speed at A, the top of the long final drop.

V_{top} = __________

$V_{av} = \frac{\text{slide length}}{T_{AtoB}}$

2. Calculate your average speed down the slide.

$V_{average}$ = __________

3. Assuming constant acceleration starting from rest, calculate your speed at point B, the bottom of the slide.

$\frac{V_f + V_i}{2} = V_{av}$

V_B =________

$V_c = \frac{L}{T_C}$

4. Calculate your speed after the splash as the boat passes point C.

V_C = _________

FINDING THE FORCE OF THE SPLASH

$P_B = mv_B$

5. Calculate your momentum (P_B) at point B.

P_B= __________

$P_C= mv_C$

6. Calculate your momentum (P_C) at point C.

P_C= __________

$\Delta P = P_C - P_B$

7. Calculate your momentum change.

ΔP = _________

$\Delta P = F\Delta t$

8. Using the time of the splash as the time needed to change the momentum, calculate the average force that you experience during the splash.

F_{splash} = __________

ff = $\frac{\text{force felt}}{\text{normal weight}}$

9. Calculate the force factor for the splash force.

ff = _________

ACTIVITIES 20 & 21:   THE CHILLER

INTRODUCTION

Batman and Robin are Six Flags Great Adventure's first electric catapult launched roller coasters. The trains start at ground level in the station and are accelerated to 65 mph in 4 seconds. After exiting the launch zone, the trains proceed through a series of track elements and approach their maximum heights. Before the trains slow to a stop, they get a boost from additional motors in the boost section. The trains slow to a stop and then proceed backwards through the track, entering the launch zone at 65 mph in reverse. Magnetic brakes slow the trains initially, and the trains are parked with traditional mechanical squeeze brakes.

The trains are launched with Linear Induction Motors (LIMs). There are 43 motor assembly pairs in each launch zone, for a total of 43x2x2 = 172 motors in the launch zone of both rides. Each ride has 7 motor pairs in the boost section, for a total of 7x2x2 = 28 motors in the boost area. The total number of motors on both rides is 178 + 28 = 200. During the launch phase of either Batman or Robin, the system is set up so that at any instant of time only 20 motors are operating.

OBSERVATIONS

NOTE: This ride is fast and it is hard to make observations. Before you get on the ride remind yourself to <u>think about the forces</u> you feel during the launch, during the braking and, if you are riding Batman, when you are going straight down when facing down and when you are going up facing down.

1. Shown on the next page in part 1, is a graph of the force factor of the seat on your back during launch. What does the graph imply about the force during the launch.

2. The ride is equipped with "boost" motors to make sure that the train always starts each return trip at the same height. Why is this important?

3. As seen in the introduction, magnetic brakes and traditional squeeze brakes are used to stop the train at the end of the ride. Most other coaster rides require only the squeeze brakes. What is the difference between this ride and other coasters that makes this necessary?

4. On what part of the rider's body are the forces acting when the train is being launched?

5. On what part of the rider's body are the forces acting during the braking portion?
   What provides this force?

6. If you have not ridden the Batman side of this ride talk to someone who has.
   Contrast and compare the sensations felt on the following portions of the ride:

   a. during the first half of the ride, when the rider is both going down and facing straight down.

   b. during the second half of the ride, when the rider is going up while facing straight down.

ACTIVITY 20: THE CHILLER Part 1

MEASUREMENTS

mass of loaded train $M = 7100$ kg

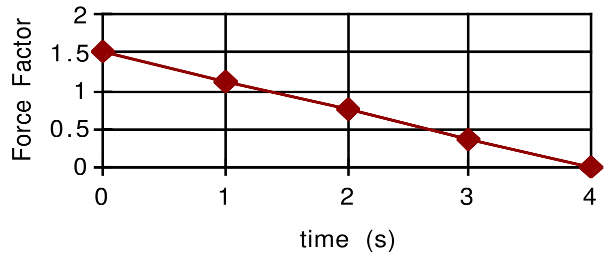
time for launch acceleration $t = 4$ seconds

efficiency of motors Eff = 44 %

Your Mass $m =$ ________

Your Weight in N $w =$ ________

Chiller Launch ff vs. Time



CALCULATIONS

(Show all substitutions)

1. Using the graph, find the average force factor during the launch

ff = ________

$F_{av} = ff \times weight$

2. Find the average force in newtons you experience.

$F_{av} =$ ________

$F_{av} = ma_{av}$

3. Find the average acceleration you experience in m/s^2

$a =$ ________

$v_f = v_i + at$

4. Find the final velocity achieved during launch.

$v_{final} =$ ________

$v_f^2 = 2ad - v_i^2$ or $d = v_i t + 1/2\, at^2$

5. Find the distance moved during the launch process.

$d =$ ________

$F_{av} = Ma_{av}$

6. Your acceleration is the same as that of the entire train. Find the average force (thrust) exerted by the motors on the entire train during the launch process.

$F_{train} =$ ________

Work = Fd

7. Find the work done by the motor during launch.

$W =$ ________

$\text{Power} = \frac{\text{work}}{\text{time}}$

8. Find the average power delivered during launch.

$P =$ ________

% difference = $\frac{\text{yours-ideal}}{\text{ideal}} \times 100$

9. According to Larry Chickola, the engineer at Six Flags Great Adventure the average power delivered during launch is 769,000 watts. Calculate the percent difference between your result and his. (Use his value as the ideal or accepted value.)

% diff = ________

ACTIVITY 21: CHILLER Part 2

DATA

Efficiency of launch motors Eff = 44 % Launch power supplied to train P = 769,000 watts

1 hp = 746 watts Number of motors operating at a given time N = 20

CALCULATIONS

(Show all substitutions)

Note: Questions 1 - 5 involve the electrical INPUT to the motors.

$\text{Eff} = \frac{P_{out}}{P_{in}} \times 100$

1. According to Larry Chicola the engineer at Six Flags Great Adventure, the efficiency of the bank of thrust motors is only 44%. How much power must be put into the bank of thrust motors, total $P_{in,}$ in order to output the 769,000 watts that must be delivered to the train?

$P_{T\,(in)}$ = ________

$P_{T\,(in)} = V_T * I_T$

2. The input power is supplied to the motors in the form of AC electricity. The voltage used is equivalent to 870 volts of DC. What is the total operating current in the bank of motors?

I_T = ________

$V_T = I_T\ R_{T(eq)}$

3. Calculate the total equivalent resistance of the entire bank of motors?

$R_{T(eq)}$ = ________

4. Using the rules for voltage, current, and resistance in series and in parallel circuits determine the voltage, current, and resistance of each of the 20 individual motors which are operating. (Assume the motors are identical. The total values for V, I, and R are calculated or given above.)

If connected in series :

$V_T = V_1 + V_2 + ..$ ª $V_{individual} = \frac{V_T}{20}$

V_{ind} = ________

$I_T = I_1 = I_2 = ..$ ª $I_{individual}$ = ans to 2

I_{ind} = ________

$R_T = R_1 + R_2 + ..$ ª $R_{individual} = \frac{R_T}{20}$

R_{ind} = ________

If connected in parallel:

$V_T = V_1 = V_2 = . .$ ª $V_{individual}$ = (see q. 2)

V_{ind} = ________

$I_T = I_1 + I_2 + . .$ ª $I_{individual} = \frac{I_T}{20}$

I_{ind} = ________

$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + . .$ ª $R_{individual} = 20\ R_T$

R_{ind} = ________

5. Based on some logical reasoning and the results above, are the motors more likely to be wired in series or in parallel? Explain your answer.

Note: Questions 6 and 7 involve the OUTPUT of the motors.

$P_{ind} = \frac{P_T}{20}$

6. The average power delivered by the combination of the 20 motors during launch is 769,000 watts. Calculate the number of watts that each individual motor must supply.

P_{ind} = ________

7. When you buy a motor rated at one Hp, you are buying a motor that can supply 1 Hp of power. What would be the rated horsepower of each motor?

hp = ________

Energy = P t

8. In question 1 you calculated the total electrical power that had to be delivered to the bank of thrust motors during the 4 second launch. Calculate the total energy supplied to accomplish one launch

   a. in joules (watt-seconds)

Energy =

________J

   b. in kilowatt hours

Energy =

______ kw-hr

9. The cost of electricity is 5¢ per kilowatt hour. Calculate the cost of launching one Chiller train. (If this answer seems strange, remember that you have braking systems, computer controls, lighting, etc. all consuming electrical energy.)

Cost = ________

ACTIVITY 22: BUMPER CARS

MEASUREMENTS

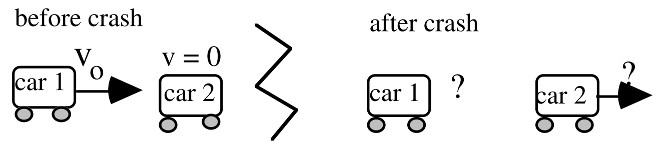
Since the speed of each car is individually controlled, we cannot make exact measurements. Instead we will try to make reasonable estimates for each required quantity.

Estimate or measure the distance between two points on the ride. distance between points d = ________

Determine the time it takes several cars to pass between the points when at <u>top speed</u>.

t_1 = _____ t_2 = ______ t_3= _____ t_{av} = ______

Watch a head on collision of a fast car with a stationary car. Estimate the speed of each car after the crash.



If it looks like 1/2 the original speed of the fast car show it as 1/2 v_o

$v_{i\#1} = v_0$ $v_{f\#1}$= ___v_0 $v_{i\#2}$ = ___v_0 $v_{f\#2}$ = ___v_0

Estimate the load in each car in terms of the number of 60 kg (132 pounds) adults.

Two children = 1 adult ♠ 1M One foot ball player ♠ 2 adults ♠ 2M Load in car #1 = ________

Load in car #2 = ________

The mass of unloaded bumper car is about 240 kg which is approximately 4 times the mass of an adult, M.

$m_{car\ empty}$ ♠ 240 kg ♠ 4 M

OBSERVATIONS

1. Observe collisions when a fast moving car hits either a stationary or very slow moving car. Compare speed and direction of motion before and after the collision, when the collision is
   a. head on

   b. glancing collision.

2. For each of the cases above sketch a diagram showing the cars before and after the collision. Use vectors to represent the approximate velocities of each car before and after the collision.
   a. head on
      before after

   b. glancing collision
      before after

3. Using the concepts of energy, impulse, momentum, and Newton's Laws of Motion discuss the collisions studied above.
   a. head on or rear end with stationary or slow moving car.

   b. glancing collision with stationary or slow moving car.

4. Observe the overall motion of the cars. Could this apparently random motion be used to model the behavior of an ideal gas?
   a. List several of the assumptions of the ideal gas model

      1.

      2.

      3.

      4.

   b Describe any similarities between an ideal gas particle and a bumper car

   c. Describe any differences between an ideal gas particle and a bumper car

5. Observe the electrical connections in this ride. In the space at the right draw a possible circuit diagram for the construction of the Bumper cars Ride. To simply this show the diagram for only three operating cars. Remember, the ride operator can start and stop the ride.

6. As you walk across the floor, compare the frictional force you feel while walking on this surface to the frictional force you feel when walking on the pavement outside the ride. The coefficient of friction between rubber soled sneakers and concrete is about 1.0.

   a. Is the coefficient of friction between the floor and your shoe larger or smaller that the coefficient of friction between your shoe and the pavement outside the ride? How can you tell?

   b. Would you expect the coefficient of friction between the floor and car to be larger or smaller than 1.0?

   c. What would happen if the coefficient of friction were to decrease?

   d. What would happen if the coefficient of friction were to increase?

7. Using the concepts of energy, impulse, momentum, and Newton's Laws of Motion, discuss why the cars have rubber bumpers around the entire car?

CALCULATIONS

(Show all substitutions)

$v = \frac{d}{t_{av}}$

1. Calculate the top speed of a car.

v=__________

2. Calculate the mass of each car in the collision you observed. (Remember, mass of unloaded bumper car is about 240 kg, approximately 4 times the average mass of a person.)

   Calculate the total mass of the moving car you observed.

$m_{\#1}$=__________

   Calculate the total mass of the stationary car you observed.

$m_{\#2}$=__________

3. Using your estimates of the speeds of each car before and after the collision and the masses of the car-rider combinations, complete the chart shown below.

	Collision Before		Collision After	
	Car #1	Car #2	Car #1	Car #2
Mass Car + Passengers				
Speed				
Momentum (p = mv)				
Total Momentum Car #1 + Car #2				

Calculation space

4. As you learned in class, momentum is a quantity that must be conserved. Do your measurements verify the Law of Conservation of momentum? Explain

$\Delta p = p_{f\#2} - p_{i\#2}$

$\Delta p = m\Delta v = F\Delta t$

5. Assuming that the collision takes place in a time of 0.1 second, determine the force on car # 2

F =_________

Medusa

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

Consider what is happening as the coaster in the following situations:

a. going up the first hill
b. going down the first hill
c. making a sharp left or right hand turn
d. going over the top of a hill when right side up
e. going through the top of a loop upside down
f. leaving a loop while right side up.

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

For each of the situations above predict what forces you or another rider would feel.

a. going up the first hill

b. going down the first hill

c. making a sharp left or right hand turn

d. going over the top of a hill when right side up

e. going through the top of a loop, upside down

f. leaving a loop, right side up.

Stand outside the ride at a place where you can see the coaster going through the first loop. Measure the time it takes for the entire coaster train to go through the top of the loop. Start your stopwatch when the first car gets to the top of the loop and stop when the last car passes this point. The coaster train is 13.1 meters long. Calculate the speed of the coaster train as it goes through the top of the loop. Show your work.

Speed = v =

v = ______________________________

We will use this value at the end of this exercise to calculate the force that a rider would feel at the top of the loop.

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

As you go through the top of the first loop try to remember the force you felt. Did the seat push on your bottom or did the shoulder harness hold you in your seat.
Use your vertical meter to get a reading at the top of the first loop.

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

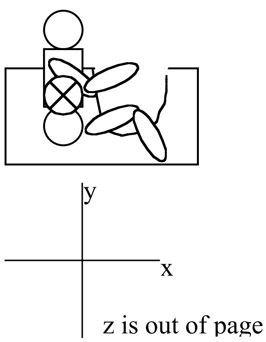
Force meter reading =force factor = ff = _____

Medusa – Free Body Diagrams

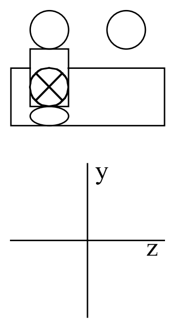
A free body diagram shows only the forces acting on an object.
<u>On this ride the object is you or your designated rider</u>.

In each situation you are to show the forces acting on you. You will be presented with three views, diagram a - a view from the side, diagram b - a view from the back, and diagram c - a view from the top.

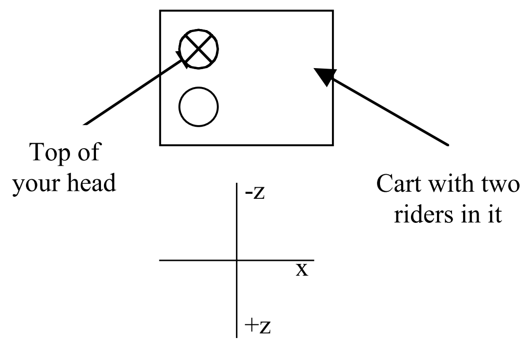
In all cases, the positive x direction will be in the forward direction, the positive y direction will be up and the positive z direction to your right. (Note: If you or your teacher prefers to label the axes differently, please do so.)



a. View from side



b. View from back



c. View from top

In all the examples we will use the following vector designations

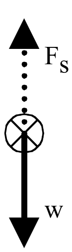

represents your weight, w, and

(Note: always acts down)

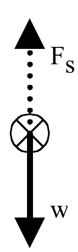

The force of the seat, F_s, and


the force due to the side or the back of the cart

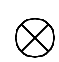
Example: You are not moving and you are in the station before the start of the ride. The ⊗ represents your center of gravity. To draw a free body diagram you must show all the forces acting on you. In the station when you are at rest, there are two forces acting you, your weight, w. and the force, F_s, of the seat acting on your bottom.
Below are the diagrams showing the forces acting on you



a. View from side



b. View from back



c. View from top

Notice in the diagrams, there are no forces in the x or in the z directions. Therefore $\Sigma F_x = 0$ and $\Sigma F_z = 0$.
In diagram **a** (view from the side) and in diagram b (view from the back) the forces in the y direction are balanced. F_s and w have the same magnitude but the opposite direction. The sum of the forces, $\Sigma F_y = 0$. According to Newton's Second Law, $\Sigma F = ma$. Since $\Sigma F = 0$ in all three directions, there is no acceleration, a. This means, the object (you), is not accelerating, i.e. you are not changing either your speed or your direction.

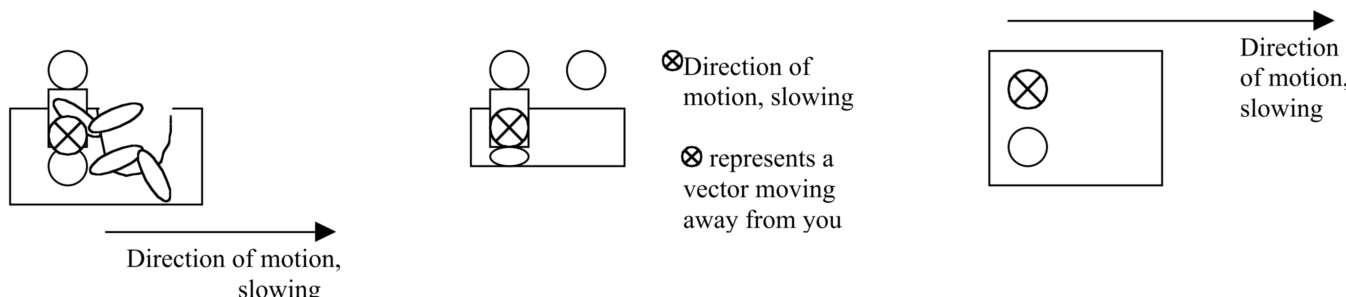
In this exercise you will determine the forces acting on the rider at various other points on the ride.

A. Returning to the station while braking
B. Going up the first hill
C. Going down the first hill
D. Turning left at the bottom of a hill
E. At the bottom of the first vertical loop
F. At the top of the first vertical loop

Now ride the ride or interview people who have ridden the ride and determine the forces that are felt by the rider in each of these locations.

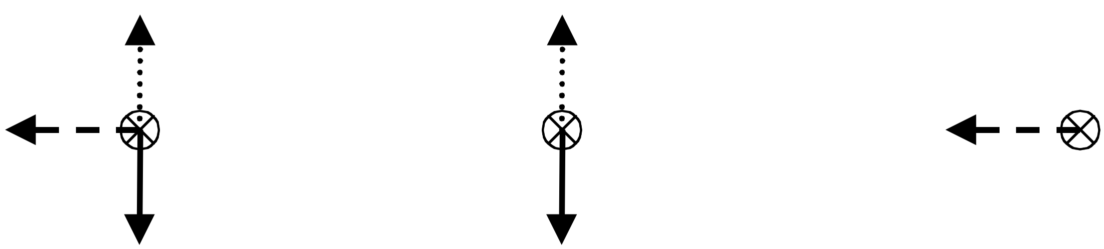
Since almost everyone has experienced a braking force either on a coaster or in a car or bus. As the vehicle undergoes braking, the seat belt or harness applies a force on you which holds you back in your seat.

<u>EXAMPLE</u> Case A Returning to the station while braking
Now consider the situation where you are coming into the station and the brake is applied. Draw the free body diagrams for this case. First, draw a diagram showing the situation.



a. View from side b. View from back c. View from top

Then draw the free body diagrams. Use the situation diagrams for reference, but draw a separate diagram showing only the forces action on the object.



a. View from side b. View from back c. View from top

Remember: the positive x direction it in the direction of forward motion, the positive y direction is up and the positive z is to your right.

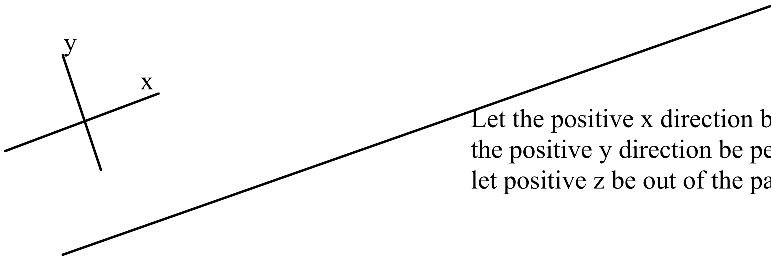
ΣF_x = force due to braking = ma
Notice this force is in the negative direction

$\Sigma F_y = F_s + w$
since F_s and w have the same magnitude, but the opposite direction, $\Sigma F_y = 0$

$\Sigma F_z = 0$

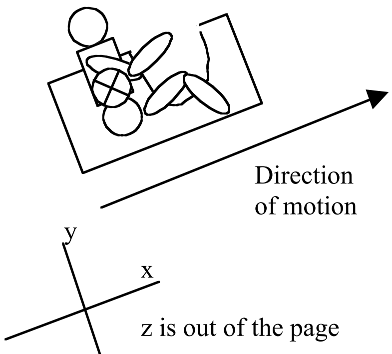
The only unbalanced force is the braking force. This force is in the direction opposite to motion and it is therefore the force that causes you to decrease your speed.

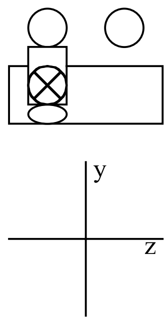
Case B - Going up the first hill. Determine the forces acting on you as you travel up the first hill either by riding Medusa or by interviewing someone who did.

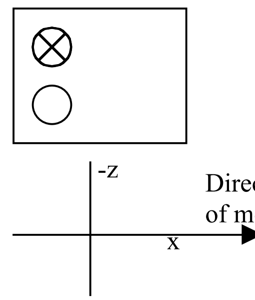


Let the positive x direction be up the incline as shown, let the positive y direction be perpendicular to x as shown and let positive z be out of the page as before.

Draw a situation diagram showing all three views as before. In this situation your weight vector will of course be straight down. When you analyze the forces in the x, y, and z directions you will have to find the components of you weight in these directions.







View from side | View from back | View from top

As you are going up the hill, are you accelerating?
Predict what the ΣF will be in each direction. State the direction and relative size of the resultant force.

$\Sigma F_x =$ $\Sigma F_y =$ $\Sigma F_z =$

Now draw the free body diagrams for this situation.

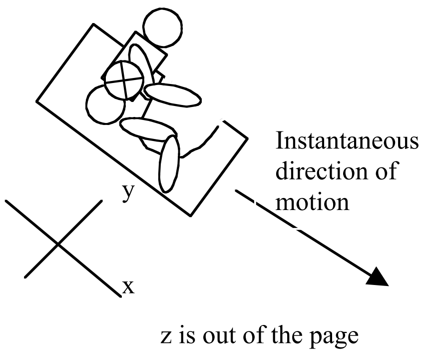
$\otimes$ $\otimes$ $\otimes$

a. View from side b. View from back c. View from top

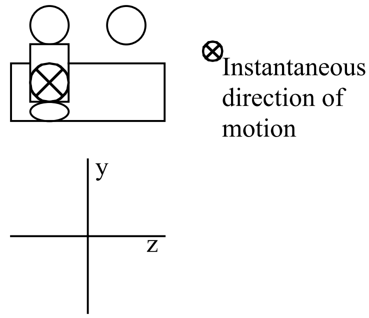
Do the results from the free body diagrams agree with you predictions made above. Explain

Case C - Going down the first hill. Determine the forces acting on you as you travel down the first hill either by riding Medusa or by interviewing someone who did.

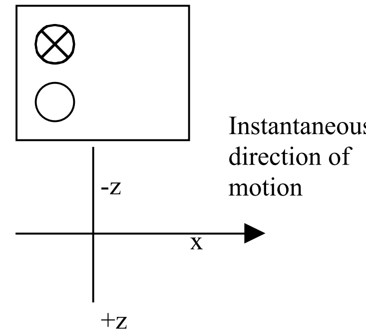
Draw a situation diagram showing all three views as before. In this situation your weight vector will of course be straight down. When you analyze the forces in the x, y, and z directions you will have to find the components of you weight in these directions.



View from side



View from back



View from top

As you are going down the hill, are you accelerating?
Predict what the ΣF will be in each direction. . State the direction and relative size of the resultant force

$\Sigma F_x =$ $\Sigma F_y =$ $\Sigma F_z =$

Now draw the free body diagrams for this situation.

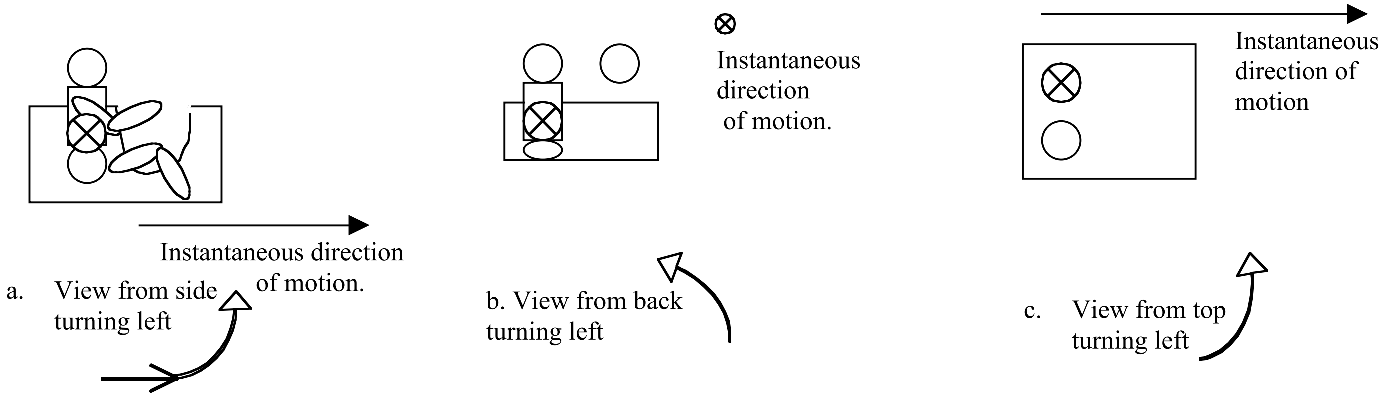

a. View from side


b. View from back


c. View from top

Do the results from the free body diagrams agree with you predictions made above. Explain

Case D - Turning to the left at the bottom of a hill. Assume that the car is not going up or down hill.



As you are turning, are you accelerating? Remember acceleration is the rate of change of velocity. A change in velocity can produce a change in speed and/or a change in direction.
Predict what the ΣF will be in each direction. . State the direction and relative size of the resultant force

$\Sigma F_x =$ $\Sigma F_y =$ $\Sigma F_z =$

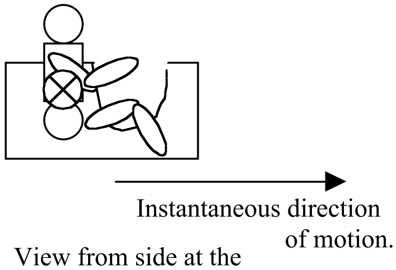
Now draw the free body diagrams for this situation.

a. View from side

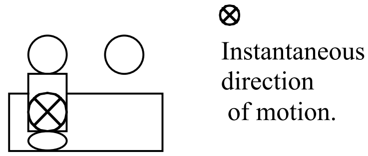
b. View from back

c. View from top

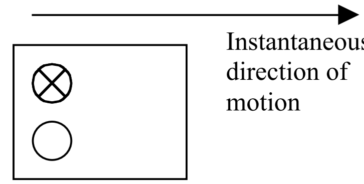
Case E - At the bottom of the first vertical loop



a. View from side at the bottom of the curve just starting up



b. View from back at the bottom of the curve just starting up



d. View from top

As you begin up the curve, are you accelerating? Remember acceleration is the rate of change of velocity. A change in velocity can produce a change in speed and/or a change in direction.
Predict what the ΣF will be in each direction. . State the direction and relative size of the resultant force

ΣF_x =

ΣF_y =

ΣF_z =

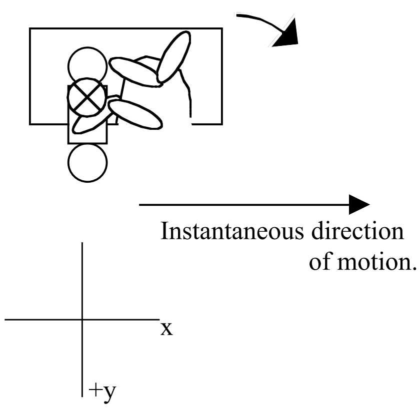
Now draw the free body diagrams for this situation.

a. View from side

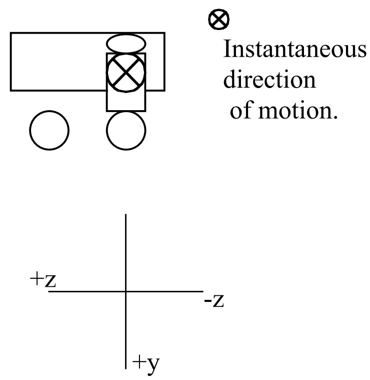
b. View from back

c. View from top

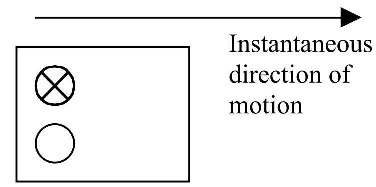
Case F - At the top of the first vertical loop



a. View from side at the top of the curve.



b. View from back when rider is upside down and at the top of the curve.



e. View of top of the head of the rider, when rider is upside down. Viewed by observer at the center of the loop

As you are going through the top of the curve, are you accelerating? Remember acceleration is the rate of change of velocity. A change in velocity can produce a change in speed and/or a change in direction.
Predict what the ΣF will be in each direction.

$\Sigma F_x =$

$\Sigma F_y =$

$\Sigma F_z =$

Now draw the free body diagrams for this situation. State the direction and relative size of the resultant force

a. View from side

b. View from back

c. View from top

At the beginning of this exercise, you were asked to calculate the speed of the coaster at the top of the loop. What is this speed. Speed = v = _____________

When you rode Medusa, or interviewed someone who had, you were asked to get a force meter reading at the top of the first loop. Record the value below

Force meter reading =force factor = ff = ______

If you multiply the Force meter reading i.e. the force factor (ff) by the weight of the rider who took the reading, you will get the force acting on the rider at the top of the loop. Calculate this value.

Weight of rider in newtons * ff =.

.

net force on rider experimental = _______________

At the top of the loop the sum of all the forces, ΣF, is equal to ΣF_y. $\Sigma F_y = w + F_s$. Since ΣF is not equal to zero, there is an acceleration. According to Newton's Second Law, $\Sigma F = ma$. At the top of the loop the acceleration is changing the direction of the car forcing the car to travel in a circular path. We therefore call this acceleration a centripetal acceleration and can calculate its value using $\Sigma F_y = ma_c = {}^{mv^2}/_r$.

The radius of the circular curve at the top of the loop is 9.22 meters. r = ______

Determine the mass of the rider, m m = ______

What is ΣF Show all your work

$${}^{mv^2}/_r =$$

net force on rider calculated = _______________

How do the two values compare? Explain why they differ. Determine a percent deviation (percent error) between the values.

DATA FOR THOSE NOT ATTENDING PARK

ON THE BUS

ACTIVITY 2: Conscious Commuting

A . Starting up

Data t = 8 seconds

ACTIVITY 3: THE FLYING WAVE

MEASUREMENTS

Your Mass = _____ kg
Your Weight _____ N
Time for 2 rev = 10 s
Period = ____
Radius of ride at top speed = 6 m
Maximum angle of chain with vertical = 43°
Force meter reading along chain = 1.4

Activity 4: Spinmeister

Your mass = _____kg
Your weight = _____N
time for 4 rotations = 12 s
Period at top speed = _____
force factor at bottom = 3.8
force factor at top = 1.8

Activity 5: Typhoon

Your mass = _____kg
Your weight = ____N
time for 10 revolutions = 30 s
Period = ____
Radius of ride = 4.0 m
Force meter = 1.8

Activity 6: Movietown Water Effect
Length of a barge = 7.0 m
time to come over top of last drop = 1.9 s
time to come down slide = 2.8 s
time for barge to pass C = 3.5 s

Activity 13 and 14: The Great American Scream Machine

Your mass = _____kg
Your weight = ____N
time for first car to top = 37.3 s.
At B sensation normal force meter = 1
At C feel heavier, force meter 3.5
At D feel pressed into seat,
Force meter = 1.2

Time for entire train to pass point E
at top of loop = 1.5 s
Length of train = 17 m