Amusement Park PHYSICS

PLAYLAND At the PNE Vancouver

PHYSICS and SCIENCE DAY 2017

Physics 11/12

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Vancouver, B.C., Canada
April 2017

Amusement Park Physics

and the new Secondary School Curriculum

In the past 18 months, the educational system has seen a shift in the science curriculum and changes to how that curriculum is delivered. The current curriculum is more inquiry based with a focus on questioning, predicting, communication, planning and conducting investigations. In addition, students are asked to analyse not only the data they collect, but also the process that was used to collect the data.

The curriculum for Science 8 has changed. Although forces are not directly in the current Grade 8 curriculum, inquiry and investigation are at the forefront. ***Amusement Park Physics*** can now be applied to any number of classes as they all include an inquiry / investigative component. Teachers are able to adapt or enhance the curriculum packages currently supplied by ***Amusement Park Physics*** as they see fit. This gives you, as an educator, tremendous flexibility in terms of how you and your class spend your time at Playland. You could focus on one ride and do an in-depth study or perhaps investigate similar rides and compare them.

In addition, classes could choose to investigate / discuss Newton's three (3) laws and then attend ***Amusement Park Physics*** to apply them. This initial investigation could be done as a class or individually as a project.

The Ministry of Education has identified some curricular competencies that students are expected to meet. All of the below mentioned competencies could be done at ***Amusement Park Physics***.

Science 8: "Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal interest"

"Collaboratively plan a range of investigation types, including field work and experiments, to answer their questions or solve problems they have identified"

'Observe, measure and record data (qualitative and quantitative), using equipment, including digital technologies, with accuracy and precision"

Science 9: "Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)"

"Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data"

Although the official grade 10 science curricula has not been released, it will likely include similar competencies designed to get students out of the classroom and start to make their own investigations and inquires.

Amusement Park Science allows students to get out of their classroom and explore real life science applications. Based on the current curriculum, students need to be able to design an investigation from start to finish, this includes data collection, analyst of results and communicating a conclusion.

Amusement Park Physics

It's hard to believe that *Amusement Park Physics* at Playland is celebrating its ***30th anniversary*** this year. The project was started in 1988 with our senior Physics students and was expanded in 1990 with the addition of the Grade 9 program. Later we added an elementary school version *The Science of Fun*. In 2008 we added a French Version for elementary schools called *La Science du Plaisir* and a curriculum for Grade 8 Science and Grade 10 Science. In 2011 we added a version for Biology 12, and in 2012 we added a version for students in Chemistry 11 and 12. A special thanks goes to Steve Simms and Mike Eckert at Clayton Heights Secondary for helping with the Chemistry module. In 2016 we added activity sheets for the Beast and the Haunted House. Rather than have them for specific grades, we have questions at the Bronze level, Silver level, and the Gold level. Teachers can choose the level they want their students to do.

The purpose of *Amusement Park Physics* is to provide students with practice in applying to real situations some of the concepts learned in the classroom study of mechanics. It has been an enjoyable conclusion to that aspect of the curriculum and can assist in preparation for final examinations. With the involvement of students from other schools and other districts, the project serves to bring together teachers and students to share their common interest in science. We welcome your participation in either or both events.

Due to the success of *Amusement Park Physics*, we have spread the events to five days in the spring and one day in the fall. You may choose any of these days but we will be limiting numbers to 2500 students per day. These will be filled on a first come basis. This should help eliminate any lineup at the rides to let students make measurements multiple times on each ride.

There is a curriculum package for each grade level – Science 8, Science 10, Physics 11/12 and Biology 12. You need to only download and print the version that you need. Please feel free to adapt any materials to better suit your students.

I'd like to thank all those involved in *Amusement Park Physics 2015*: Michelle Pattison, Steven Simms, Jennifer Campbell, Peter Male and the staff of the Pacific National Exhibition and Playland for their support. The work and dedication of all these people make *Amusement Park Physics 2017* possible.

Jim Wiese

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Introduction

The accompanying materials have been divided into several sections: one with information concerning measurements, one containing information on instrument construction, and one with the ride worksheets for Physics 11 and Physics 12, and one with make-up assignments. Teachers are given flexibility for its use but are reminded that this educational program is used by many schools.

We try to have consistency between schools' implementation by asking each teacher to remind their students that this is an educational event. A rule of thumb is to have each student or group of students complete 3 or 4 of the modules. That is a reasonable expectation for them and keeps them on task during the day. Schools that are wishing to use this event as a reward for "hard work" through the year and that do not intend to have their students working on this material are asked to make arrangements to visit Playland at another time.

This year's curriculum reflects the different demands that are placed on students in Science 8, Science 10, Physics 11 and Physics 12. This has hopefully brought it more in line with Provincial Ministry Physics guidelines and the Physics 12 Provincial Examination.

Students *must* be using the following materials throughout the day:

1. Packet of activities
2. Pencil
3. Timing devices (digital watches with stopwatch mode are nice)
4. Vertical and lateral accelerometers (see packet for details – make arrangements for sharing between students if supply is short). Each school is responsible for providing their own accelerometers.
5. Calculator

Critical Safety Note

Any instrument or devices carried on rides by students should be made of plastic and provided with some kind of wrist tether made of heavy string, so that if dropped, the instrument will not break or fall off the ride and cause injury or damage.

Sample Timetable

Please adapt to fit your circumstances

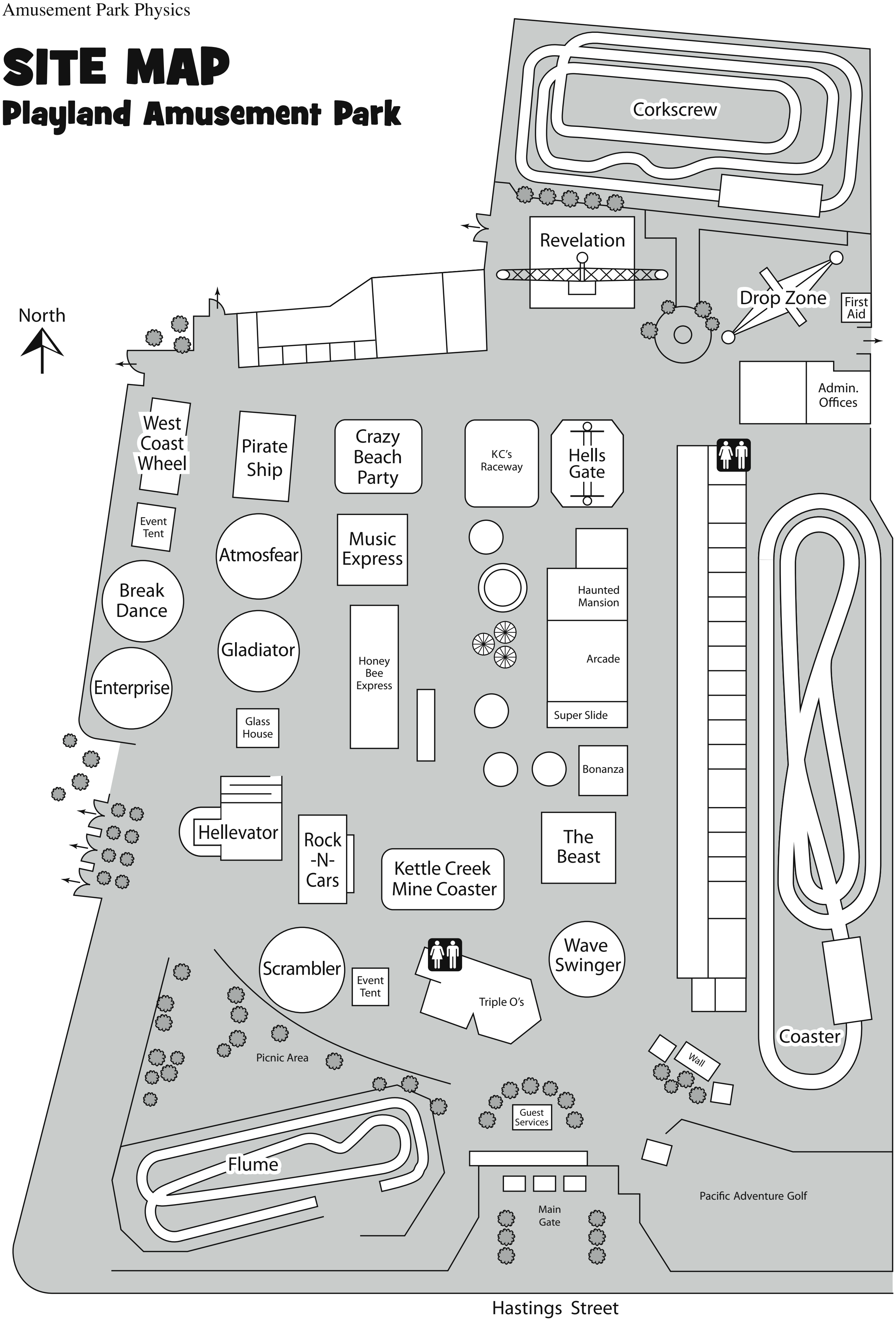
Time Schedule

8:30	Buses leave school
9:15	Arrive at Playland
9:30	Enter Playland Amphitheatre for opening session
9:45 – 10:00	Opening Presentation at Playland Amphitheatre
10:00	Gates to Playland open to admit students
10:00 – 2:00	Carry out pre-planned activities involving observations and measurements of selected aspects of the rides. Arrange a meeting time with your teacher for problems that arise or questions you have.
2:00	Playland closes and event ends
2:15	Board buses for return to school
3:00	Buses arrive back at school

Things to Bring:

- ❏ BRING A LUNCH (You will <u>NOT</u> be allowed to leave the park for lunch)
- ❏ BRING A PENCIL
- ❏ Bring a calculator if you wish
- ❏ Don't forget to bring this assignment package!
- ❏ Try to bring a watch with a second hand or digital seconds to record times on the rides. A digital watch with a stopwatch mode works very well.
- ❏ Try to return all equipment (dropper bottles, chemicals, etc.) to your teacher when you are not using them during the day. You'll be sharing them with other students and we need to make sure everyone gets a chance to use them.

SITE MAP
Playland Amusement Park



Section A
Making Measurements

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Time

The times that are required to work out the problems can easily be measured by using a watch with a second hand or a digital watch with a stop watch mode. When measuring the period of a ride that involves harmonic or circular motion, measure the time for several repetitions of the motion. This will give a better estimate of the period of motion than just measuring one repetition. You may want to measure the time two or three times and then average them.

Distance

Since you cannot interfere with the normal operation of the rides, you will not be able to directly measure heights, diameters, etc. All but a few of the distances can be measured remotely using the following methods. They will give you a reasonable estimate. Try to keep consistent units, i.e. meters, centimeters, etc., to make calculations easier.

Pacing: Determine the length of your stride by walking at your normal rate over a measured distance. Divide the distance by the number of steps and you can get the average distance per step. Knowing this, you can pace off horizontal distances.

My pace = __________ m

Ride Structure: Distance estimates can be made by noting regularities in the structure of the ride. For example, tracks may have regularly spaced cross-members as shown in ***figure a***. The distance **d** can be estimated, and by counting the number of cross members, distances along the track can be determined. This method can be used for both vertical and horizontal distances.

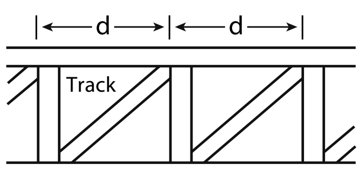


figure a

Triangulation: For measuring height by triangulation, an astrolab such as that shown in ***figure b*** can be constructed.

Practice this with the school flagpole before you come to Playland.

Suppose the height $\mathbf{h_T}$ of the **Coaster** must be determined.

❶ Measure the distance between you and the ride. You can pace off the distance.

distance **d** = __________ m

❷ Measure the height of the string hole.

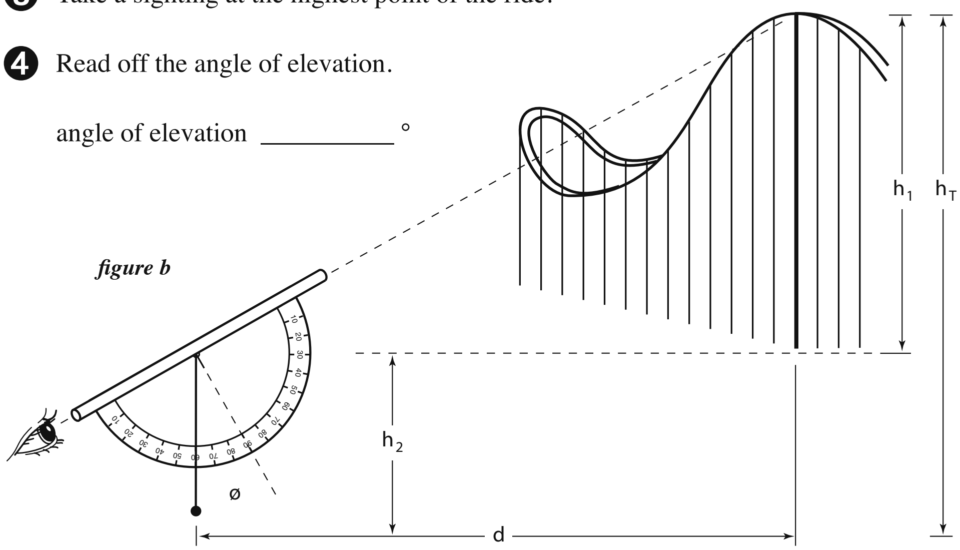
string hole height $\mathbf{h_2}$: $\mathbf{h_2}$ =__________ m

❸ Take a sighting at the highest point of the ride.

❹ Read off the angle of elevation.

angle of elevation __________ °

figure b

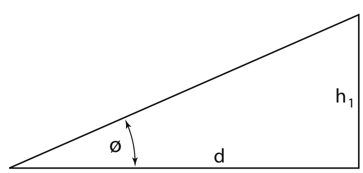


Then since $h_1/d = \tan ø$

$h_1 = d(\tan ø)$

❺ Look up the tangent value for the angle measured:

tangent value: __________



angle	tangent	angle	tangent	angle	tangent
0°	.00	30°	.58	60°	1.73
5°	.09	35°	.70	65°	2.14
10°	.18	40°	.84	70°	2.75
15°	.27	45°	1.00	75°	3.73
20°	.36	50°	1.19	80°	5.67
25°	.47	55°	1.43	85°	11.43

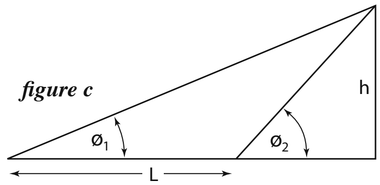
❻ Multiply this tangent value by the distance from the ride: h_1 =__________m

❼ Add this product to the height of the string hole: + h_2 = __________ m

This number is the height of the ride. h_T =__________ m

Other: There are other ways to measure distance. If you can think of one, use it. For example, a similar but more complex triangulation could be used. If you can't measure the distance **L** because you can't get close to the base of the structure, use the Law of Sines as in ***figure c*** below.

figure c



Knowing $\mathbf{Ø_1}$, $\mathbf{Ø_2}$, and **L**, the height **h** can be calculated using the expression:

$$\mathbf{h} = \left[\frac{\sin \mathbf{Ø_1} \quad \sin \mathbf{Ø_2}}{\sin \mathbf{Ø_2} - \sin \mathbf{Ø_1}} \right] \mathbf{L}$$

Speed

In linear motion, the average speed of an object is given by:

$$V_{ave} = \frac{\Delta d}{\Delta t} = \frac{\text{distance travelled [in m]}}{\text{time for trip [in sec.]}}$$

In circular motion, where speed of rotation is constant:

$$V_{ave} = \frac{\Delta d}{\Delta t} = \frac{2\pi r}{\Delta t} = \frac{\text{distance in circumference of a circle [in m]}}{\text{time for one revolution [in sec.]}}$$

Challenge

Both these cases involve fairly constant speed. Be careful of measuring speed when the speed is changing. If you want to determine the speed at a particular point on the track, measure the time that it takes for the length of the train to pass that particular point. The train's speed then is given by:

$$V_{ave} = \frac{\Delta d}{\Delta t} = \frac{\text{length of train [in m]}}{\text{time to pass point [in sec.]}}$$

In a situation where it can be assumed that total mechanical energy is conserved, the speed of an object can be calculated using energy considerations. Suppose the speed at point C is to be determined (see ***figure d***). From the principle of conservation of total mechanical energy it follows that:

$$PE_A + KE_A = PE_C + KE_C$$

$$mgh_A + \tfrac{1}{2}mv_A^2 = mgh_C + \tfrac{1}{2}mv_C^2$$

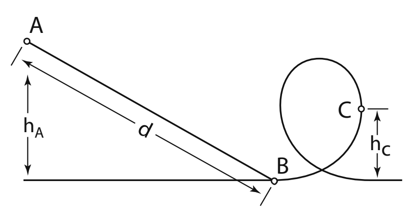


figure d

Since mass is constant, solving for v_C:

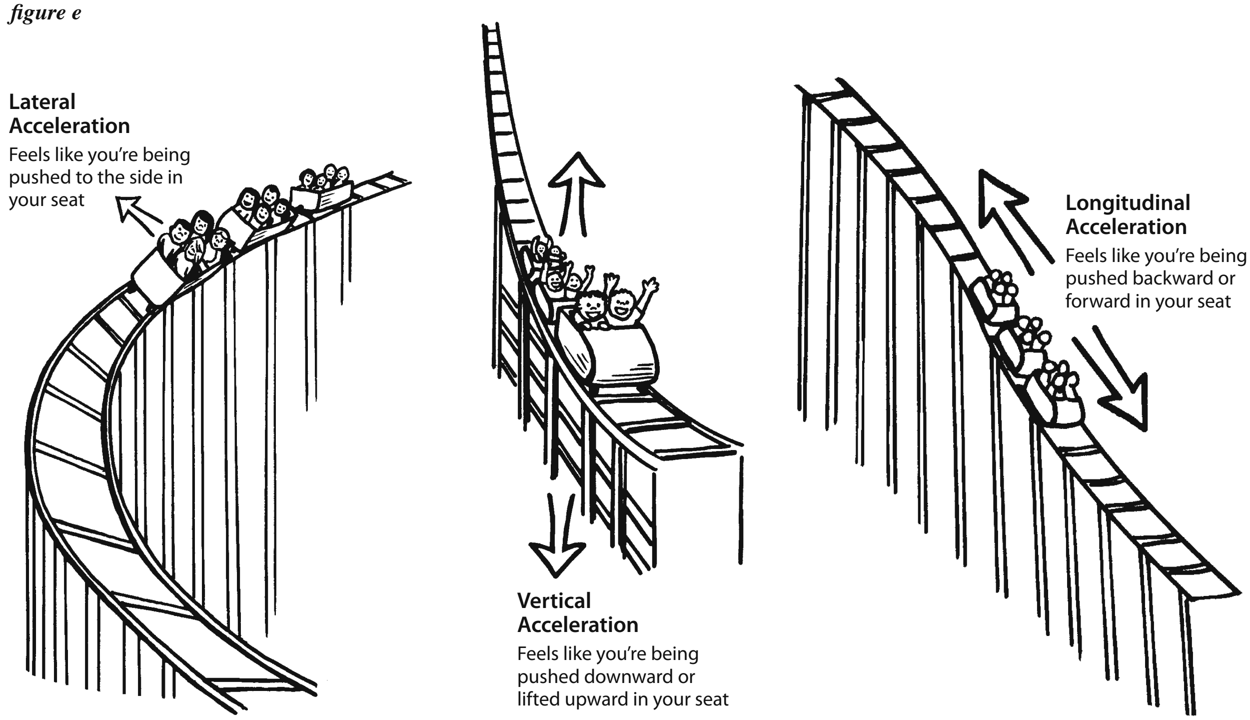
$$v_C = \sqrt{2g(h_A - h_C) + v_A^2}$$

Thus by measuring the speed of the train at point A, and the height h_A and h_C, the speed of the train at point C can be calculated.

Acceleration

Accelerometers are designed to record the g forces felt by a passenger. Accelerometers are usually oriented to provide force data perpendicular to the track, longitudinally along the track, or laterally to the right or left of the track (see ***figure e***).

figure e



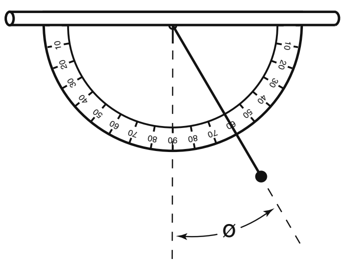
Accelerometers are calibrated in **g**'s. A reading of 1 g equals an acceleration of 9.8 m/s^2. As you live on earth, you normally experience 1 g of acceleration vertically (no g's laterally or longitudinally). Listed below are the sensations of various 'g forces'. These are rough estimates, but may be helpful in estimating accelerations on the various rides.

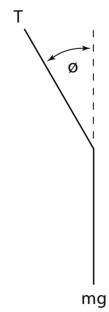
Accelerometer Reading	Sensation
3 g	3 times heavier than normal (maximum g's pulled by space shuttle astronauts)
2 g	twice normal weight
1 g	normal weight
0.5 g	half-normal weight
0 g	weightlessness (no force between rider and coaster)
–0.5 g	half-normal weight – but directed upward away from coaster seat (weight measured on bathroom scale mounted at rider's head!)

Lateral Acceleration

Astrolab

The astrolab discussed earlier as a triangulation instrument may also be used to measure lateral accelerations. Device is held with sighting tube horizontal, and weight swings to one side as you round a curve. By measuring angle, acceleration can be determined. See drawing below:

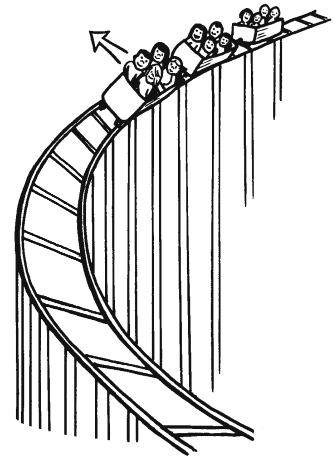




$$T \cos \varnothing = mg$$
$$T \sin \varnothing = ma$$

solving for a:

$$a = g \tan \varnothing \,*$$

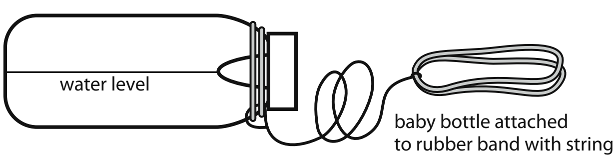


* *Note: If G-meter is used, values for* a = g tan Ø *have been marked on the accerometer.*

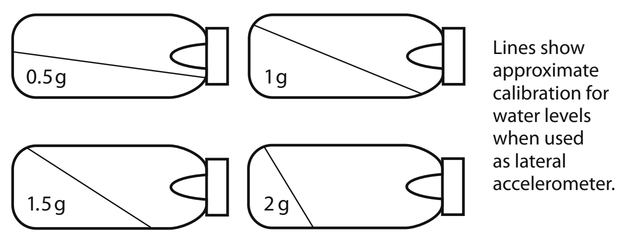
Baby Bottle

Similarly, the baby bottle accelerometer can be used to directly read an approximation of the lateral acceleration.

Lateral Accelerometer

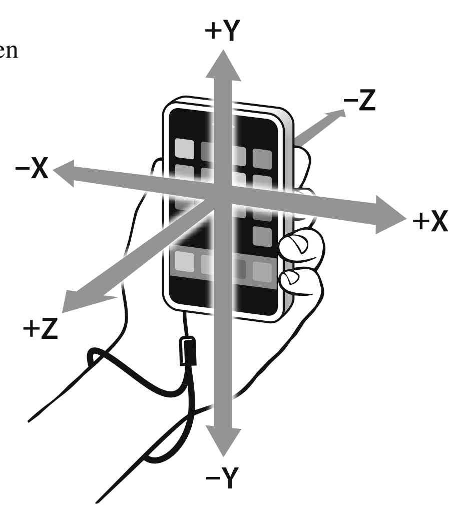


Approximate Calibration



Smart Phone Accelerometers

Many smart phones have built-in accelerometers that allow them to change their screens from vertical to horizontal views. This same built-in accelerometer has been used to create a number of apps that can be loaded onto the smart phone and used to measure the acceleration of various rides at an amusement park. They range in price from free to a couple of dollars.



Once you have located an appropriate app on the smart phone (Try “acceler-ometer” or “roller coaster” in the app search), they are easy to use. When you get on the ride, start the app and put the smart phone in a safe place, like in a secure pocket. Once the ride is over, remove the smart phone and turn the app off. For many roller coaster accelerometer apps, you should be able to read the collected data off the screen or download the data onto a computer.

Caution: Some accelerometer apps will only give real time data you read while the ride is in operation. If you are going to collect data while holding your smart phone on the ride, secure it to your body with a tether (thin cord) in case you drop it during the ride. Using your smart phone on a field trip is your responsibility and neither the amusement park nor your school is responsible for loss or damage.

Centripetal Acceleration

With uniform circular motion remember that: $v = \frac{2\pi r}{t}$

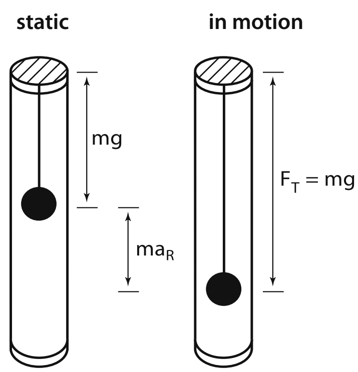
and the centripetal acceleration is given by: $a_c = \frac{v^2}{r} = \frac{4\pi^2 r}{t^2}$

where **r** is the radius of the circle and **t** is the period of rotation.
Thus centripetal acceleration can be measured on a ride.

Vertical Acceleration

A simple device for measuring vertical accelerations is a 0-5 Newton spring scale with a 100 g mass attached. The plastic tubes with elastics and fishing weights approximate this equipment. The forces on the mass are as drawn where F_T is the reading on the scale.

The forces on the masses are shown in the diagram.



If the person is holding the scale right side up, then:

$$F_T = mg + ma_{(Ride)} \quad \text{or} \quad ma_{(Total)} = mg + ma_{(Ride)}$$

since m is constant,

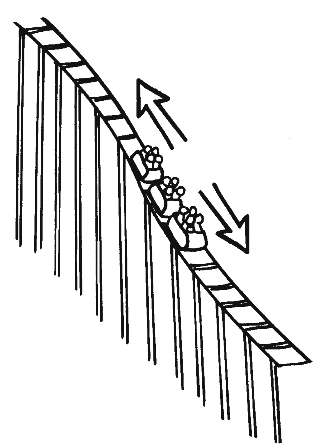
$$a_T = g + a_R \quad \text{or} \quad a_R = a_T - g$$

If the person is holding the scale upside down against gravity as might be found at the top of the Enterprise, then:

$$a_R = -(a_T + g) \qquad \text{ie. acceleration is upwards}$$

In either situation, then, the acceleration can be calculated by knowing F_T (or a_T).

Longitudinal Acceleration



Acceleration of a person on a ride can also be determined by direct calculation.
Down an incline, the average acceleration of an object is defined as:

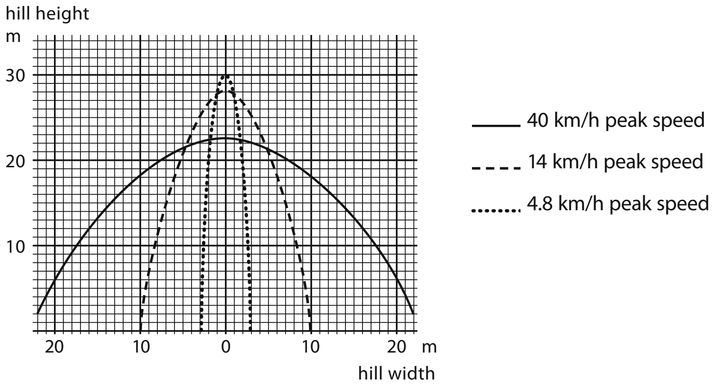
$$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\text{change in speed}}{\text{change in time}}$$

Using methods previously discussed it is possible to estimate speeds at both the top and bottom of the hill and the time it takes for the coaster to make the trip. Thus, average acceleration can be found during that portion of the ride.

Parabolic Paths

A coaster has a shape called a *parabola*.

The curves on the graph show three different parabolic coaster hills for three different hilltop speeds:



Describe a relationship between the sharpness or smoothness of coaster hills and their speeds.

____

____

Can you explain why coasters are built in this manner?

____

____

____

Coaster Hill Shapes for Different Speeds at the Park

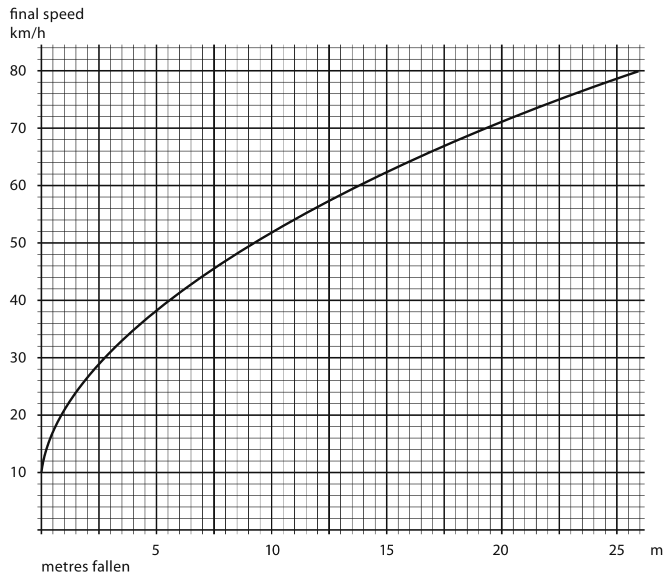
Use this graph to predict hilltop speeds for as many hilltops as you can identify on Corkscrew or the Coaster. Use the space provided to try to identify the location of the hilltop in question (e.g. right before corkscrew loops; first hill; etc. – the two examples are hypothetical, and may not correspond to actual hilltops).

Ride	Speed (fast or slow)	Location of Hilltop

Speed of a Falling Coaster
(assumes a free fall parabolic arc)

The graph shows the coaster's speed as a function of falling distance. The graph assumes no speed at the hilltop, and no energy losses to friction and air resistance. This will help you estimate the speed on various hills.

As the coaster falls and its speed increases, gravitational potential energy is converted to kinetic energy.



What is the speed after falling:

5 m ________________ 10 m ________________ 20 m _________________

How far does the coaster have to fall to be travelling:

20 km/h _____________ 40 km/h _____________ 60 km/h _____________

On a coaster, part of the gravitational potential energy is converted into the heat of friction and the kinetic energy of moving air particles pushed by the moving coaster. Since this is the case, are actual coaster speeds greater or less than those shown on the graph?

____

What does the shape of this graph tell you about the relationship between the variables graphed (speed vs meters fallen). Explain why the shape of the graph makes sense.

____

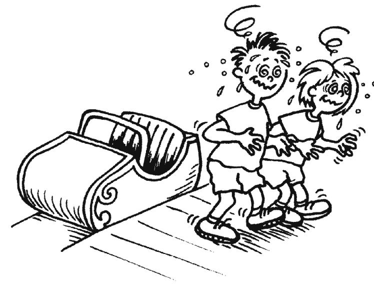
____

____

____

Physiology of Amusement Park Rides

For each of the rides listed below, measure your pulse rate and breathing rate before and after the ride. Indicate any symptoms that you had by placing numbers of those appropriate from the list below.



Symptoms:

1. dry mouth
2. dizziness
3. tense muscles
4. unable to move
5. cold hands/feet
6. enlarged eye pupils
7. trembling
8. sweaty hands
9. upset stomach
10. fast breathing
11. stomach butterflies
12. other: ________________

Ride	Pulse Rate		Breathing Rate		Symptoms	
	before	*after*	*before*	*after*	*before*	*after*
Coaster						
Enterprise						
Wave Swinger						
Atmosfear						
Scrambler						
Corkscrew						
Pirate Ship						
Rock-N-Cars						
Music Express						
Hellevator						
Hell's Gate						
Crazy Beach Party						
Flume						
Gladiator						
Break Dance						
The Beast						

Ride Design

❶ Amusement Park rides are designed to give the illusion of danger and speed. Which rides, based on the symptoms that you had, seem to give the greatest illusion?

❷ Based on your observations, how could an amusement park design a ride to give a greater illusion of speed and danger? Diagram your design below.

Useful Formulae

$F = ma$ | $E_P = mgh$ | $E_K = \frac{1}{2} mv^2$

$mgh = \frac{1}{2} mv^2$ | $v^2 = 2\,gh$ | $v = \sqrt{2\,gh}$

$g = 9.8\,m/s^2$ | $p = m \cdot v$

$W = F \cdot d$ | $P = \frac{w}{t}$

$d = \left(\frac{v_i + v_f}{2}\right)t$ | $d = v_i t + \frac{1}{2} at^2$

$v_f = v_i + at$ | $v_f^2 = v_i^2 + 2ad$

$a = \frac{v^2}{r}$ | $F = \frac{mv^2}{r}$

$a = \frac{4\pi^2 r}{t^2}$ | $F = \frac{m4\pi^2 r}{t^2}$

$$t_f = \frac{t_i}{\sqrt{1 - v^2/c^2}}$$

$$m_f = \frac{m_i}{\sqrt{1 - v^2/c^2}}$$

$$l_f = l_i \times \sqrt{1 - v^2/c^2}$$

$$c = 3.00 \times 10^8 \text{ m/s}$$

Section B
Constructing The Equipment

page B-1 Astrolab

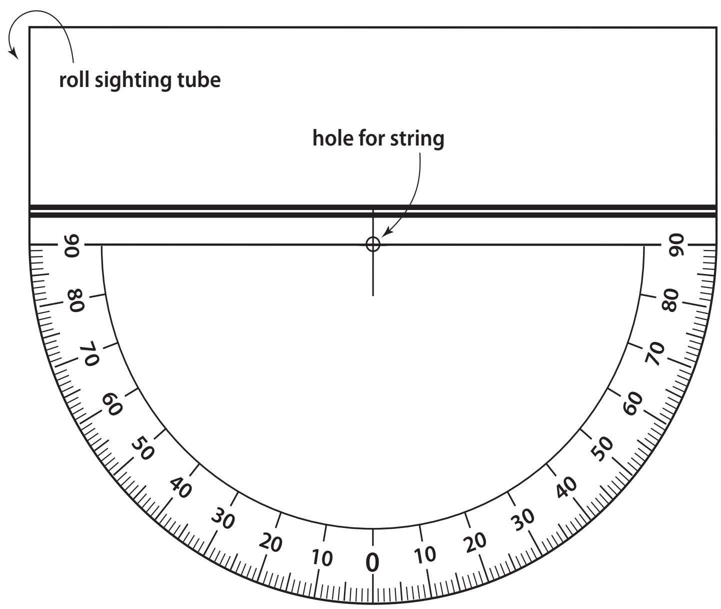
page B-3 Lateral Accelerometer

page B-3 Vertical Accelerometer

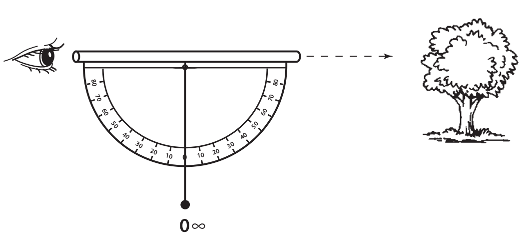
page B-4 G-Meter

ASTROLAB
Triangulation Instrument and Accelerometer

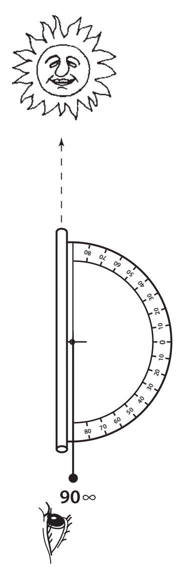
1. Cut out the Astrolab.
2. Fold the top section over a pencil and roll it down to the heavy double line to make a sighting tube.
3. Tape the rolled paper tube closed and then let the pencil slide out.
4. Glue the Astrolab to a 8” x 5” index card and trim.
5. Take about 20 cm of heavy thread and tie one end to a weight such as a key or washer. Tie the other end through the hole at the top of the Astrolab.
6. Let the thread hang free. The angle it marks off is the angular height of an object seen through the tube.



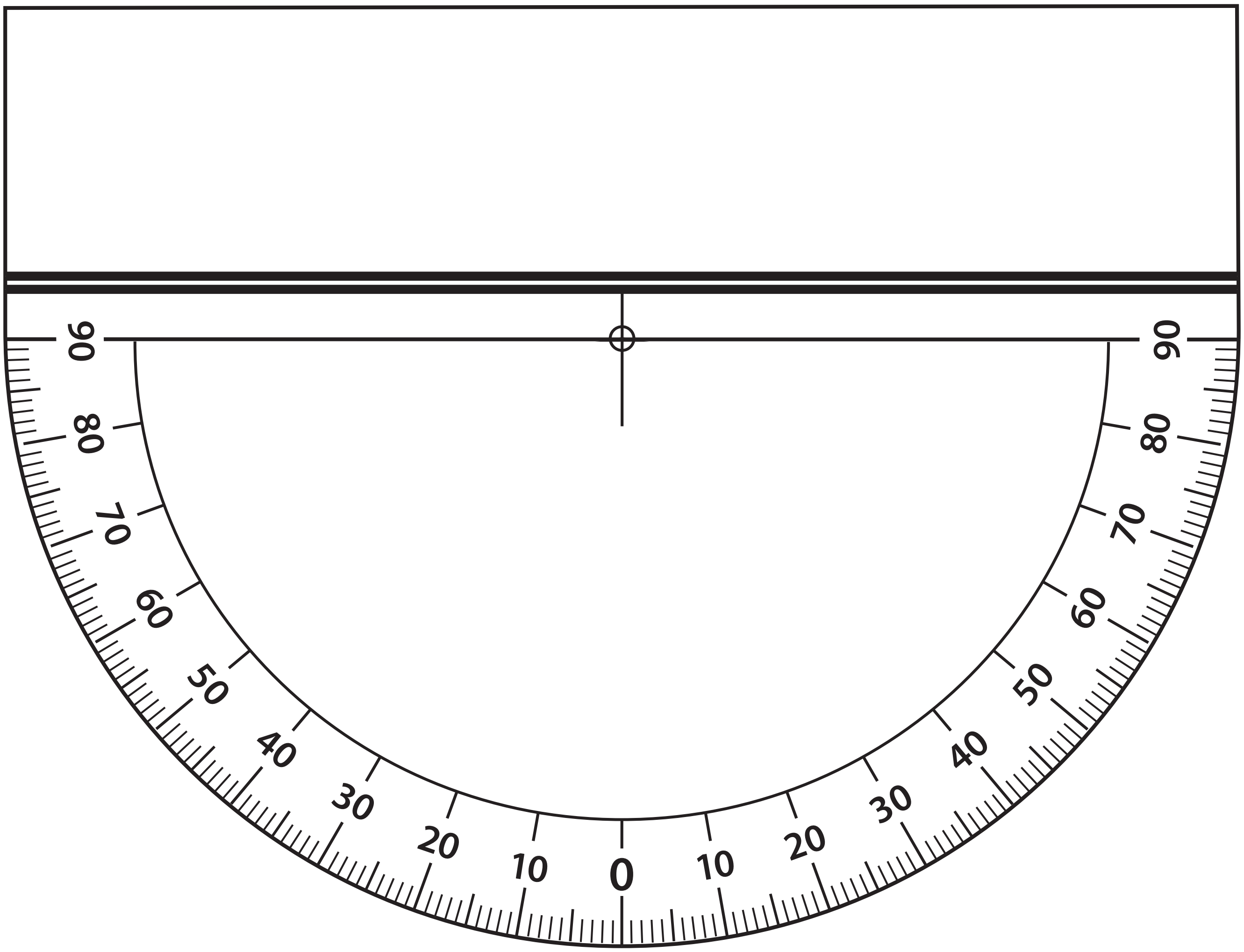
For instance:



An object on the horizon has an angular height of 0 degrees.



An object directly overhead has an angular height of 90 degrees.


90
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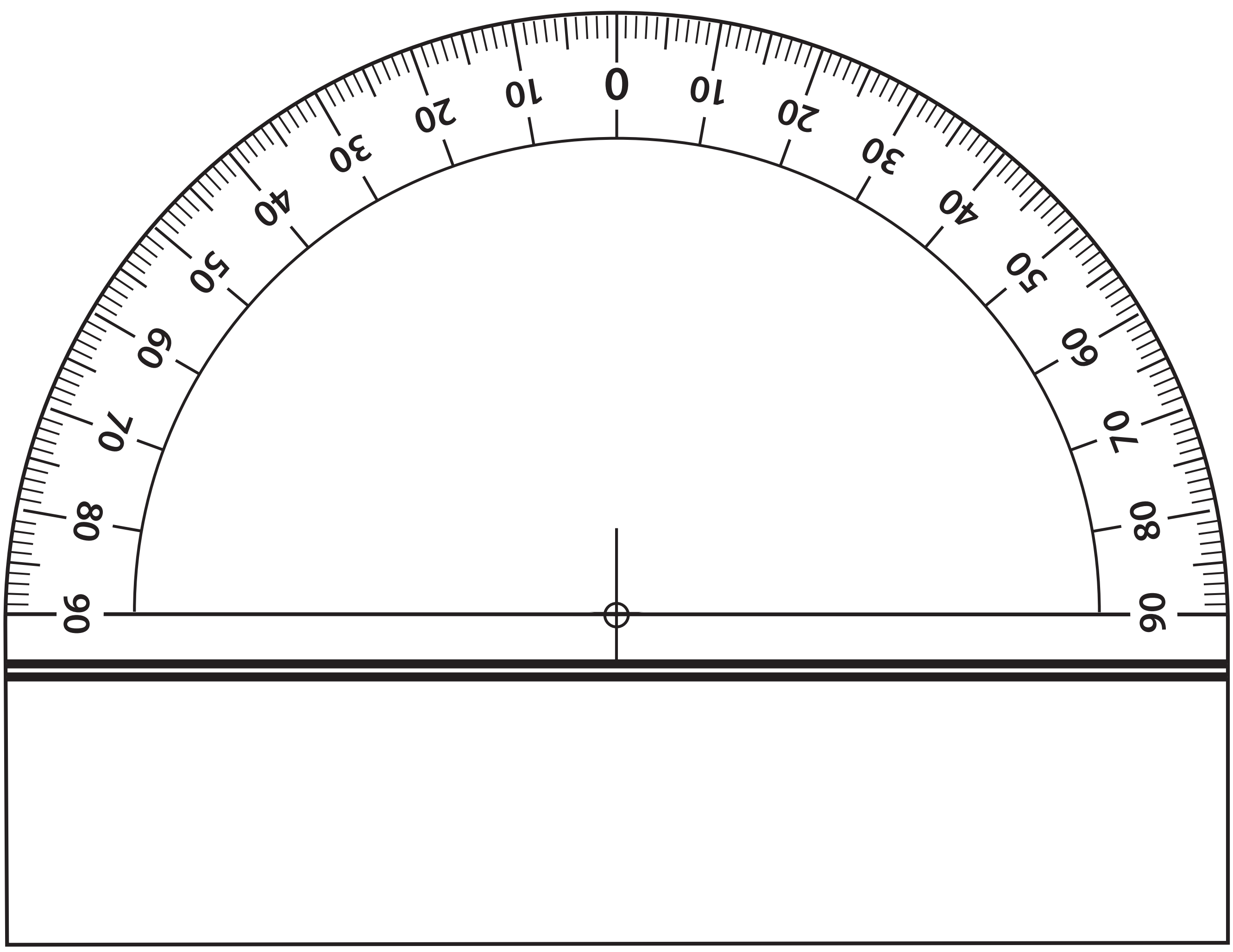
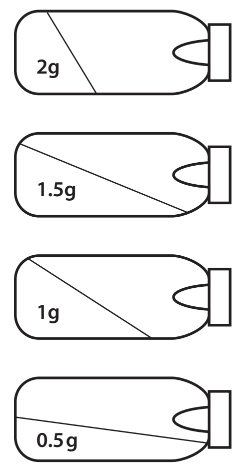
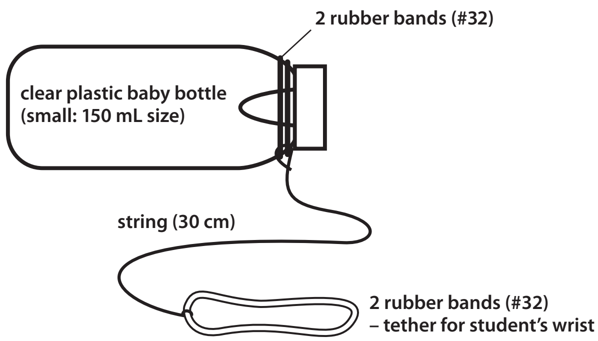


LATERAL ACCELEROMETER

1. Obtain the following (eg) materials for each accelerometer:
   - ☐ 1 small clear plastic baby bottle 150 mL (plastic only for safety reasons)
   - ☐ 4 rubber bands #32
   - ☐ 30 cm string
   - ☐ 50 mL water
   - ☐ food colouring
   - ☐ permanent felt marker
2. Assemble the accelerometer as shown in the diagram. Notice that the nipple is inverted.
3. Add the coloured water to the baby bottle.

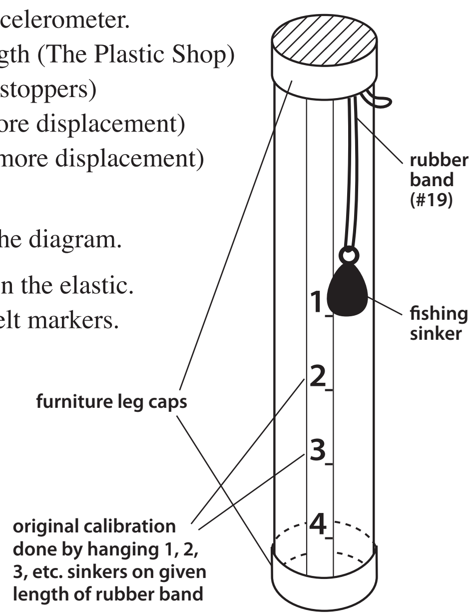


Lines show approximate calibration for water levels when used as lateral accelerometer.



VERTICAL ACCELEROMETER

1. Obtain the following materials for each accelerometer.
   - ☐ 3/4" i.d. rigid plastic tubing, 20 cm length (The Plastic Shop)
   - ☐ 2 caps to fit (furniture leg caps, rubber stoppers)
   - ☐ #19 elastic band (thinner band gives more displacement)
   - ☐ 4 oz. fishing sinker (larger mass gives more displacement)
   - ☐ permanent felt marker
2. Assemble the accelerometer as shown in the diagram.
3. Calibrate by hanging 1, 2, 3 etc. weights on the elastic. Mark calibration on tube using indelible felt markers.



G –METER

A common unit to describe forces we feel is the "g." One g is equal to the force of earth's gravity. When the space shuttle takes off, astronauts feel about three g's of force (three times the force of earth's gravity). How many g's do you feel on the swings, on your bicycle, on an amusement park ride, or in a car? You can make a "g" meter to measure these forces.

1. Obtain the following materials for each g meter:
   - ☐ copy of g meter on next page
   - ☐ thin cardboard
   - ☐ glue
   - ☐ scissors
   - ☐ string or heavy thread
   - ☐ metal washer

2. Make a copy of the g meter.

   Cut out the g meter.

   Glue the g meter to a thin cardboard and trim to size.

   Take about 15 cm (6 inches) of heavy thread and tie one end to a weight such as a key or washer. Tie the other end through the hole at the top of the g meter.

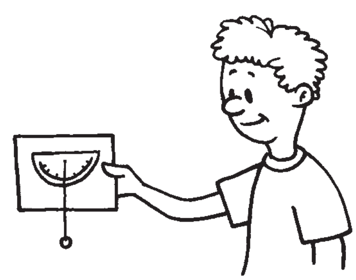
   Hold the g meter in front of you. Let the thread hang down so that it lines up with the 0 g mark.

   If the g meter moves in the direction of the arrows, the weight and string will tell you the force in g's.

   In order to have the g meter work properly, the top edge must be horizontal, level with the horizon.

3. Now that you have your g meter, try it out.

   Hold the g meter in front of you when your parents drive the car around a corner. How many g's did you feel? Is there a difference between going around a corner slowly and going around it fast?

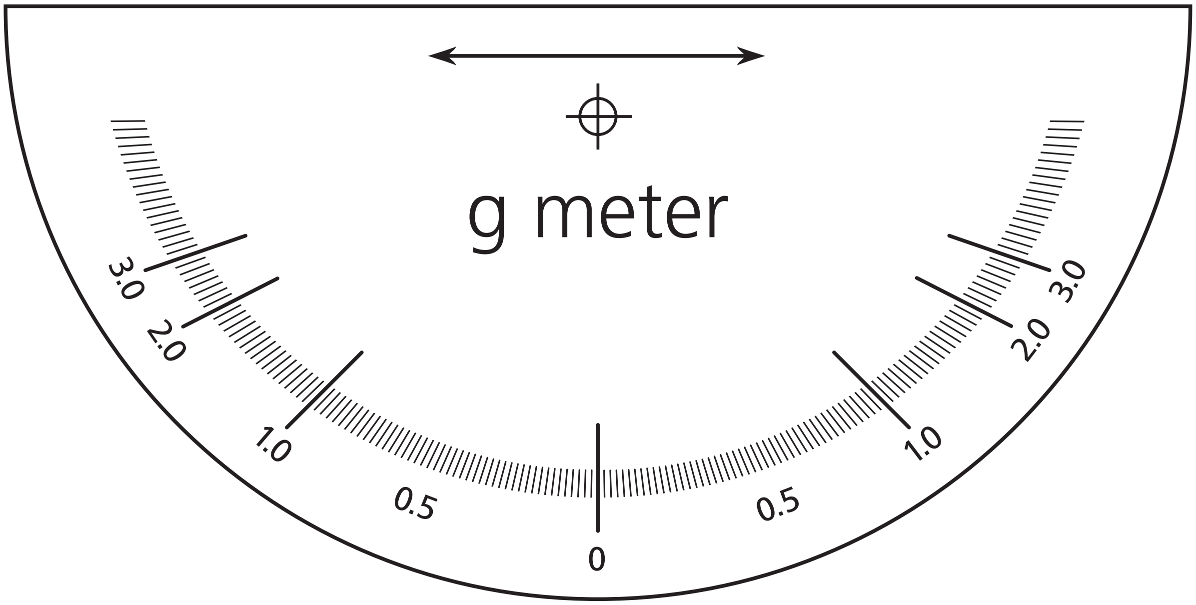
   Hold the g meter beside you while you are on a swing. Hold it so that the arrows point in the direction you will be going. As you swing, how many g's did you feel?

   Use the g meter on the merry-go-round at the playground. Sit on the outside edge of the ride and point the arrow toward the centre. How many g's do you feel? What happens to the number of g's as the ride moves faster? What happens to the g's if you sit closer to the centre of the ride?

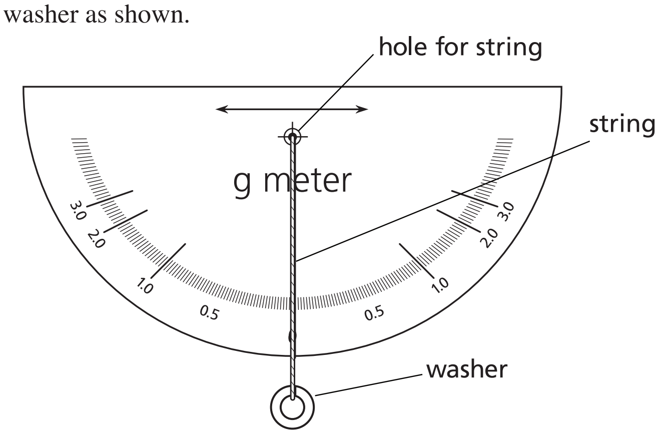
   Use the g meter on the Amusement Park rides. How many g's does each ride create? How does each ride do it? Do some use speed or turns to create large forces?

G–METER

Trace and cut out this g meter.



Attach string and washer as shown.



Section C
Physics II Worksheets

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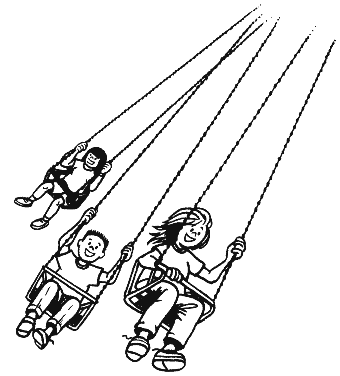
Wave Swinger

A. Data



1. Distance from center of rotation to chain attachment ____________m
2. Length of chain ___________ m
3. Radius of rotation ___________ m
4. Time for one revolution ____________ s
5. Angle of swing to rotation axis ____________ °
6. Accelerometer reading __________ g's

B. Qualitative Tasks

1. Will an empty swing or one with someone in it ride higher? Why?

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2. Describe your sensations as the ride increased in speed.

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3. Explain your sensations described in #2 in terms of the physics of the ride.

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4. Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

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calculations

C. Quantitative Calculations

1. Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

_____________ m/s

_____________ m/s^2

2. Draw a vector diagram of the forces acting on you during the ride. These are due to the different accelerations you are undergoing.

3. Using the calculation in #1 and the acceleration due to gravity (9.8 m/s^2), determine the resultant acceleration that you should feel. How many g's was it?

4. Compare #3 with your accelerometer reading. How do they compare? Explain any differences.

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5. From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

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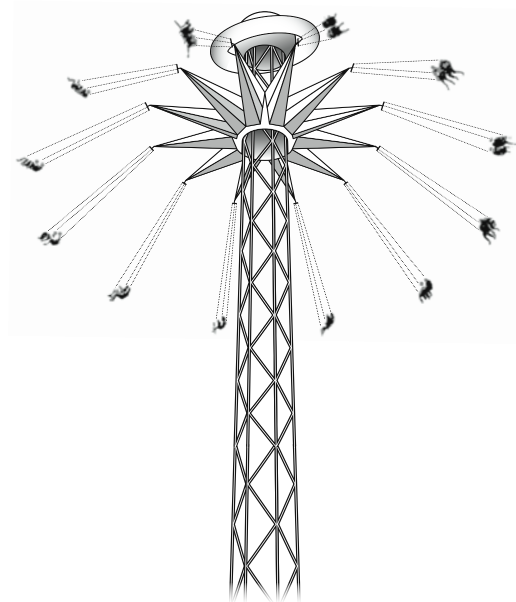
Atmosfear



A. Data

1. Distance from center of rotation to chain attachment __________ m
2. Length of chain __________ m
3. Radius of rotation __________ m
4. Time for one revolution ___________ s
5. Angle of swing to rotation axis ___________ °
6. Accelerometer reading __________ g's

B. Qualitative Tasks

1. Will an empty swing or one with someone in it ride higher? Why?

____

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2. Describe your sensations as the ride increased in speed.

____

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3. Explain your sensations described in #2 in terms of the physics of the ride.

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4. Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

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calculations

C. Quantitative Calculations

1. Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

_______________ m/s

_______________ m/s^2

2. Draw a vector diagram of the forces acting on you during the ride. The forces are due to the different accelerations you are undergoing. Use the angle of the swing to make your vector diagram as accurate as possible.

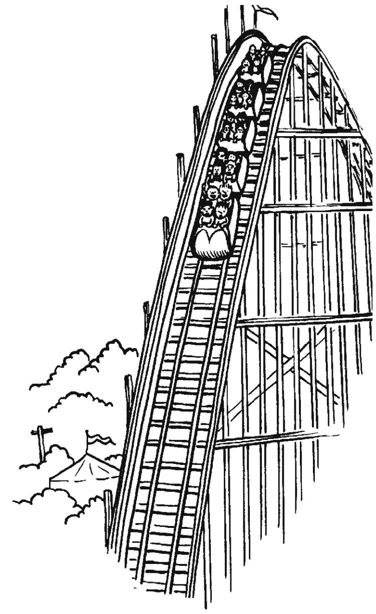
3. Using the calculations in #1, the vector diagram in #2 and the acceleration due to gravity (9.8 m/s), determine the resultant acceleration that you should feel. How many g's was it?

4. Compare the value in #3 to your accelerometer reading. Explain any similarities or differences. What is your percent error?

5. From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

Coaster

A. Data



Length of track 1,001 m

Measurements while standing in line:

Time for ride: ____________ s

Length of train: ____________ m

(*hint: length of car* × *number of cars*)

Measurements while on ride: (using accelerometer)
(Hint: Sit in rear cars to make measurements on ride)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

Measurements from observation area:

1. Distance from hill to observation area: ____________ m

   Angle: ____________ °

   Calculated height of hill: ____________ m
2. Time for train to go from bottom to top of first hill _____________ s
3. Time for train to pass point at top of hill _____________ s
4. Time for train to pass point at bottom of hill _____________ s
5. Time for train to go from top of hill to bottom _____________ s

B. Qualitative Observations

❶ Where was the highest hill on the ride? Why is it there?

____

____

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❷ Did you feel lateral forces while on the ride (i.e. were you thrown from side to side in the train car)? If so, what forces caused that feeling? Use a diagram if necessary to help explain.

____

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❸ Where on the ride did you feel you were going the fastest? Why?

____

____

____

4. Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

____

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5. Draw a free body diagram labeling the forces acting on you at the bottom of the first hill.
Is the net force greater or less than normal?

____

____

____

____

____

calculations

C. Quantitative Calculations

1. Average speed of train for total ride (show work):

__________ m/s

__________km/h

2. Speed at top of first hill (show work):

__________ m/s

__________km/h

3. Speed at bottom of first hill (show work):

__________ m/s

__________km/h

4. Calculate the acceleration of the train during the trip down the first hill.

__________ m/s^2

5. If each car has a mass of 1200 kg, and assuming the coaster is filled with riders whose average mass is the same as yours, how much total work is done getting the filled coaster to the top of the first hill?

____________ joules

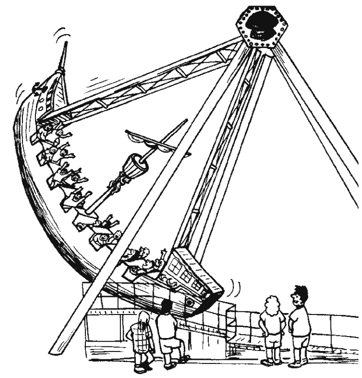
6. How much power does the motor have to put out in order to lift the loaded coaster to the top of the first hill? (Answer in both watts and horsepower: 746 watts = 1 hp)

_____________ watts

_____________ hp

Pirate Ship

A. Data



1. Time for one period (complete cycle) ____________ s
2. Estimated radius of the ship's path ____________ m
3. Maximum angle of displacement ____________ °
4. Maximum accelerometer reading ____________ g's
5. Maximum height reached by the car ____________ m
6. Approximate mass of car and riders ____________ kg

B. Qualitative Tasks

1. Consider the rocking boat described above as a pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

   A simple pendulum at small displacements exhibits simple harmonic motion with the period **t** of the pendulum's swing expressed by the following relationship:

   $$t = 2\pi\sqrt{\frac{L}{|g|}}$$

   Where **L** = the length of the pendulum's string.

   Calculate the period of the Pirate if it were a pendulum.

   _______________ s

2. From your results above, decide if the boat is a simple pendulum. Why or why not?

   ____

   ____

   ____

   ____

3. In each arc, where did you feel:

   a) the strongest push against your back?

   ____

   b) the most pressure against your seat?

   ____

   c) the least pressure against your seat?

   ____

4. When did you feel you were going the fastest?

   ____

   ____

   ____

5. If you have a vertical accelerometer, hold it in front of you during the ride. Observe the motion of the suspended mass.
   a) In what part of the ride was the mass pulled farthest down the tube?

____

   b) In general, describe the motion of the suspended mass during an arc and during a loop.

____

____

____

____

calculations

C. Quantitative Calculations

1. Calculate the distance of the ship's arc.

____________m

2. Calculate the ship's average speed in the arc.

a) __________m/s

b) __________km/h

3. Calculate the potential energy of the ride at its highest point.

4. Use the Law of Conservation of Energy (E initial = E final) to determine the velocity of the ride at its lowest point. Compare that value to what you calculated in question 2 and explain any differences.

Music Express

A. Data

1. Radius of the ride ____________ m
2. Time for one revolution ____________ s
3. Height gain to the highest point of the ride ____________ m

B. Qualitative Tasks

1. Describe the sensations that you felt on the ride. Include any differences you felt as the ride progressed.

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____

2. Was there any difference in the sensation of speed at the highest point of the ride compared to the lowest point? If so, explain.

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____

3. Imagine that all the music system speakers were placed at one spot next to the ride.
Would the music sound any differently to the passengers? Explain.

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____

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calculations

C. Quantitative Calculations

1. What is the distance a car travels in one revolution?

   __________________ m

2. What is the average speed that the cars go during the ride?

   __________________ m/s

3. If each car has a mass of 200 kg, what is the increase in potential energy as the car moves from the lowest point to the highest point on the ride?

   __________________ joules

4. What happens to that energy that the cars gained in going to the highest point in the ride?

5. Use the time dilation equation to calculate the difference in time for a clock on the ride and one not on the ride due to the relativistic effect cause by velocity. Is this time difference significant?

***Note**: Many of the **Coaster** questions can apply to this ride also!*

Rock-N-Cars

A. Qualitative Tasks

Make observations that will allow you to answer the following questions.
State the observed facts that justify each of your answers.

1. If your car is hit head on by another car, what direction is your car accelerated? How do you know?

2. If your car is hit head on by another car, what determines whether your car continues to move forward or backward after the collision?

3. If you hit another car on the side, at right angles to its direction of forward motion, what immediately happens to the motion of the other car upon impact? Of course, the other driver may immediately respond by changing the speed and direction of his/her car. This is a difficult observation to make unless you work with a friend in the other car.

4. What is the role of friction between the cars and the floor? In which direction do you think that the friction is greater?

5. Answer these questions using the concepts of energy, impulse and Newton's Laws of Motion.
   Don't use vague terms like "shock".
   a) What is the reason for having the rubber bumpers around the cars?
   b) Why would you not design a bumper car with very soft bumpers?
   c) Why would you not design a bumper car with no bumpers at all?

❻ If you were riding the only car with a much smaller mass that the other cars, how would your ride be different from the one you have just experienced? Explain why.

❼ Under what conditions do the following happen?

a) driver will feel the strongest jolt.

b) driver will be thrown forward.

c) car will accelerate at the crash.

d) driver will be thrown backward.

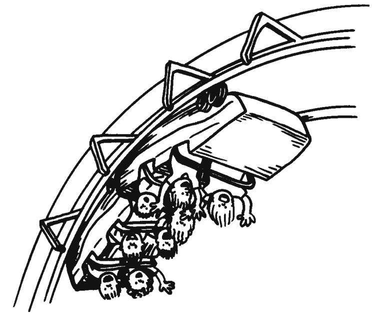
e) car will change direction at crash.

❽ How is electrical energy supplied to the bumper cars? Describe and draw a complete circuit for one of the cars.

❾ During a collision, is kinetic energy conserved? Explain.

Corkscrew

***Note**: Many of the **Coaster** questions can apply to this ride also!*



A. Data

Length of track 702m

Measurements while standing in line:

(a) height of first hill ____________m

(b) Approximate length of first drop ____________m

(c) time for first drop ____________ s

(d) time for entire ride ____________ s

Measurements while on ride: (using accelerometer)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

Measurements from observation area: (Collect data you need to answer the questions)

1. Height of first hill: ____________ m
2. Time for train to go from bottom to top of first hill _____________ s
3. Time for train to pass point at top of hill _____________ s
4. Time for train to pass point at bottom of hill _____________ s
5. Time for train to go from top of hill to bottom _____________ s

B. Qualitative Tasks

❶ Where is the highest point of the ride? Why is it there?

____

____

❷ Where on the ride did you feel you were going the fastest? How fast (in m/s)?

____

____

❸ Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

____

____

❹ How accurate were your accelerometer measurements? Explain.

____

____

❺ Does the ride always rotate in the same direction? Explain.

____

____

calculations

C. Quantitative Calculations

Average speed of train for total ride (show work):

__________ m/s

__________km/h

2 Speed at top of first hill (show work):

__________ m/s

__________km/h

3 Speed at bottom of first hill (show work):

__________ m/s

__________km/h

4 Calculate the acceleration of the train going down the hill.

__________ m/s^2

5 If each car has a mass of 1350 kg, and assuming the coaster is filled with riders whose average mass is the same as yours, how much total work is done getting the filled coaster to the top of the first hill?

____________ joules

6 How much power does the motor have to put out in order to lift the loaded coaster to the top of the first hill? (Answer in both watts and horsepower: 746 watts = 1 hp)

_____________ watts

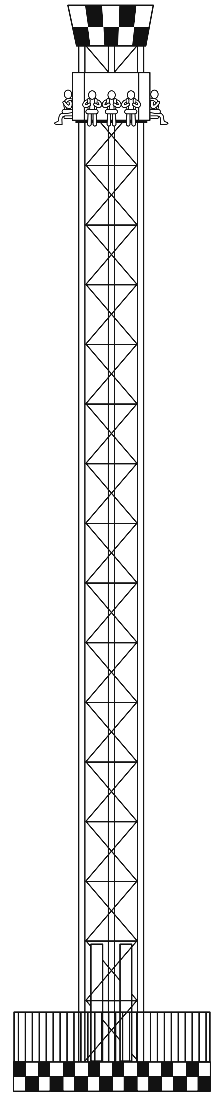
_____________ hp

7 Although question #1 asks for the average speed for the total ride, ride the train again and calculate the average speed of the ride beginning with the drop on the first hill and ending just before braking begins at the end. You'll need to measure the time for that part of the trip and subtract the amount of track that is not included in this measurement.

_____________ m/s

_____________ km/h

Hellevator



A. Data

1. Height of tower ________ m
2. Height of riders at top of flight ________ m
3. Mass of riders (estimated) ________ kg
4. Time of ride up ________ s
5. Time of ride down (freefall) ________ s
6. Measure the forces:
   - during ride up ________ g
   - at top of ride ________ g
   - during ride down ________ g
   - at bottom of ride ________ g

B. Qualitative Tasks

1. Have the riders take their pulse rate:

   (a) before they get on this ride. ____________________

   (b) immediately after they have finished this ride. ____________________

   (c) Explain any changes. ____________________

____

____

2. In a few words, have the riders describe how they felt:

   (a) before the ride started ____________________

   (b) at the highest point of the ride ____________________

   (c) during free fall ____________________

   (d) at the end of the ride ____________________

3. Where on the ride do riders experience:

   (a) more gs than normal ____________________

   (b) less gs than normal ____________________

4. Explain the riders' sensations and the gs they felt in #3 in terms of the physics of the ride.

____

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____

calculations

C. Quantitative Tasks

1. Calculate the average velocity as the riders travel up the ride in m/s.

_______________ m/s

2. Calculate the final velocity the riders reach at the end of their free fall in m/s.

_______________ m/s

3. Use the maximum height the cars reach to calculate the initial velocity of the ride.

_______________ m/s

4. If the acceleration up the tower happens during the first 5 meters, what is the acceleration during this time?

_______________ m/s^2

_______________ g's

5. Use the acceleration found in #4 above to calculate the force necessary to achieve the acceleration.

_______________ N

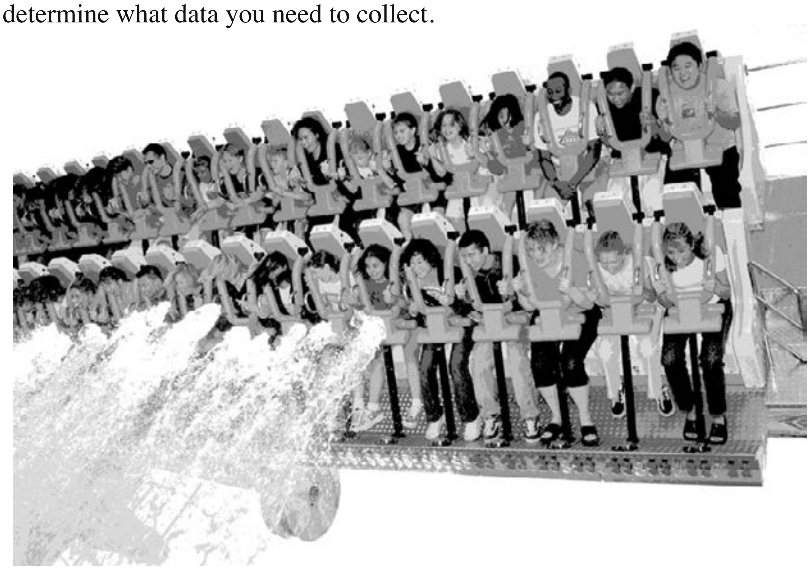
6. What is the acceleration during the free fall part of the ride?

_______________ m/s^2

Hell's Gate

Stand in a position where you can observe the ride. Take data and answer the following questions. After reading the questions, you must determine what data you need to collect.

A. Data



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Measurements while on ride: (using accelerometer)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

B. Qualitative Tasks

1. Have the riders take their pulse rate:
   (a) before they get on this ride. __________________________
   (b) immediately after they have finished this ride. __________________________

2. In a few words, have the riders describe how they felt:
   (a) before the ride started ____
   (b) during the ride ____
   (c) after the ride ended ____

3. Where on the ride do the riders experience:
   (a) more g's than normal ____
   (b) less g's than normal ____

4. Explain the riders' sensations and the g's they felt in #3 in terms of the physics of the ride.

____

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____

____

calculations

C. Quantitative Tasks

1. Calculate the average speed during the ride in m/s.

______________ m/s

2. Estimate the mass of the ride and the riders.

______________ kg

3. Calculate the amount of work necessary to move the ride and the riders from the lowest point to the highest point on the ride.

______________ Joules

4. How much power do the motors have to supply to move the ride and the riders in calculation #3?

______________ kW

5. Present data and calculations for any other portion of the ride.

Flume

Stand in a position where you can see the final drop of both rides, take data and answer the following questions. Some data will be provided, some will not. After reading the questions, you must determine what data you need to collect.

A. Data

B. Qualitative Tasks

1. Look at the place where each boat begins its final drop. What can you say about the vertical height of each of these? Is one higher than the other, or are they both about the same height?

2. According to your answer to the last question and considering the data which is supplied, what can you say about the potential energy of each boat when they have people of roughly the same weight?

3. As you watch the boats make their drop, do you notice any difference in the path that each takes to the bottom?

4. When each boat gets to the bottom of the run, what has happened to the potential energy each one had at the top?

5. Does the amount of potential energy each loses depend on the path each one takes to the bottom? Explain why or why not.

6. Considering everything you've answered so far, what would you expect to be true of the final velocity of each boat? Is one higher than the other or are they the same?

7. If you put more people into a boat (thus increasing the mass) would you notice any difference in the final speed?

calculations

C. Quantitative Calculations

1. Look at the place where each boat begins its final drop. Determine the vertical distance of this drop for each boat using any method you prefer. Is one higher than the other, or are they both about the same height? Show work or describe method for credit.

2. Using potential and kinetic energy relationships, calculate the theoretical maximum speed at the end of the final drop for each ride (assume no energy loss). Before you complain that this is too much work, think about it: will the different path each ride takes to the bottom affect the final speed? Show work for full credit.

3. Go to a place where you can see the end of each ride. Calculate the final speed using the marked distances (see Data section). Should the speeds agree? Show work for full credit. Assume zero velocity at the top.

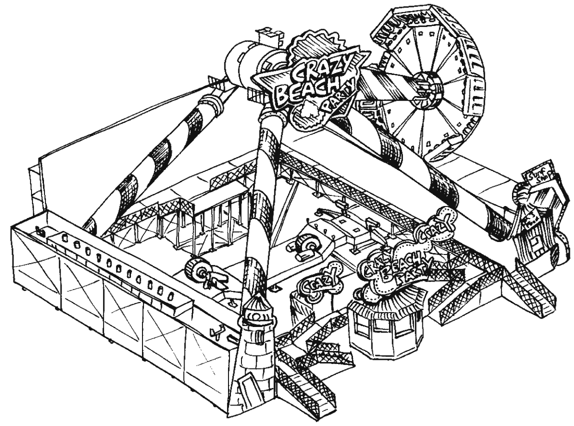
4. Do the results of #2 and #3 agree? List two reasons why they might not.

5. You have calculated the theoretical maximum speed at the bottom of the hill (#2) and you have measured the actual speed at the bottom of the hill (#3). Now select one of the hills and calculate the percent of energy that was at the top of the drop which was lost to friction during the drop. Assume the boat began from rest.

Extra for Experts: Do the same calculations as above but consider the boat's kinetic energy before making the final drop.

Crazy Beach Party

A. Data



Length of pendulum arm ____________ m

Radius of seat rotation ____________ m

Time for one pendulum swing ____________ s

Time for one seat rotation ____________ s

Acceleration reading during pendulum swing ____________ g's

Acceleration reading during seat rotation ____________ g's

# of degrees the pendulum moves through ____________ °

B. Qualitative Tasks

1. What forces do you feel as the ride first starts to swing back and forth? Explain how the ride creates them.

2. What forces to you feel as the ride begins to rotate? Explain how the ride creates them.

3. Describe your feelings when the ride is moving its fastest with both the pendulum swing and rotation.

4. What happens on the ride to cause the feelings in question #3? Use physics terms to describe this.

5. How does your pulse rate change from the time before the ride first starts to after it reaches full speed and then ends?

calculations

C. Quantitative Tasks

1. Use your data and the pendulum formula to determine if the ride acts like a true pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

   A simple pendulum at small displacements exhibits simple harmonic motion with the period **t** of the pendulum's swing expressed by the following relationship:

   $$t = 2\pi\sqrt{\frac{L}{|g|}}$$ Where **L** = the length of the pendulum's string.

   Calculate the period of the ride if it were a pendulum.

   _______________ s

2. Determine the # of °/s that the pendulum moves at maximum speed.

   _____________ °/s

3. Describe the rides motion relative to the following frames of reference. Use diagrams if helpful.

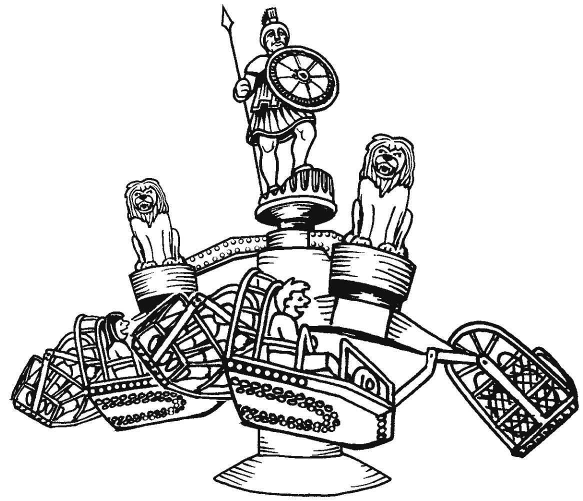
   a. Relative to a person sitting directly across from you.

   b. Relative to the centre of the ride.

   c. Relative to a person standing in line.

Gladiator

This ride uses unusual centripetal force.



Procedure and Questions

Ride the Gladiator and answer the following questions.

1. Does the large wheel at the centre of this ride turn clockwise (move to the left) or counter-clockwise (move to the right)?

____

____

____

2. What direction(s) does the small wheel, that holds the ride cars, turn? If it turns different directions, keep track of the direction of the turns for one full ride. For example, record how many times it turns in each direction.

   Spins left: Doesn't spin: Spins right:

3. Describe the forces you felt while on the ride. Are the forces always the same or do they change during the ride? If the forces change on the ride, where do they change? Draw a free body diagram of the forces that act on you at two different times on the ride.

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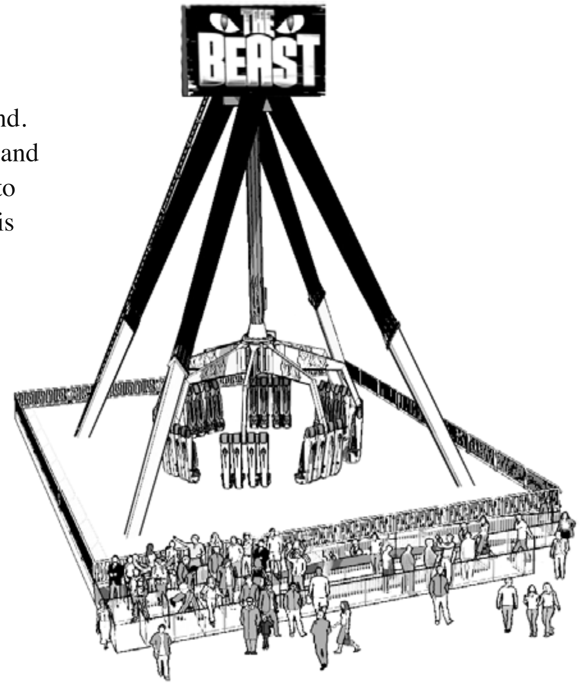
4. How many g’s does this ride create? Are the g’s constant or do they change? Explain your answer.

5. Concentrate your attention on one rider during the ride and follow this single rider’s path for at least one full revolution of the ride. Draw a diagram of the path he took for that single revolution. (Your diagram should be what you would see if you watched the rider’s path while looking down on the ride from above.)

The Beast



You have been commissioned to investigate a new ride here at Playland. The Beast is our newest addition and it is your job to explore the ride and discover what secrets it holds. The Beast is a wild ride. You're going to need a steady stomach and maintain a level head if you are to tame this ride, but we're hoping that you have the dedication and perseverance to get the job done.

Procedure

Approach the Beast like you would any scientific problem. Take a moment before the ride starts and think about how it may make you feel. Gather your data as you ride the Beast. How do the forces affect your body? What sensations do you feel? Then go over your data and interpret the results. Were you right? Did you predict how the ride would make you feel? Or did your data and experiences push you in totally new direction? Once you have recovered from the ride, answer the questions below.

Questions - Bronze Level

1. What was your first impression when you saw the Beast?

2. Before you rode the Beast for the first time, what did you think the first ride was going to feel like?

3. Immediately after riding the Beast for the first time, how did you feel? Describe in detail your experience.

❹ Did you successfully predict how the Beast would make you feel? What did you predict that was right, what was different?

____

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____

____

❺ What forces did your body experience when riding the Beast? Where they same throughout the whole ride or did they change at some point?

____

____

____

❻ Compare how you felt when the ride was in full swing to the bottom of the swing and when you were at a standstill.

____

____

____

❼ When the ride is moving, which direction do you feel pushed? Is there a name for this force? Collect data to support your observations.

____

____

____

❽ If the ride was to increase in speed, does the pushing sensation increase by the same amount? (i.e. If the speed doubled, would the pushing sensation double).

____

____

____

Questions - Silver Level

❾ Think of three scientific questions, other than the ones posed above, that you could ask about the Beast. Then answer your own questions.

a) Question: ____

____

____

a) Answer: ____

____

____

____

____

____

b) Question: ____________________

b) Answer: ____________________

c) Question: ____________________

c) Answer: ____________________

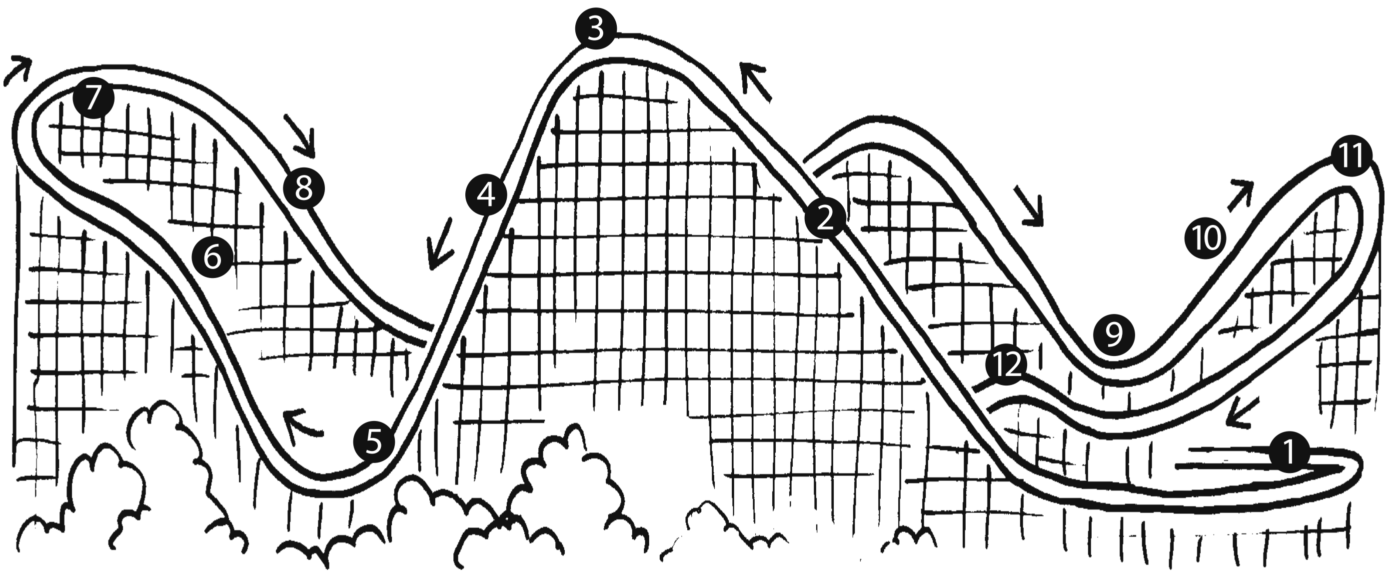
⑩ Explain any principles of science you saw in the ride. List three things you experienced / learned during the ride.

a) ____________________

b) ____________________

c) ____________________

Physics 11 Quiz



List the number (or numbers) on the Coaster that best match the phrases below:

__________ freefall area

__________ weightless zone

__________ where a machine makes the ride go instead of gravity

__________ where car moves because of momentum roll

__________ banked curve

__________ parabolic arc

__________ centripetal force at work

__________ greatest gravitational potential energy

__________ where the Coaster's velocity increases

__________ high g-force zone

__________ where car moves the slowest assuming a frictionless track

__________ where riders decelerate

__________ greatest kinetic energy

On the Coaster, positive g's are felt for very short time periods. Periods of 0 to 1g are maximized to minimize rolling friction with the track. Negative g's are avoided as much as possible for obvious safety reasons.

Recall your own Coaster experiences and combine them with your understanding of Physics.

a. When would you expect to pull the most g's on the Coaster?

b. When would you expect to be nearly weightless?

c. When would you expect to pull negative g's? Which seat would be most likely to provide this experience?

d. Where would you expect to pull lateral g's (to the sides of the Coaster)?

e. Where would you expect to pull longitudinal g's (forward or backward)?

Section D
Physics 12 Worksheets

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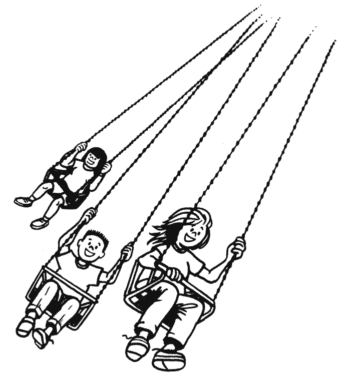
Wave Swinger



A. Data

1. Distance from center of rotation to chain attachment ____________m
2. Length of chain ___________ m
3. Radius of rotation ___________ m
4. Time for one revolution ____________ s
5. Angle of swing to rotation axis ____________ °
6. Accelerometer reading __________ g's

B. Qualitative Tasks

1. Will an empty swing or one with someone in it ride higher? Why?

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2. Describe your sensations as the ride increased in speed.

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3. Explain your sensations described in #2 in terms of the physics of the ride.

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4. Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

____

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____

calculations

C. Quantitative Calculations

1. Using the radius of rotation, determine the centripetal acceleration of the ride. Determine the centripetal force.

_____________ m/s^2

_____________ N

2. Draw a vector diagram of the forces acting on you during the ride. These are due to the different accelerations you are undergoing.

3. Using the calculation in #1 and the acceleration due to gravity (9.8 m/s^2), determine the resultant acceleration that you should feel. How many g's was it?

_____________ g's

4. Compare #3 with your accelerometer reading. How do they compare? Explain any differences.

____

____

____

5. From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

____

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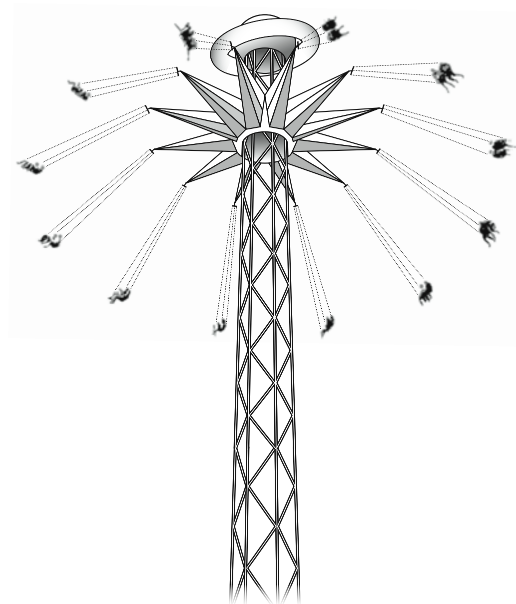
____

6. What is the tension in the chain of the swing that held you? Assume the chain and chair have a mass of 25 kg.

_____________ N

Atmosfear



A. Data

1. Distance from center of rotation to chain attachment __________ m
2. Length of chain __________ m
3. Radius of rotation __________ m
4. Time for one revolution __________ s
5. Angle of swing to rotation axis __________ °
6. Accelerometer reading __________ g's

B. Qualitative Tasks

1. Will an empty swing or one with someone in it ride higher? Why?

____

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2. Describe your sensations as the ride increased in speed.

____

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3. Explain your sensations described in #2 in terms of the physics of the ride.

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4. Watch the ride from the beginning until it reaches full speed. What happens to the angle of the chain attached to the seats as the ride increases in speed? Why?

____

____

____

____

calculations

C. Quantitative Calculations

1. Using the radius of rotation, determine the speed and centripetal acceleration of the ride. Determine the centripetal force.

______________ m/s

______________ m/s^2

2. Draw a vector diagram of the forces acting on you during the ride. The forces are due to the different accelerations you are undergoing. Use the angle of the swing to make your vector diagram as accurate as possible.

3. Using the calculations in #1, the vector diagram in #2 and the acceleration due to gravity (9.8 m/s), determine the resultant acceleration that you should feel.
How many g's was it?

4. Compare the value in #3 to your accelerometer reading. Explain any similarities or differences. What is your percent error?

____

____

____

____

5. From #3 above, determine the angle at which you should have been swinging. Compare this to Data #5. Explain any differences.

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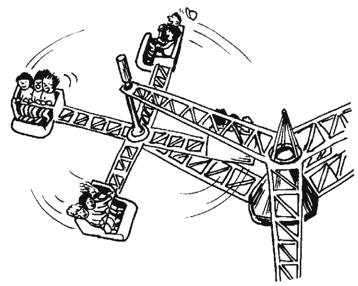
Scrambler

A. Data



1. Estimated radius of primary axis (center of ride to center of cluster) ______________ m

2. Estimated radius of secondary axis (center of cluster to rider) ______________ m

3. Turning rate around primary axis ________ rev/min

4. Clockwise or counterclockwise rotation around primary axis ________________

5. Turning rate around secondary axis ________ rev/min

6. Clockwise or counterclockwise rotation around secondary axis ________________

7. Concentrate your attention on one rider, and follow this single rider's motion for at least one full rotation of the ride. Draw the path of the rider for one turn. (*Your sketch should be what you would see the rider do if you were looking down on the rider from above*.)

B. Qualitative Tasks

1. Describe the sensations you felt during the ride.

____

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____

2. Describe the direction of both the primary and secondary rotation. Are they in the same or different directions?

____

____

3. What effect does #2 have on your sensations during the ride?

____

____

____

4. What would happen if both the primary and secondary rotation were in the same direction? How would a ride like that feel?

____

____

____

calculations

C. Quantitative Tasks

1. Determine the centripetal acceleration around the primary axis.

_____________ m/s^2

2. Determine the centripetal acceleration around the secondary axis..

_____________ m/s^2

3. Draw a diagram showing both rotation axes. Where is acceleration additive? Where is acceleration in opposite direction?

4. Give the net acceleration at each point in #3.

Enterprise

A. Data

Estimated radius of the ride ____________ m

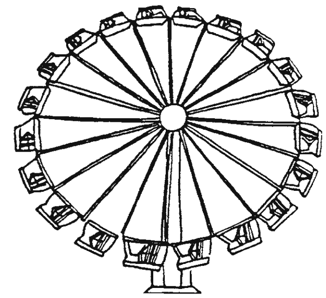
Estimated time of one revolution when ride is at full speed. ____________ s

Measured values (use accelerometer):

Acceleration experienced at side of vertical path __________ g's

Acceleration experienced at top of vertical path __________ g's

Acceleration experienced at bottom of vertical path __________ g's



B. Qualitative Tasks

1. Observe the Enterprise as it is starting out. As it starts to move in a horizontal orbit, what do you notice about the cars in relationship to the ride?

___

___

___

2. Continue to watch the ride as it changes from horizontal to vertical. Now what do you notice about the cars in relationship to the ride?

___

___

___

3. Why do you suppose that the cars changed their positions?

___

___

___

4. How long does it take one car to go completely around on this ride?

___

5. While riding the ride, notice at what particular point you appear to be going faster. Where on the ride do you feel this? (At the top, bottom, etc.) Why do you suppose that this is so?

___

___

___

6. Also notice at what point in the ride you appear "heavier". Where on the ride do you feel this? Why do you suppose that this is so?

___

___

___

7. Observe the movement of the weight on your Astrolab as you experience the ride. Describe the movement of the weight through one complete turn of the ride when the ride is going sideways and when the ride is going up and down.

calculations

C. Quantitative Calculations

1. Calculate the circumference of the ride.

_______________m

2. Calculate the frequency of the ride at full speed.

____________ rev/s

3. Calculate the centripetal acceleration during the ride and the net force at the top and bottom of each turn.

F_c __________m/s²

F_{net} at top ___________ N

F_{net} at bottom ___________ N

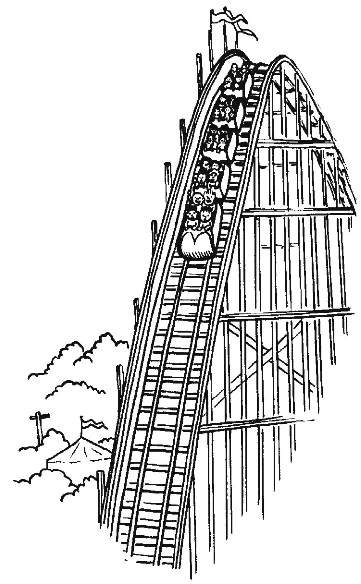
4. Compare the values of the calculated F_{net} and those from your accelerometer. Explain any differences.

5. Where is acceleration at its highest value? At the top or the bottom of the ride?

6. Draw a free body diagram of the forces acting on you at the top and bottom of each turn. How does this help explain your calculations and accelerometer readings?

Coaster

A. Data



Length of track 1,001 m

Measurements while standing in line:

Time for ride: ____________ s

Length of train: ____________ m

(*hint: length of car* x *number of cars*)

Measurements while on ride: (using accelerometer)
(Hint: Sit in rear cars to make measurements on ride)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

Measurements from observation area:

1. Distance from hill to observation area: ____________ m

   Angle: ____________ °

   Calculated height of hill: ____________ m

2. Time for train to go from bottom to top of first hill _____________ s
3. Time for train to pass point at top of hill _____________ s
4. Time for train to pass point at bottom of hill _____________ s
5. Time for train to go from top of hill to bottom _____________ s

B. Qualitative Observations

❶ Where was the highest hill on the ride? Why is it there?

❷ Did you feel lateral forces while on the ride (i.e. were you thrown from side to side in the train car)? If so, what forces caused that feeling? Use a diagram if necessary to help explain.

❸ Where on the ride did you feel you were going the fastest? Why?

4. Where on the ride did you feel like you were lifted off your seat? How did the ride cause that feeling?

____
____
____

5. Draw a free body diagram labeling the forces acting on you at the top and bottom of the first hill. Is the net force greater or less than normal in these places?

____
____
____
____

calculations

C. Quantitative Calculations

1. Average speed of train for total ride (show work):

__________ m/s

__________km/h

2. Speed at top of first hill (show work):

__________ m/s

__________km/h

3. Speed at bottom of first hill (show work using kinematics):

__________ m/s

__________km/h

4. Calculate the acceleration of the train during the trip down the first hill.

__________ m/s^2

5. Use potential and kinetic energy relationships to determine the speed of the train at the bottom of the first hill.

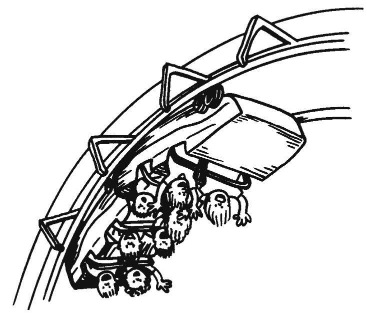
__________ m/s

6. Compare answers #3 & #5 and explain the results.

____
____
____

Corkscrew

A. Data



Length of track 702m

Measurements while standing in line:

(a) height of first hill ____________m

(b) approximate length of first drop ____________m

(c) time for first drop ____________ s

(d) time for entire ride ____________ s

Measurements while on ride: (using accelerometer)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

g forces at bottom of hill: __________ g's

g forces in the loop: __________ g's

Measurements from observation area: (Collect data you need to answer the questions)

Time for length of train to pass point at top of first hill ____________ s

Approximate length of first drop ____________ m

Time for first drop ____________ s

Time for length of train to pass point at bottom of first hill ____________ s

Time for length of train to pass point in loop section of ride ____________ s

Radius of loop ____________ m

B. Qualitative Tasks

1. What sensations do you feel in the curves of the loop section of the ride?

____

____

____

2. Where is the highest point of the ride? Why is it there?

____

____

____

3. Where on the ride did you feel you were going the fastest? Why?

____

____

____

❹ How do your feelings in #3 compare with the results in the calculations section?

___

___

___

❺ Where was there negative acceleration during the ride?

___

___

___

calculations

C. Quantitative Calculations

❶ Average speed of train for total ride (show work):

__________ m/s

__________km/h

❷ Speed at top of first hill (show work):

__________ m/s

__________km/h

❸ Speed at bottom of first hill (show work, using kinematics):

__________ m/s

__________km/h

❹ Calculate the acceleration of the train during the roll down the hill.

__________ m/s^2

❺ Use potential and kinetic energy relationships to determine the speed of the train at the bottom of the first hill.

__________ m/s

❻ Compare answers #3 and #5 and explain the results.

___

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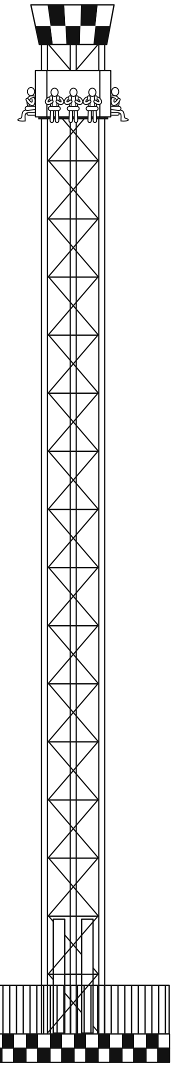
___

Hellevator



A. Data

1. Height of tower __________ m
2. Height of riders at top of flight __________ m
3. Mass of riders (estimated) __________ kg
4. Time of ride up __________ s
5. Time of ride down (freefall) __________ s
6. Measure the forces:
   during ride up __________ g
   at top of ride __________ g
   during ride down __________ g
   at bottom of ride __________ g

B. Qualitative Tasks

1. Have the riders take their pulse rate:
   (a) before they get on this ride. ______________________________
   (b) immediately after they have finished this ride. ______________________________
   (c) Explain any changes. ______________________________

____

____

2. In a few words, have the riders describe how they felt:
   (a) before the ride started ______________________________
   (b) at the highest point of the ride ______________________________
   (c) during free fall ______________________________
   (d) at the end of the ride ______________________________

3. Where on the ride do riders experience:
   (a) more gs than normal ______________________________
   (b) less gs than normal ______________________________

4. Explain the riders' sensations and the gs they felt in #3 in terms of the physics of the ride.

____

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____

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calculations

C. Quantitative Tasks

1. Calculate the average velocity as the riders travel up the ride in m/s.

_______________ m/s

2. Calculate the final velocity the riders reach at the end of their free fall in m/s.

_______________ m/s

3. Calculate the initial velocity of the ride needed to propel it to its maximum height.

_______________ m/s

4. If the acceleration up the tower happens during the first 5 meters, what is the acceleration during this time?

_______________ m/s^2

_______________ g's

5. Use the acceleration found in #4 above to calculate the force necessary to achieve the acceleration.

_______________ N

Hell's Gate

Stand in a position where you can observe the ride. Take data and answer the following questions. After reading the questions, you must determine what data you need to collect.

A. Data

____
____
____
____
____
____
____
____
____

Measurements while on ride: (using accelerometer)

Maximum **g** __________ g's at ______________________________ (location)

Minimum **g** __________ g's at ______________________________ (location)

B. Qualitative Tasks

1. Have the riders take their pulse rate:
   (a) before they get on this ride. ___________________________
   (b) immediately after they have finished this ride. ___________________________

2. In a few words, have the riders describe how they felt:
   (a) before the ride started ________________________________
   (b) during the ride ________________________________
   (c) after the ride ended ________________________________

3. Where on the ride do the riders experience:
   (a) more g's than normal ________________________________
   (b) less g's than normal ________________________________

❹ Explain the riders' sensations and the g's they felt in #3 in terms of the physics of the ride.

____

____

____

____

calculations

C. Quantitative Tasks

❶ Calculate the average speed during the ride in m/s.

_______________ m/s

❷ Estimate the mass of the ride and the riders.

_______________ kg

❸ Calculate the amount of work necessary to move the ride and the riders from the lowest point to the highest point on the ride.

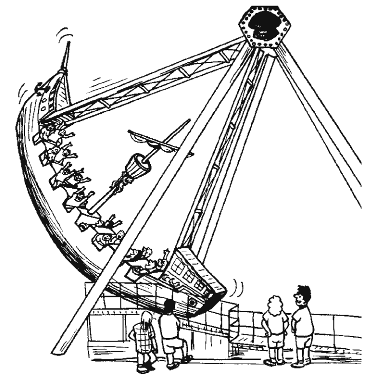
_______________ Joules

❹ How much power do the motors have to supply to move the ride and the riders in calculation #3?

_______________ kW

❺ Present data and calculations to show why your maximum g measurement was accurate.

Pirate Ship



A. Data

1. Time for one period (complete cycle) ____________ s
2. Estimated radius of the ship's path ____________ m
3. Maximum angle of displacement ____________ °
4. Maximum accelerometer reading ____________ g's

B. Qualitative Tasks

1. Consider the rocking boat described above as a pendulum. In a simple pendulum, the mass is considered to be concentrated at the end of a weightless string.

   A simple pendulum at small displacements exhibits simple harmonic motion with the period **t** of the pendulum's swing expressed by the following relationship:

   $$t = 2\pi\sqrt{\frac{L}{|g|}}$$ Where **L** = the length of the pendulum's string.

   Calculate the period of the Pirate if it were a pendulum.

   ____________ s

2. From your results above, decide if the boat is a simple pendulum. Why or why not?

___

___

___

3. In each arc, where did you feel:

   a) the strongest push against your back?

___

   b) the most pressure against your seat?

___

   c) the least pressure against your seat?

___

4. When did you feel you were going the fastest?

___

___

___

5. If you have a vertical accelerometer, hold it in front of you during the ride. Observe the motion of the suspended mass.
   a) In what part of the ride was the mass pulled farthest down the tube?

____

   b) In general, describe the motion of the suspended mass during an arc and during a loop.

____
____
____
____

calculations

C. Quantitative Calculations

1. Calculate the distance of the ship's arc.

____________m

2. Calculate the ship's average speed in the arc.

a) __________m/s
b) __________km/h

3. Calculate the average centripetal acceration experienced in the loop. Include your unit label.

____

4. Express the answer to #3 above in g's.

____________ g

Flume

Stand in a position where you can see the final drop of both rides, take data and answer the following questions. Some data will be provided, some will not. After reading the questions, you must determine what data you need to collect.

A. Data

B. Qualitative Tasks

1. Look at the place where each boat begins its final drop. What can you say about the vertical height of each of these? Is one higher than the other, or are they both about the same height?

2. According to your answer to the last question and considering the data which is supplied, what can you say about the potential energy of each boat when they have people of roughly the same weight?

3. As you watch the boats make their drop, do you notice any difference in the path that each takes to the bottom?

4. When each boat gets to the bottom of the run, what has happened to the potential energy each one had at the top?

5. Does the amount of potential energy each loses depend on the path each one takes to the bottom? Explain why or why not.

6. Considering everything you've answered so far, what would you expect to be true of the final velocity of each boat? Is one higher than the other or are they the same?

7. If you put more people into a boat (thus increasing the mass) would you notice any difference in the final speed?

calculations

C. Quantitative Calculations

1. Look at the place where each boat begins its final drop. Determine the vertical distance of this drop for each boat using any method you prefer. Is one higher than the other, or are they both about the same height? Show work or describe method for credit.

2. Using potential and kinetic energy relationships, calculate the theoretical maximum speed at the end of the final drop for each ride (assume no energy loss). Before you complain that this is too much work, think about it: will the different path each ride takes to the bottom affect the final speed? Show work for full credit.

3. Go to a place where you can see the end of each ride. Calculate the final speed using the marked distances (see Data section). Should the speeds agree? Show work for full credit. Assume zero velocity at the top.

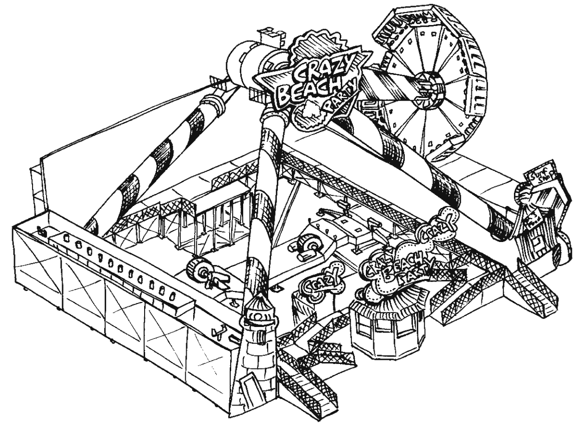
4. Do the results of #2 and #3 agree? List two reasons why they might not.

5. You have calculated the theoretical maximum speed at the bottom of the hill (#2) and you have measured the actual speed at the bottom of the hill (#3). Now select one of the hills and calculate the percent of energy that was at the top of the drop which was lost to friction during the drop. Assume the boat began from rest.

Extra for Experts: Do the same calculations as above but consider the boat's kinetic energy before making the final drop.

Crazy Beach Party

A. Data



Length of pendulum arm ______________ m

Radius of seat rotation ______________ m

Time for one pendulum swing _______________ s

Time for one seat rotation _______________ s

Acceleration reading during pendulum swing _____________ g's

Acceleration reading during seat rotation _____________ g's

# of degrees the pendulum moves through _______________ °

B. Qualitative Tasks

1. What forces do you feel as the ride first starts to swing back and forth? Explain how the ride creates them.

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2. What forces to you feel as the ride begins to rotate? Explain how the ride creates them.

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3. Describe your feelings when the ride is moving its fastest with both the pendulum swing and rotation.

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4. What happens on the ride to cause the feelings in question #3? Use physics terms to describe this.

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5. How does your pulse rate change from the time before the ride first starts to after it reaches full speed and then ends?

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calculations

C. Quantitative Tasks

1. Calculate the centripetal acceleration of the ride while it rotates.

______________ m/s^2

2. Calculate the centripetal acceleration of the pendulum part of the ride.

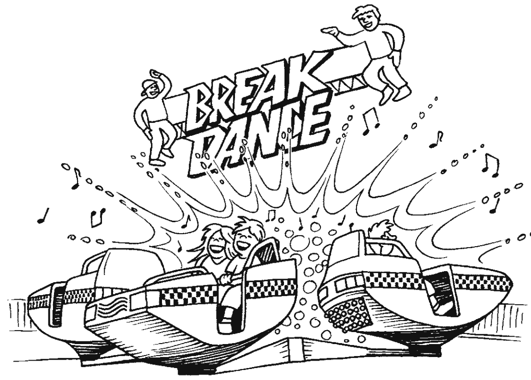
______________ m/s^2

3. Combine the results from questions 3 and 4 above to determine the net acceleration at the lowest point on the ride.

______________ m/s^2

Break Dance

A. Data



1. Length of time for complete ride ________ s
2. Length of time for one primary rotation on the ride ________ s
3. Number of secondary rotations in one primary rotation ________
4. Diameter of the ride ________ m
5. Diameter of secondary rotation ________ m
6. g force readings using a lateral accelerometer:

   minimum reading while the ride is moving ______ g's

   maximum reading while the ride is moving ______ g's
7. Mass of the rider ______ kg
8. Concentrate your attention on one rider during the ride and follow this single rider's path for at least one full revolution of the ride. In the box a the right, draw a diagram of the path he took for that single revolution. (Your diagram should be what you would see if you watched the rider's path while looking down on the ride from above.)

B. Qualitative Tasks

1. Does the primary rotation on this ride turn clockwise or counter-clockwise?

2. What direction(s) does the secondary rotation on this ride turn? If it turns different directions, keep track of the direction of the turns for one full ride.

   Spins clockwise: Doesn't spin: Spins counter-clockwise:

3. Explain the rider sensations and the g's they felt due to the results in question 2 and the physics of the ride.

calculations

C. Quantitative Tasks

1. Calculate the average velocity of the ride.

   ___________ m/s

2. Calculate the average centripetal acceleration and centripetal force the rider feels due to the primary rotation of the ride.

   ___________ m/s^2

   ___________ N

3. Calculate the average centripetal acceleration and centripetal force the rider feels due to the secondary rotation of the ride.

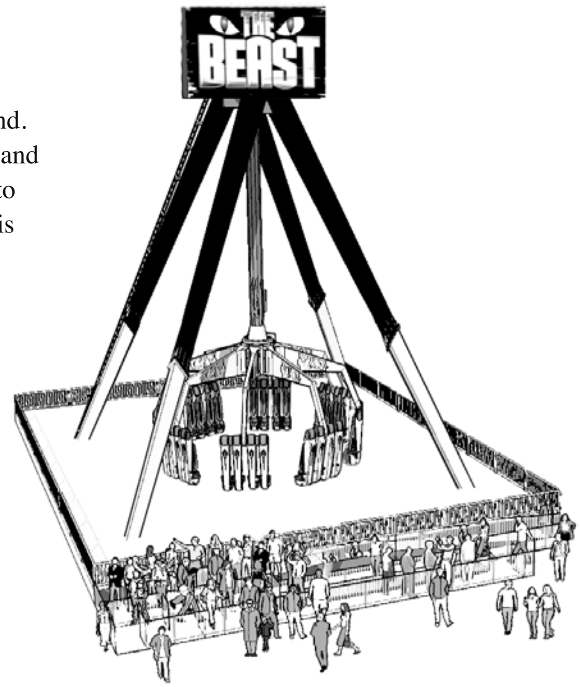
   ___________ m/s^2

   ___________ N

4. Calculate the net centripetal force and net centripetal acceleration due to your results from questions #2 and #3. How do these values compare to your accelerometer readings. Explain any differences.

5. Draw a vector diagram for different places on the ride and use it to explain the physics of the ride and the sensations you feel.

The Beast



You have been commissioned to investigate a new ride here at Playland. The Beast is our newest addition and it is your job to explore the ride and discover what secrets it holds. The Beast is a wild ride. You're going to need a steady stomach and maintain a level head if you are to tame this ride, but we're hoping that you have the dedication and perseverance to get the job done.

Procedure

Approach the Beast like you would any scientific problem. Take a moment before the ride starts and think about how it may make you feel. Gather your data as you ride the Beast. How do the forces affect your body? What sensations do you feel? Then go over your data and interpret the results. Were you right? Did you predict how the ride would make you feel? Or did your data and experiences push you in totally new direction? Once you have recovered from the ride, answer the questions below.

Questions - Bronze Level

❶ What was your first impression when you saw the Beast?

❷ Before you rode the Beast for the first time, what did you think the first ride was going to feel like?

❸ Immediately after riding the Beast for the first time, how did you feel? Describe in detail your experience.

4. Did you successfully predict how the Beast would make you feel? What did you predict that was right, what was different?

5. What forces did your body experience when riding the Beast? Where they same throughout the whole ride or did they change at some point?

6. Compare how you felt when the ride was in full swing to the bottom of the swing and when you were at a standstill.

7. When the ride is moving, which direction do you feel pushed? Is there a name for this force? Collect data to support your observations.

8. If the ride was to increase in speed, does the pushing sensation increase by the same amount? (i.e. If the speed doubled, would the pushing sensation double).

Questions - Silver Level

9. Think of three scientific questions, other than the ones posed above, that you could ask about the Beast. Then answer your own questions.

a) Question:

a) Answer:

b) Question: ____

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b) Answer: ____

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c) Question: ____

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c) Answer: ____

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⓾ Explain any principles of science you saw in the ride. List three things you experienced / learned during the ride.

a) ____

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b) ____

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c) ____

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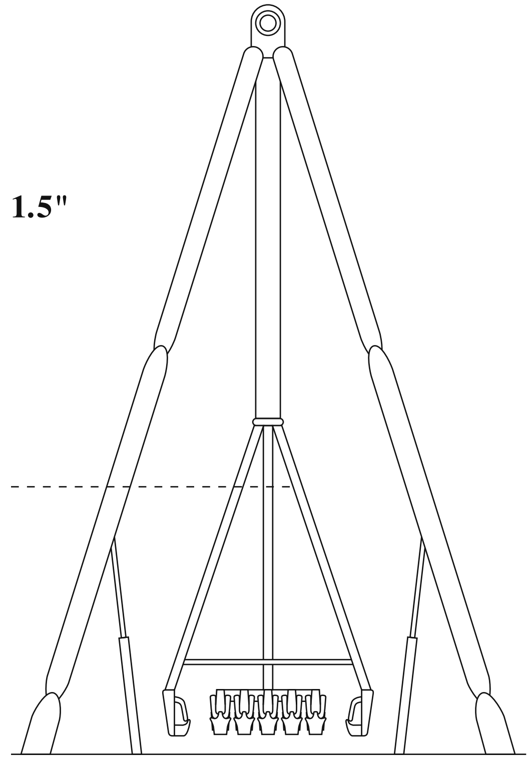
Questions - Gold Level

Challenger Questions

i) Find the combined acceleration at the bottom of the swing.



Measurements needed:

Arm Radius (estimate) ______________________

Velocity at the bottom ______________________

(Hint: Average velocity = Platform Length / Time)

Acceleration at the bottom of the swing = ______________________

ii) Use the accelerometer app to isolate the specific axis and verify your calculations in question i.

iii) Find the centripetal acceleration of the seated platform.

Measurements needed:

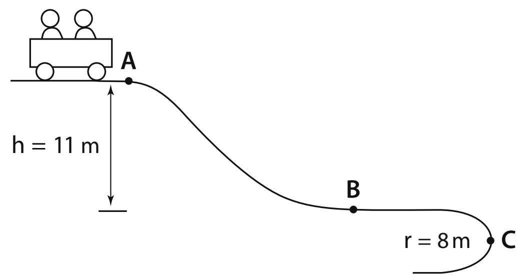
- Measured Radius ______________________________
- Measured Velocity ______________________________

Physics 12 Quiz

A coaster-type ride begins at the top of an 11 metre hill. After going down the hill, the cars make a lateral circle with a radius of 8 metres. The data below was collected on this ride.

Data

Train Length	=	10.5 m
Time to pass point A	=	2.1 s
Time to pass point B	=	0.7 s
Height of hill	=	11 m
Radius of lateral circle	=	8 m



1. Calculate the velocity of the car at point A.

_____________________ m/s

2. Calculate the velocity of the car at point B.

_____________________ m/s

3. Use the energy relationship ($E_P + E_K$) to calculate the velocity at point B.

_____________________ m/s

4. Compare answers #2 and #3 above and explain any differences.

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5. Calculate the centripetal acceleration at point C.

_____________________ m/s

6. Calculate the bank of the track at point C to ensure no lateral acceleration occurs.
Show your work and a vector diagram.

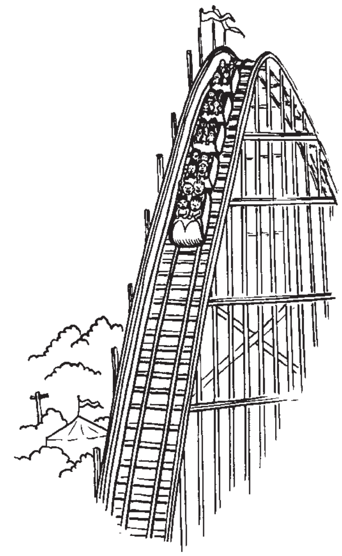
Section E
Make-Up Assignments

page E-1 Coaster Calculations

page E-2 Klothoid Loop

Coaster Calculations

The following data pertains to the **American Eagle** coaster near Chicago, Illinois.
Use the data table to work the problems listed below.



Data

Track length	=	1417 m
Train mass	=	4536 kg
Greatest height	=	38.7 m (first incline)
Length of 1st vertical drop	=	44.8 m
Angle of 1st drop	=	55°
Length of 1st lift	=	100 m (chain speed: 2.7 m/s)
Maximum speed	=	106.7 km/h
Length of ride	=	2 min, 23 s
Gravity forces	=	Up to 1.65 g's in the dips (1 g = 9.8 m/s^2)

1. How long does it take for the coaster to climb the first hill?

2. What is the climbing angle of the first incline?

3. What is the maximum gravitational potential energy for the coaster as measured above the lowest point in the ride?

4. What is the average speed of the entire ride?

5. What is the maximum kinetic energy for the coaster?

6. Assume a speed at the top of the 1st hill of 2.7 m/s and a vertical drop of 44.8 m. What should be the speed at the bottom of the hill with no friction or air resistance losses?

7. How large are the actual friction and air resistance losses in km/h?

8. How long is the track down the first drop?

9. What is the friction and air resistance loss per metre during the drop?

10. If the coaster had the same frictional and air resistance losses for the whole trip, would it reach the station?

11. Do you expect friction/air resistance losses to be greater or less in the latter part of the ride? Explain.

The Klothoid Loop

A Klothoid loop has an ever decreasing radius as the rider enters the loop at point **A** and climbs to point **B**. From point **B** to point **C** the loop is circular, with constant radius. At point **C** the radius begins to increase until it reaches its maximum value again at point **D**.

1. What is the advantage of this curve over a circular loop?

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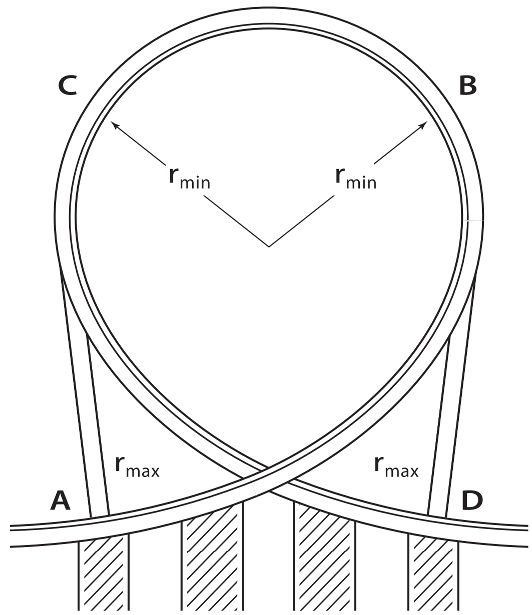


2. Assume a coaster speed of 96.5 km/h as the centre of the coaster enters the loop, a loop height of 23.16 m, and a uniform decreasing radius of curvature from 49 metres to 7 metres with a circular top loop of 130.6°. Next assume a frictionless track and calculate the velocity as the middle of the coaster passes: (a) Point **A**, (b) Point **B**, and (c) Point **C**.

a) ____________________

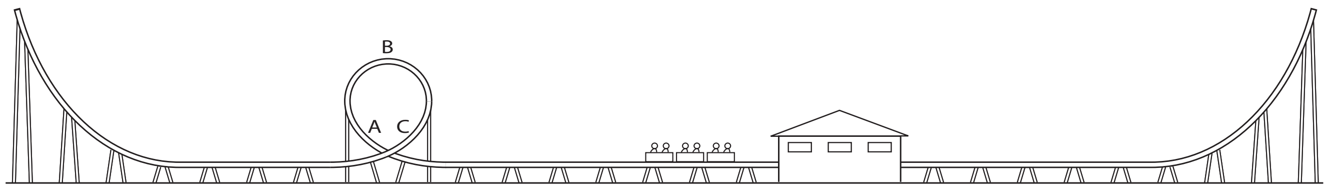
b) ____________________

c) ____________________

The picture below illustrates a Shuttle Loop Coaster which uses a Klothoid loop.

The coaster carries riders through the loop forward and then backward. A slingshot flywheel catapult mechanism propels the coaster along the track.

The coaster makes the loop going forward and climbs the left ramp. The coaster then rolls down the ramp, through the loop backward, and up the right ramp. In just over 30 seconds, the coaster is back at rest in the station.



Accelerometers mounted in the front and rear cars measure the force component perpendicular to the rider's seat. The table below gives the data recorded. Use it in answering the following questions:

Accelerometer Data
Going Forward and Backward Through Loop

Entering loop forward	(Point A)	=	4.8g	(front car)	3.4g	(back car)
Top of loop forward	(Point B)	=	1.5g	(front car)	1.4g	(back car)
Exit of loop forward	(Point C)	=	3.2g	(front car)	4.8g	(back car)
Entering loop backward	(Point C)	=	2.6g	(front car)	4.2g	(back car)
Top of loop backward	(Point B)	=	0.5g	(front car)	0.3g	(back car)
Exit of loop backward	(Point A)	=	4.2g	(front car)	2.8g	(back car)

❸ Explain differences in accelerometer readings for the front and back cars at Point A going forward and backward.

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❹ Explain why the g-force is less at the loop top when the coaster goes through the loop backward.

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