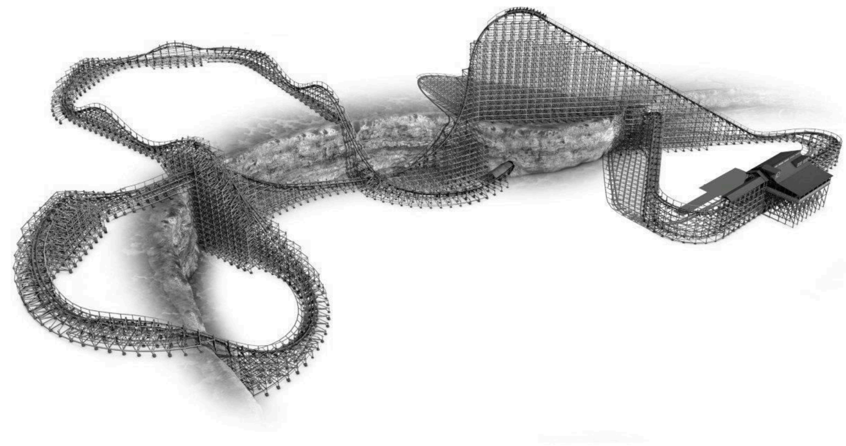
OUTDOOR CLASSROOM S.T.E.M WORKBOOK

QUESTIONS FOR GRADES 6- 12

Teachers may pick and choose portions for their students to complete.

Roller Coasters:
Iron Rattler



There are several roller coasters in the park, but this question focuses on the Iron Rattler. you may choose a different coaster to analyze if you choose.

Preliminary questions:

Roller coasters are sometimes called gravity machines. Why do you think so?

You friend says that moving at high speed is what makes rides exciting. Do you agree or disagree? Explain your thinking.

Observe the ride and answer the following questions:

Do the trains use motors for the entire trip or only part of it? Explain your reasoning.

Coasters typically wind around and around to conserve space. Draw a sketch of what the coaster would look like if it were straightened out. Do not take out the loops and curves; just draw it as if it were laid out in a straight line. If the coaster is extremely long, just draw the first 5 or 6 hills and drops. Draw your sketch on the back of this page or another paper. This will be the ride profile.

Label your sketch with the following points: maximum Potential Energy, minimum Potential Energy, maximum Kinetic Energy, minimum Kinetic Energy, maximum velocity

Be brave and ride the coaster (or have someone in your group). Describe your feelings at different points of the ride. Label the sketch where you feel the heaviest and where you feel the lightest (or weightless).

Where was your acceleration the greatest? What caused this large acceleration? (Remember that acceleration is a vector quantity and depends on two things)

Some coaster enthusiasts say that passengers in the first car, middle car and last car experience the ride differently. What do you think? Use your observations of the ride and your gut feeling while riding the ride.

Information Needed:

Time of ride	t =	______	sec
Length of track	L =	995.5 m	
Length of the train.	L =	14	m
Height of the lift hill	h =	54.9	m
Estimate the mass of a full train of passengers. (empty train is 7020 kg, 24 seats, assume 60kg/person)	m =	______	kg
Time to lift a loaded train up to the top of the first hill.	t =	______	sec
Time for train to pass a point at the bottom of the first hill.	t =	______	sec

Calculations:

Time the ride from beginning to end. Calculate the average speed of the ride.

Calculate the Potential Energy of the loaded train at the highest point. Assume that velocity at this point is essentially zero. PE = mgh

Calculate the velocity of the train at the bottom of the first drop using Conservation of Energy. (assume PE = 0) $\Delta PE = \Delta KE$ v = _______ m/s

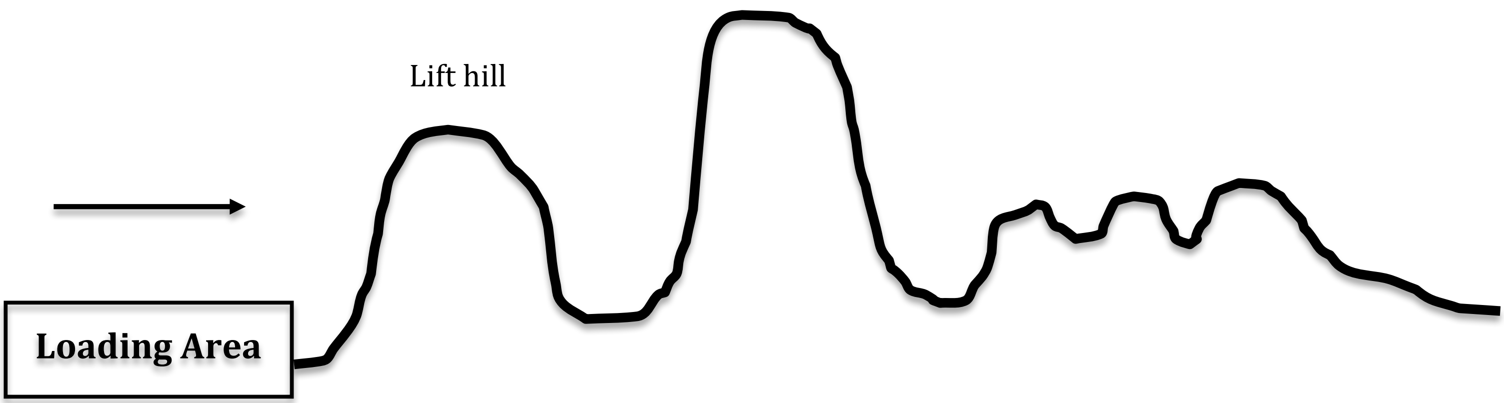
Measure the velocity of the train at the bottom of the first drop by timing the train past a fixed point. $v = \Delta d/\Delta t$ v = _______ m/s

Compare your answers for velocity of the train. Do they agree? Should they? Explain.

Calculate how much work is done to lift the train to the highest point.
$W = Fd$ W = _______ J

Calculate the power of the lift system.
$P = W/t$ P = _______ watts

Fiesta Texas is considering a new gravity roller coaster. As part of the engineering team, you are sent this rough sketch to review. Should you approve it or send it back to the drawing board? Explain your reasoning.



Interesting facts:

The first roller coasters were built in 17th century Russia. People rode down steep ice-covered slides in sleds made of wood or ice. They were sometimes known as Russian Mountains.

The Iron Rattler was designed to make use of an existing tunnel through a quarry wall. Approximately 50% of the engineer's time was used to make it fit that tunnel.

Looping Coasters: Boomerang

Several of the coasters have vertical loops. We will focus on the Boomerang. If you have time you may want to analyze other looping coasters. Sketch the shape of the vertical loop and discuss what you notice about the shape.

The very first looping coasters had circular loops, but the designers soon changed to an irregular loop called a Klothoid (Clothoid).

Explain why the Boomerang uses a motor to lift the train further up the second ramp before it returns backwards through the loop.

<u>Information Needed</u>

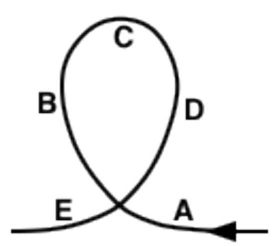
Length of the train. L = 15 m

Height of the loop. h = 10 m

Estimate the mass of a full train m = _____ kg
(empty train is 6350 kg, 28 seats, assume 60kg/person)

Time for train to pass:

Point A _______ s
Point C _______ s
Point E _______ s



Where was the train going the fastest in the loop? Why was it the fastest at that point?

Where was it going the slowest in the loop? Use physics principles to explain why the speed was the slowest in the place you identified.

Calculations:

Calculate the speed of the train just before it enters the loop.

$v = \Delta d/\Delta t$ v = _________m/s

Calculate the speed of the train at the top of the loop.

$v = \Delta d/\Delta t$ v = _________m/s

Calculate the KE, PE and total energy of the loaded train at the top of the loop.

PE= mgh KE = $1/2mv^2$ TE = PE+ KE

Pilots undergoing extreme maneuvers and roller coaster riders sometimes talk about experiencing G's. This is a shorthand way to talk about how large the force is that they experienced in units equal to their normal weight. A person feeling a force of 2 G's would feel a force twice their normal weight. Forces this large are usually due to accelerations that occur to them added onto the normal force of gravity.

For an object to move along a circular path at a constant speed, there must be a net *inward force* acting upon the rider. This is commonly referred to as the centripetal force.

At the bottom of a loop, centripetal (net) force is directed upward. Weight is directed downward. The seat of the car applies the normal force, which is also pushing upward. The acceleration the person feels is found by adding the centripetal acceleration and "g".

$G's_{felt} = a_c/9.8m/s^2 +1$

At the top of a loop, centripetal (net) force is directed downward. Weight is also directed downward. The normal force (the seat of the car) is also pushing downward. The acceleration the person feels is found by subtracting "g" from the centripetal acceleration.

$G's_{felt} = a_c/9.8m/s^2 -1$

Calculate the G's you feel entering the bottom of the Klothoid loop. Assume a radius of 11m. Remember you must add 1g.

Bottom: $a_c = v^2/r$ G's $_{felt} = a_c/9.8m/s^2 + 1$

Calculate the G's you feel at the top of the Klothoid loop. Assume a radius of 3m. Remember you must subtract 1g.

Top: $a_c = v^2/r$ G's $_{felt} = a_c/9.8m/s^2 - 1$

What would happen if the ride had been made with a circular loop instead of a Klothoid loop? Assume a circular loop with a diameter **equal** to the height of the Klothoid loop Assume a diameter of 10 m. Since it is circular, the radius at top and bottom is the same. Assume that the top and bottom velocities would be the same as the Klothoid.

Calculate the G's felt entering the bottom of the circular loop. Remember you must add 1g.

Bottom: $a_c = v^2/r$ G's $_{felt} = a_c/9.8m/s^2 + 1$

Calculate the G's felt at the top of the circular loop. Remember that you must subtract 1g.

Top: $a_c = v^2/r$ G's $_{felt} = a_c/9.8m/s^2 - 1$

The very first looping coasters had circular loops, but the engineers soon changed to an irregular loop called a Klothoid (Clothoid). Compare the Klothoid and circular loop data. Why do you think Klothoid loops are used instead of circular ones?

Interesting Facts:

The Boomerang design is one of the most popular of all time. There are many "clones" of this ride all over the world. The name comes from what the designers call the first interaction, a "Boomerang". This is also sometimes known as a "Cobra Roll".

Poltergeist

The Poltergeist is different from the rest of the coasters. A student, without even seeing the start of the ride, concludes that the train must be catapulted out of the station at great speed. Why?

The Poltergeist uses Linear Induction Motors (LIM) to launch the train. The Poltergeist requires 4,500 amps and 520 volts of electricity for each launch.

Information Needed

Time how long the train is being accelerated during the launch.

t = _______ sec

Calculations:

Measure the velocity of the train at the end of the launch rail by timing the train past a fixed point. The train is 14.6 m long.

$v = d/\Delta t$ v = _______ m/s

Calculate the acceleration from the change in velocity.

$a = \Delta v/\Delta t$ a = ________m/s^2 = _______G's

Estimate the mass of a fully loaded train.
(empty train is 4968 kg, 24 seats, assume 60kg/person) m = __________ kg

Calculate the amount of net force needed to accelerate the loaded train to top velocity.

$F = ma$ F = ________N

Use conservation of energy to calculate the maximum theoretical height that the train could rise to.

$\Delta PE = \Delta KE$ h = _______m

Calculate the power used during a launch.

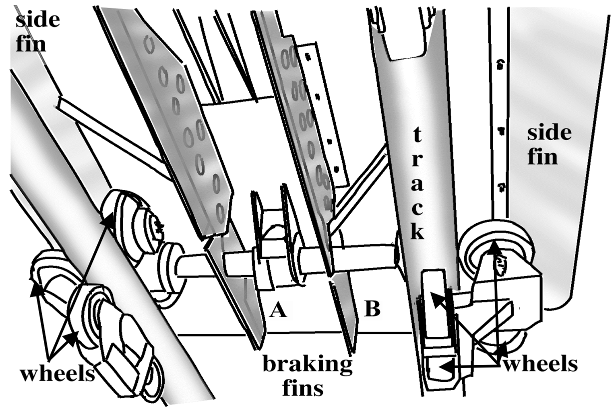
$P=VI$ ____________ watts

How much heat would be generated if the train was stuck and could not move, while the normal launch energy was expended?

$P = E/\Delta t$

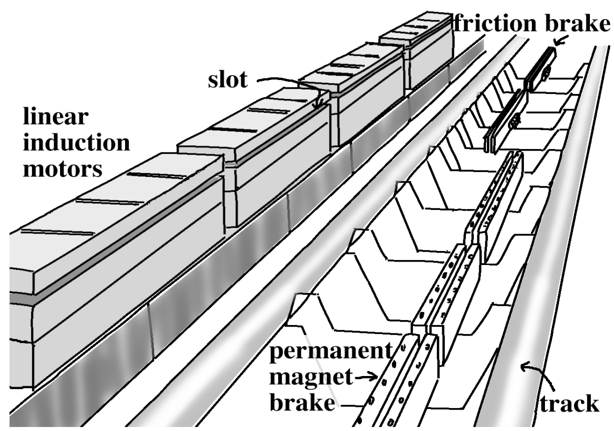
In the movie *Back to the Future*, Dr. Brown created a time machine out of a DeLorean DMC-12 car. The time machine required 1.21 Gigawatts to operate. How does this compare to the launch power of the Poltergeist?

Observe the train and launching system while waiting to board. The side fins on the train fit into the slots of the linear induction motors on both sides of the track. The motors use electromagnets to launch the train down the track. The fins are made of aluminum, and aluminum is not attracted to a magnet. How then can this system work?



The first picture shows the bottom of a Poltergeist train car.

The second picture shows part of the track and the linear induction motors.



LIM graphics from Six Flags St. Louis materials.

Interesting Fact:

The 0-60 mph acceleration of the Poltergeist is about the same as a Corvette.

The Carousel

The carousel is a replica of those that were first designed in the early part of this century. This carousel, containing hand-painted panels, animals, and chariots, sends riders back to the romantic times of carnivals and county fairs.

One of your friends thinks that all of the animals on the carousel are moving at the same velocity. Another friend thinks that they are moving at different velocities. What do you think? Explain your reasoning.

Count the number of stationary animals. Determine the number of stationary animals compared to the total number of animals, and express this fraction as a percentage.

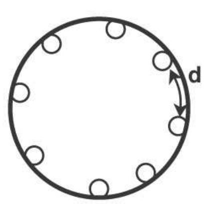
Information Needed:

1. Determine the period of rotation (time it takes to make one revolution). Take several readings and average the values.

T = __________

2. As soon as you get on the platform, estimate the circumference of the inner ring of animals by measuring the distance between two adjacent animals and then counting the number of animals in one complete rotation. Do the same for the outer ring of animals.

(Inner ring of animals) C_i = ________ m
(Outer ring of animals) C_o = ________ m



3. Using the circumference, calculate the radius for both the inner and outer ring of animals.

$C = 2\pi r$

(Inner ring of animals) r_i = _______m
(Outer ring of animals) r_o = _______m

CALCULATIONS: show your work and clearly identify your final answers

1. Find the linear speed of an outside rider.
   $v = 2\pi r/T$

2. Find the linear speed of an inside rider.
   $v = 2\pi r/T$

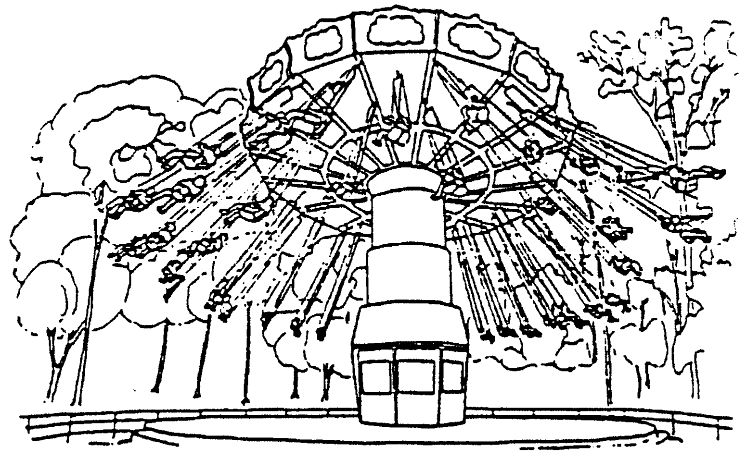
3. Calculate the centripetal acceleration of the outside rider in m/s^2 and G's.
   $a_c = v^2/R$

4. Calculate the centripetal acceleration of the inside rider in m/s^2 and G's.
   $a_c = v^2/R$

5. Calculate the angular velocity for an inside and outside rider. Discuss how they compare.
   $\omega = 2\pi/T$

6. Imagine that all riders are riding outside horses. Once the carousel is turning, the motor is turned off and the carousel continues to turn freely with no frictional loss. If all riders then move from the outside horses to inside horses while the carousel is turning, what effect would this have on the motion of the carousel? Explain.

Super Villains Swings



Your friend says that an adult will enjoy the swings more than a child since more weight will make them swing out farther. Predict what you think will happen before the ride starts. How will an empty swing behave compared to one with a rider? Draw a sketch of your prediction for an empty swing and one with a rider.

Observe the ride in motion. How did your prediction compare to what actually happened with an empty swing? Draw a diagram of the ride:

a.) at rest

b). rotating at full speed

<u>Before:</u>

Measure the period of the swing when it is rotating at full speed.

Estimate the diameter (and radius) of the circular path of the swings.

Estimate the angle of the chains with the vertical when the ride is rotating.

<u>During:</u>

Describe your sensations when the ride is:

a). rotating but not tilted

b). rotating and tilted moving downward

c). rotating and tilted moving upward

Calculations: Assume the ride is rotating at full speed (ignore tilt).

Calculate the linear velocity of the swings.

$v = 2\pi r/T$

Calculate the centripetal force acting on a rider.

$F_c = mv^2/r$

Draw a vector diagram of the forces acting on you when the ride is rotating.
(Hint: tension, weight, centripetal force)

Calculate the angle the chain makes with the vertical.

Calculate the tension in the chain.

Combine equations to show the effect (or lack thereof) of mass on the angle of the swing.

Train

Devise a way to calculate the average speed and total length of the track.

DO NOT DO ANYTHING DANGEROUS OR VIOLATE PARK RULES!

Describe the measurements or estimates that you made and show your thinking and calculations.

Wait, Wait, Wait!

Many of the rides in the park have queue lines like "mazes" in which people wait in line to ride the ride. Choose one such ride and analyze the waiting time.

Choose a ride that has a long line potential. Sketch the layout of the waiting area.

Ride:______________________________

Diagram of Waiting Area:

Data to collect:
Determine guest capacity of the ride (riders/hr)
count # seats
time ride
time load/unload

Ride capacity: ________riders/min _______ riders/hr

1. Identify a place in the waiting line from which you will estimate waiting time.
2. Count the number of people ahead of a person in line at your chosen location.
3. Estimate the waiting time, and show how you arrived at your estimation.
4. Observe 2-3 ride cycles (this can be done while waiting in line). Record how many passengers actually get on each time. Calculate the typical percentage of the ride that is filled.
5. Assume 0.8 m for a person's "space". Calculate length of a queue line for your ride with a wait time of 10 minutes. Explain your thinking.
6. You must be back at the gate to meet your class in half an hour. You are at the end of a long line. After a quick count, you realize you are the 100th person in the line. Will you be able to ride and get off in time to meet your class? Show your thinking and calculations.

Interesting fact:

The lines we wait in are called queue lines. Queue is a term borrowed from the French in about 1748. It literally meant "tail", from the Latin cauda.

queue ***noun*** *\ˈkyü*
:a braid of hair usually worn hanging at the back of the head
: a line of people who are waiting for something
: a series of instructions that are stored in a computer so that they can be processed later

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