Cedar Point

PHYSICS, SCIENCE & MATH DAYS

# Physics, Science & Math Day Workbook

**Name:** ______________________________

**School:** ______________________________



# Greetings,

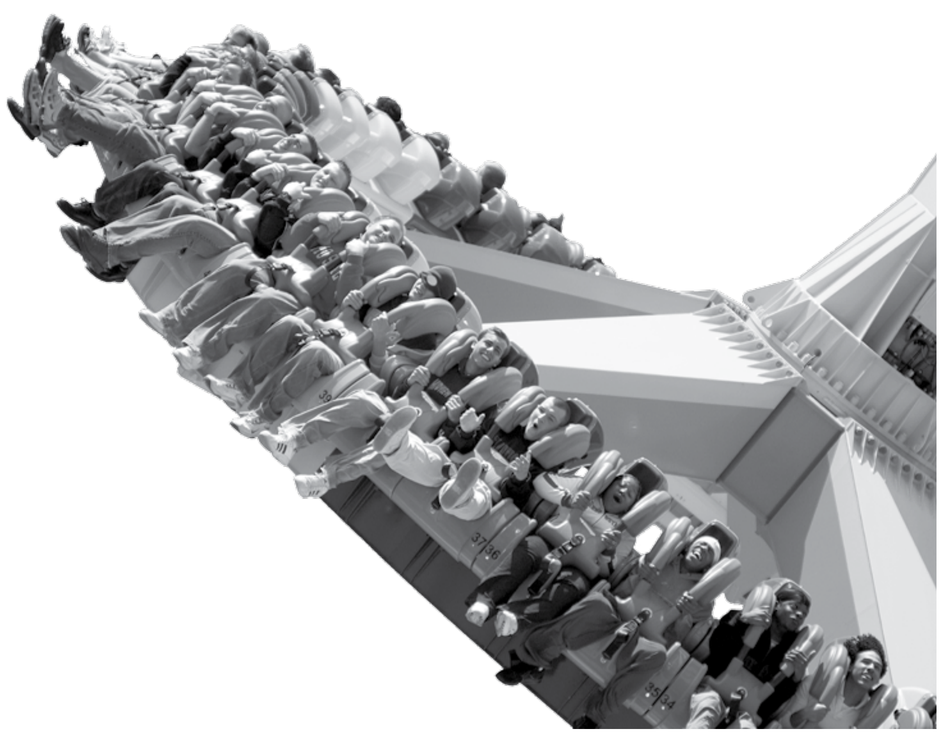
We have created this packet to assist you with your curriculum for your visit to Cedar Point during Physics, Science & Math Days. The information can be used as is, or if you wish you may customize the activities/questions for your students. While every effort has been made to ensure accuracy of the information, please remember Cedar Point is not an education institution. Over the years we have had contributors assist with this packet. We would like to give special thanks to Perkins Local Schools in Sandusky, Ohio for their help in developing portions of this packet. We also would like to thank Baldwin Wallace University from Berea, Ohio. If you have questions on how to work through a problem visit their booth on the midway from 10am – 2pm during the Physics, Science and Math Days event.

- Dr. Edwin Meyer – Problems
- Dr. Lisa Ponton – Problems, Illustrations
- Dr. Peter Hoekje – Problems
- Brandon Dropic – Problems, Graphs
- Alan Duncan – Problems, Illustrations
- Jame Emigh – Review
- Dave Revta – Problems, Compilations, Review, Graphs , Illustrations

We know this workbook can and will add to the educational enjoyment of the day.

See you on the midway!

**Sincerely,**
**Cedar Point Staff**



# Cedar Point Math & Science Workbook
# A Note From The Compiler

Baldwin Wallace University is pleased to be an academic partner with Cedar Point. Students, faculty, and staff from our departments of Physics and Chemistry have worked together to develop problems for this workbook with the aim that it support Ohio Physical Science Standards for Grades 5-8. This isn't just a workbook; it's an invitation to explore and think about one of America's premier destinations in a way that is both educationally relevant, and also fun.

We've attempted to bring in aspects of the park that involve not just thrill rides, but chemistry, math, foods, mild rides and even light. Some problems lend themselves toward discussion or pencil and paper calculation, and others involve information gathering. Of course, timing and instrument use are important in science, but so are simple observational techniques.

Many attractions lend themselves to a variety of topics and grade levels. For example, the Cedar Point & Lake Erie Railroad uses levers, forces and energy, and the coal and steam aspects of the boiler lend themselves to chemistry problems. The overlap of scientific disciplines, the range of grade levels and varying needs of students and educators within a level makes it impractical to assign a specific grade level to each problem individually. Still, we have tried to identify various problem sets in terms of their relevance to various educational topics. Most of the content can work at various grade levels, depending on how it is presented. It's our belief that the workbook will be of the most benefit in an environment where an educator selects problems or topics that are the most appropriate for the needs of their students, then looks to take advantage of the teachable moments that happen during an interactive learning experience such as Cedar Point Science and Math Week.

An answer will be available, and may include ideas for expanding on some of the problems. We also plan to have some content available online. Just like the park itself, we've tried to provide something for everyone. We hope you'll use the workbook and other resources as starting points for learning. The questions are intended to be thought provoking. Many of the problems involve assumptions, simplifications, estimates and/or rounding. We acknowledge that some problems may have more than one approach that could lead to slightly different answers. We've tried to keep our information accurate, but the problems are for illustration and education, rather than engineering or technical purposes. We've tried to provide coverage of a breadth of topics, but we don't want to lose sight of the fact that this really is supposed to be fun and not just topics in science!

The project has been different for us, and we imagine the results will be different than what the park has used in the past. We welcome your feedback, and we hope to see you during the 2015 Science and Math Week event at Cedar Point. Look for us there!

Baldwin Wallace University Contributors
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Dave Revta - problems, compilation, review, graphs, illustrations

# Blue Streak

**Ride data available at Blue Streak entrance.**

- Slope of brake run:

1. As you approach the queue entrance to Blue Streak, you'll walk past the brake house where the train stops at the end of the ride. Observe the train coming to a full stop, then approaching the station. Determine the acceleration of the train that results from the slope of the brake run when the brakes are released.

___

___

2. If you ride the front seat of Blue Streak, you can observe how a flat curve is constructed as you leave the station by watching the track as you ride. Why are the track boards more likely to be cut into shape along a flat curve, rather than simply forced to bend?

___

___

3. Observe the lift hill of Blue Streak from the cue line. The lift hill is straight as viewed from the top, but the profile of the hill curves up and down (we might call this a vertical curve). Is the track made of one really thick beam, or several smaller layers? Why do you think the track is built the way it is?

___

___

4. If you enjoy Blue Streak, it's fun and constructive to ride in a couple of different seats and compare the rides. For example, you could take a ride in one of the first three or four rows of the train, and then take a subsequent ride in one of the last three or four rows. Pay attention to your feeling of weightlessness (or "airtime") as you go over the hills (sometimes called bunny hills) of the ride when riding toward the front, and toward the back.

   When your near the front, do you experience more air time when the train is rising a hill, such as when it is entering the turn at the far end of the ride, or do you experience the air time more when the train is going down hill?

___

___

5. How about if you ride near the back of the train - is the air time occurring more as the train is approaching the crest of a hill, or as the train descends? ______________________________________________________

   If you pay close visual attention to the top of the track on the small hill right after the turn, you'll see visual evidence of the air time experience. What is this evidence, and what does it tell you about the Blue Streak train as it is going over that baby bunny hill after the turn?

___

___

6. Is the gravitational force on your body different when you are riding as opposed to when you're standing on the midway? What changes when you ride?

___

___

7. Where are you on the ride when you experience the largest and most consistent sideways force? Explain where this force originates from, and the resulting motion of the train and your body. Can you give the scientific name for this force?

___

___

# Cedar Downs

**Useful to Know:**

- Speed of ride in MPH ______
- Type of wood used for decking:__________
- Density of said type of wood:____________

**Ride data available at Cedar Downs entrance.**

- Diameter of track for inner (first) row horses:________
- Diameter of track for second row horses:________
- Diameter of track for third row horses:__________
- Diameter of track for outer (fourth) row horses:________
- Overall outer diameter of moving ride platform_______
- Width of moving ride platform: 16' 4"

1. The maximum posted speed for Cedar Downs applies to the outside row of horses. Use this information to determine the maximum rotational speed of the ride in revolutions per minute, and in radians per second.

2. Calculate how fast the inner row of horses is traveling in miles per hour, and also meters per second.

3. Calculate the centripetal acceleration of the inner row of horses.

4. As you ride Cedar Downs, you will notice that the horses race each other in groups of four as they go around the track. Qualitatively describe the contribution that this motion makes to the centripetal acceleration as the ride is in motion. When does the centripetal acceleration increase? When does it decrease? When you ride, do you experience perception of this change? Why or why not?

5. Just for fun: How many spotted horses are on Cedar downs? ______________________________

# Cedar Downs

**The pinnacle in the development of the carousel is a ride known as the racing derby, of which Cedar Downs is a pristine example. The ride actually may have more in common with roller coasters than merry go rounds, as it is entirely supported from below on roller coaster track. The scale of the ride is also quite large, in fact, some carousels could easily fit in the open courtyard in the center of Cedar Downs!**

1. Take a look at the platform deck as you board Cedar Downs. Is the deck made of individual boards, or larger pieces such as plywood? How is a large circular deck constructed from rectangular pieces, and sections that use straight edges?

2. Given the dimensions of the ride, find the overall surface area of the decking. You may neglect the small slots where the supports for the horses go, but be sure to account for the fact that the ride has a large open area in the center!

3. Suppose that the deck boards are 3/4" thick pine. What is the total volume of wood decking?

4. In the United States, lumber is often traded and specified in units of board feet. How many board feet of decking is on Cedar Downs?

5. How much does the decking weigh? ______________________________

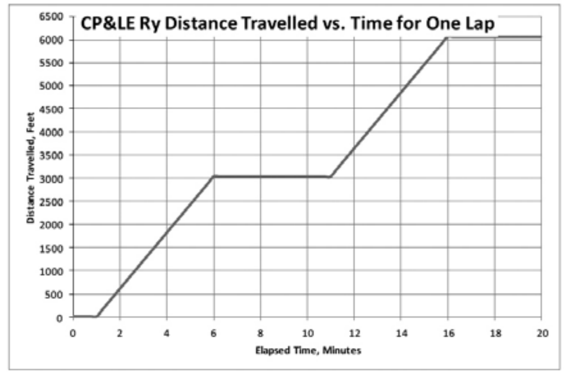
6. Approximations are often used for situations when an exact answer would be difficult or impossible to obtain, but they are also appropriate for situations where an exact answer is unnecessary or even meaningless. For example, while it's certainly possible to count the number of nails in a structure, calculating the exact number needed in advance isn't meaningful. We know some fasteners will be dropped or bent during installation, and sometimes boards need to be readjusted requiring replacement fasteners. Also, we can't usually buy an arbitrary number of nails, as they're sold by the units of boxes or sometimes pounds. What's needed is a reasonable estimate so that we can purchase the right amount of supplies to have the amount we need, with some spares, but not too much waste.

   Imagine that you need to know how many pounds or sticks of nails to order to replace the decking. If there's an average of two nails for every 16" of linear decking material, how many nails will it take?

# CP&LE Railroad

**Ride data available at CP&LE Railroad entrance.**

- Track Length:




**A group of students decides to take a relaxing trip on the Cedar Point & Lake Erie Railway. They begin their journey at the Funway station. An approximate plot of their distance traveled vs. time is presented above.**

1. How long after they are seated does the ride begin? ___________________

2. What is the travel time from Funway station to Frontier Town Station? ___________________

3. How long is the train stopped at Frontier Town Station? ____________________

4. How long does it take to get from Frontier Town Station to Funway Station? ______________________

5. What is the average speed of the train while it is in motion from Funway Station to Frontier Town Station, in miles per hour? ________

6. What is the average speed of the train over its entire twenty minute ride cycle, in miles per hour? ________

7. Make a graph of speed vs. time for one lap of the CP & LE Ry.

8. When the train is in motion between stations, is the magnitude of the velocity fairly constant, or is the ride punctuated by periods of high acceleration?

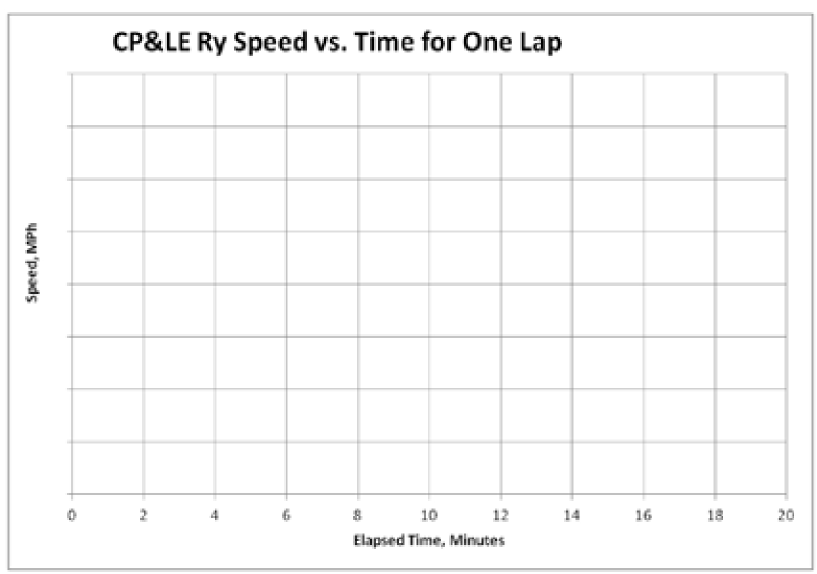
_______________________________________

9. What does this tell you about the force from the locomotive; would you expect large variations in force after the train is in motion, or a fairly steady pull?

_______________________________________

_______________________________________

_______________________________________



# CP & LE Railroad

**Problems involving friction are often modeled in terms of rectangular blocks. It's easy to visualize, but we can still make reasonable estimates for things that aren't flat. Suppose that an irregular steel object sits on a steel surface as shown below and a horizontal force is applied in such a manner as to make the object slip along the surface (assume the force is applied so that the object can either slip or not, but the object won't rotate).**

**Useful to Know:**

- Coefficient of friction of clean steel on steel at 20C is 0.58 according to page F-15 of the $54^{th}$ edition of the CRC Handbook of Chemistry and Physics
- How to calculate area of a circle
- Pressure = Force / Area
- Work = Force * Distance

**Ride data available at CP&LE Railroad entrance.**

- Normal force on object:
- Applied pressure to cylinder:
- Internal diameter of cylinder:
- Stroke (movement) of cylinder:

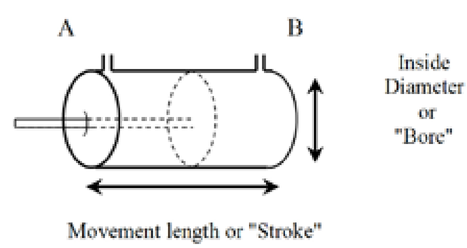
1. Determine the maximum horizontal force that can be applied before the object slips.

______________________________

______________________________

2. Draw a free body diagram of the object with a horizontal applied force of 2250 lb

**The drawing at the right shows a cylinder, which is a tube containing a piston which moves in response to pressurized fluid pushing on it. The device is based on Pascal's principle that a fluid exerts pressure equally in all directions, and the relation that pressure is force per unit area. A rod extends through one end of the cylinder so the motion can be used outside of the device. The fluid, such as oil, air, or steam (steam is a fluid, but steam isn't a liquid!), is put into one or the other side of the cylinder through a port (A or B), which is selected by valves (not shown) that help control the motion. Such devices are used extensively in heavy equipment and amusement rides.**




Simple piston to convert fluid pressure to mechanical motion. Cylinder piston & rod in middle position

3. Consider the cylinder and data above and calculate the amount of force that can be exerted by the rod.

______________________________

4. If the piston moved a total distance of 18" under the above conditions, how much work does it do?

______________________________

5. If the cylinder cycles four times, how much work would it do?

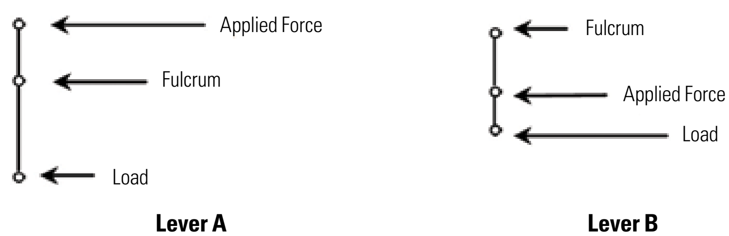
______________________________

# CP & LE Railroad

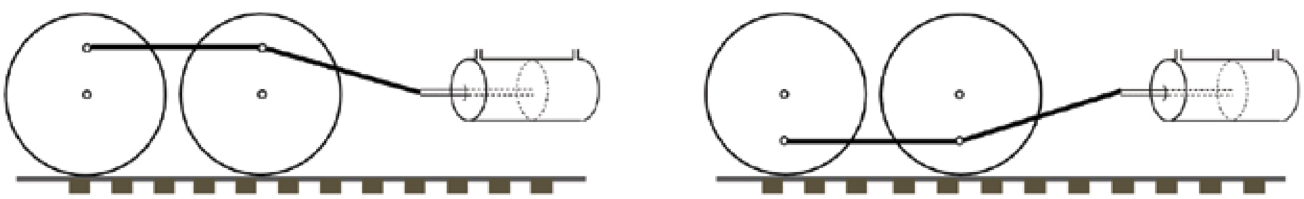
**Ride data available at CP&LE Railroad entrance.**

- Distance between applied force and fulcrum:
- Distance between fulcrum and load:
- Applied force:

1. For each of the levers shown below, determine the class of the lever, the torque experienced by the lever from the applied force, the force delivered to the load by each lever, and the mechanical advantage of each lever. Summarize your findings in a sentence that describes how these levers are similar and how they are different.



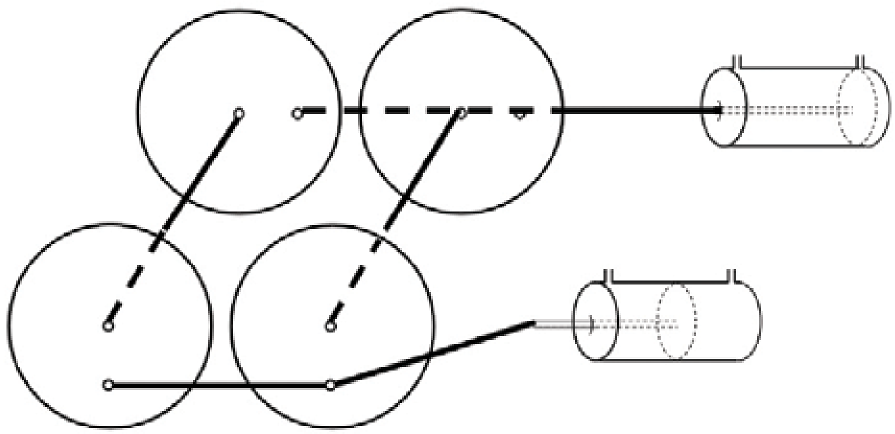

2. One side of the drive wheels of a locomotive is shown below for two different positions of the connecting rod. Describe which of the above levers applies to each of the wheel depictions.



**At this point, you're probably wondering where all this information and calculation is going. One of the classical engineering challenges on a rail road is to figure out what a locomotive is capable of. For example, the maximum force a locomotive can exert is called the tractive effort. By working with some drawings and calculations, you're on your way to finding the tractive effort without having to formally derive the equation. You are solving a complex problem in a series of simple steps.**

# CP & LE Railroad

**The drawing below shows the major components of the power train of a CP&LE locomotive (the dashed lines represent parts hidden from view, such as parts of the axles and the tie rod between the wheels on the far side of the locomotive. The drawing correctly shows that all four drive wheels operate as a unified whole, all turning at the same time and speed. Though the locomotive weight and the applied forces are distributed between all four wheels, the effect is about the same as if all of the weight and force operated on one big wheel. It's just a lot easier to balance the locomotive on many wheels, as opposed to one!**



1. By filling in the blanks based on your work on the last couple of pages, you should be able to develop a clear understanding of how the locomotive works and the relationship between various scientific concepts and the tractive effort of the locomotive.

   The steam pressure from the boiler is applied to a ____________, which converts fluid pressure into mechanical force. When applied over a certain distance, this force does __________. The force from the piston is applied to the wheels, which sometimes act like class ________ levers, and sometimes act like class ________ levers. Levers have a property known as mechanical _________, which means that the applied force and the load force can be different.

2. The load force from the lever represents the tractive effort of the locomotive... as long as the wheels don't slip. In order for the wheels to grip, static friction must apply and the horizontal force (tractive effort) must be less than the normal force times the coefficient of friction. Fortunately, you already worked this out two pages ago by modeling the locomotive as one big wheel and determining the maximum horizontal force (you just didn't know it at the time). All that's left to do is to make the comparison and select the smaller of the two numbers.

   ______________________________________________________________________________

   ______________________________________________________________________________

   ______________________________________________________________________________

**At this point, you have a lot of tools you could use to answer a variety of mechanical questions about steam locomotives. For example, you should be able to predict how changes in boiler pressure would affect the tractive effort of the locomotive. You may also have many questions, such as why the timing of the pistons as shown in the drawing above is purposely offset by 90°. The CP&LE Ry staff are quite friendly, and some are very knowledgeable as well. While the engineers do have chores to do at station stops, they or other staff members may be able to answer a brief question from you. Just be sure to remain in areas designated for guests.**

# CP&LE Railroad

**The Cedar Point Lake Erie Railroad was first established in 1963. Since then, it has utilized the power of steam produced by the burning of coal in order to pull the railcars. The CP locomotive burns ¾ ton of coal and 1200 G of water in a 12 hour time period. In order for the steam to drive the locomotive, the pressure of the boiler must be 100 psi. Can you finish these problems for a round trip to and from Funway Station? This journey takes 10 minutes of motion and 10 minutes of resting. If you get stuck, keep cho choo choooing along!**

**Important Conversion Factors:**

- PV=nRT
- 1 Gal= 3.79L
- K=273.15+°C
- R= 0.082057 L*atm/Mol*K
- 1 atm= 14.7 psi
- 1 ton= 907.185 kg
- 1kg=1000g
- 1 mol C= 12.01g
- 1 mol H2O=18.02g

1. Water 

, is boiled by the heat of coal burning. What phase is water transitioning from and to?

______________________________________________________________________________________

2. Is this a physical or chemical change that occurs? ____________________

3. When this happens, what type(s) of intermolecular forces are broken when water transitions from liquid to gas?

______________________________________________________________________________________

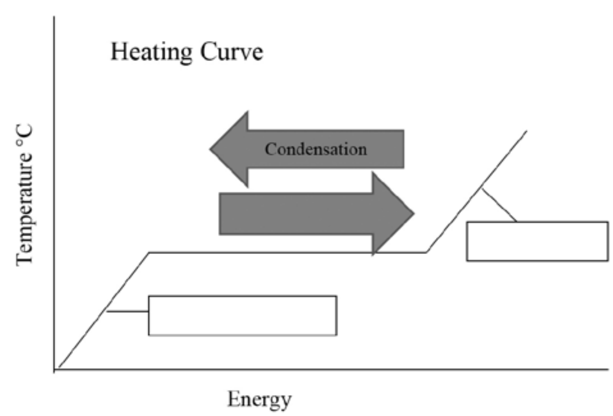
4. Draw three water molecules connected by the predominant intermolecular force above.

5. While the locomotive is operation, what is the vapor pressure of the water in the boiler?__________________

6. Middle School Challenge: Identify and label the following in the Heating Curve shown;

   a) Phase and corresponding temperature (in each textbox)

   b) Phase Change Process (in the arrow)



# CP & LE Railroad

1. In order for the locomotive to function, steam must be produced. How many gallons of water are used in 10 min? Round to the nearest gallon.

2. If the locomotive uses 10 min of water, how many moles of water would be used? Use the Ideal Gas Law with the boiler pressure to solve!

3. How many moles of water would be used in 1 hour?

4. How many moles of coal are burned in 10 min of operation?

# CP & LE Railroad

1. Carbon must be burned to produce heat energy to generate the steam to operate the locomotive. The reaction generally looks like the following: Balance the following equation;

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta H} CO_{2(g)}$$

$$3C_{(s)} + O_{2(g)} \xrightarrow{\Delta H} CO_{2(g)}$$

2. Based upon the above equation, what is the limiting reagent?

3. In actuality, what is the limiting reagent?

4. If the limiting reagent above ran out in the boiler, what would the effect be upon the locomotive? Be sure to include coal, water, heat transfer, and speed of the locomotive.

5. Summary (Fill in the blanks)

So you have learned that in traveling from __________ to ____________, it takes about 10 minutes.________ moles of coal and _________ moles of water are required to get you there. You have also learned that the coal produces _______ which allows the water to undergo a phase change from the __________ to _________ phase called ___________.This occurs because the _________ bonds are broken from the heat transfer from _______ to ________. Finally, the ideal gas law, ___________ allowed you to calculate the number of moles of water used in 10 minutes. You are now Cedar Point Railroad Chemical Engineers!

# Dodgem

**Useful to Know:**

- How many ride units are in use (go observe the ride, and make a count when the ride is being loaded; this may change from day to day)
- 1 lb ≈ 4.5 N

**Ride data available at Dodgem entrance.**

- Maximum Speed:
- Weight of empty ride unit:
- Voltage of ride units:
- Current used by one ride unit:

1. Unlike with Cadillac Cars, you're actually allowed to bump other riders on the Dodgem. Also unlike Cadillac Cars, Dodgem is electrically powered. Observe the ride carefully when the ride is in operation. Do you think that collisions between ride units are perfectly elastic, perfectly inelastic, or in between? If in between, is it closer to one than the other? Explain your conclusion in terms of what you see at the ride.

______________________________________________

______________________________________________

2. Under what conditions, if any, on the Dodgem, will the momentum during a collision be lost?

______________________________________________

______________________________________________

3. Does the collection of ride units on the ride represent a series circuit, or a parallel circuit? ____________________

4. Calculate the current used by all of ride units while they are in operation. ____________________

5. Calculate the power used by each ride unit during operation. ____________________

6. How much power does the ride require to run all of it's ride units at the same time? ____________________

7. Assume the motor in each Dodgem unit is 75% efficient. Calculate the mechanical power delivered by the motor.

______________________________________________

8. Use the relation P = FV to approximate the total effective friction force on the Dodgem ride unit while in operation. Give your answer in Newtons, and in lb.

______________________________________________

9. Suppose that you are asked to verify your calculation of the effective friction force on Dodgem. Describe how you might accomplish this using a known length, a timer, and some observations and kinematic equations.

______________________________________________

______________________________________________

10. Do you think the friction force is greater when the Dodgem car is rolling, or when it is stopped? Why?

______________________________________________

______________________________________________

# GateKeeper

1. Points of maximum potential and kinetic energy – Label on picture.
2. Points of maximum and minimum velocity – Label on picture.
3. Explain how the shape or position of the track affects the speed.

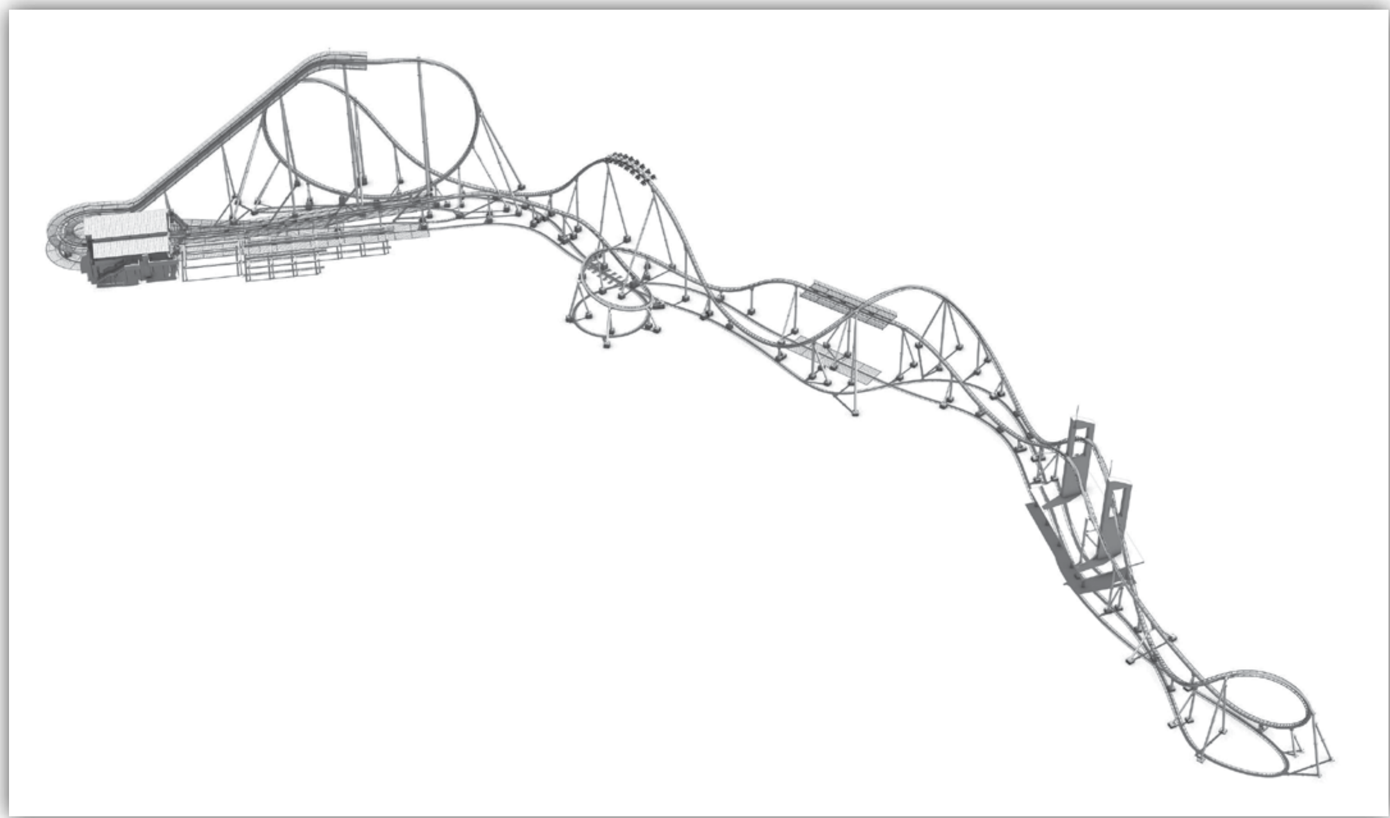
______________________________________________________________________

______________________________________________________________________

4. Explain where the speed was at its maximum and minimum.

______________________________________________________________________

______________________________________________________________________



# Gemini

**A helix is a banked circular section of track sometimes used as the grand finale to a roller coaster ride. While going through a helix, the force that the rider experiences is mostly directed upwards from the perspective of the rider, rather than lateral (side to side). The average lateral force is fairly low in the Gemini helix.**

**Ride data available at Gemini entrance.**

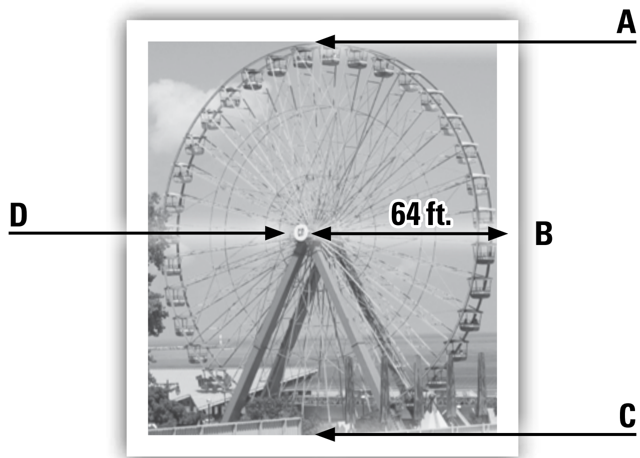
- Angle of track in helix at end of ride:
- Diameter of helix at end of ride:

1. Take a ride on Gemini, and pay special attention to your experience in the helix to verify this. After you ride, use your ride experience and the data provided above to estimate the speed that the Gemini train is traveling at when it goes through the helix.

Hint: Start by drawing a cross sectional view as the ride goes through the helix and a top view. Think about the relationship between the centripetal acceleration of the ride travelling in a circle and the direction and relationship of the components of that acceleration. Drawing these vectors on your diagrams will help you to solve this problem.

2. What other Cedar Point roller coasters have a helix element at the end of the ride?

# Giant Wheel




**Types of Angles**

1. What angle and how many degrees does Point A, Point D and Point C make?

2. What angle and how many degrees does Point A, Point D and Point B make?

3. What is the distance from Point A to Point C? What is this called?

**Area of the Giant Wheel** ***(Hint: π times radius squared)***

4. Find the Area of the Giant Wheel.

**Circumference**

5. If you do one full rotation, how far have you traveled?

6. If you do a half rotation, how far have you traveled?

7. Pythagorean Theorem (_____+_____=_____)

8. What is the distance from Point A to Point C? *(Hint: look at what shape it would make!)*

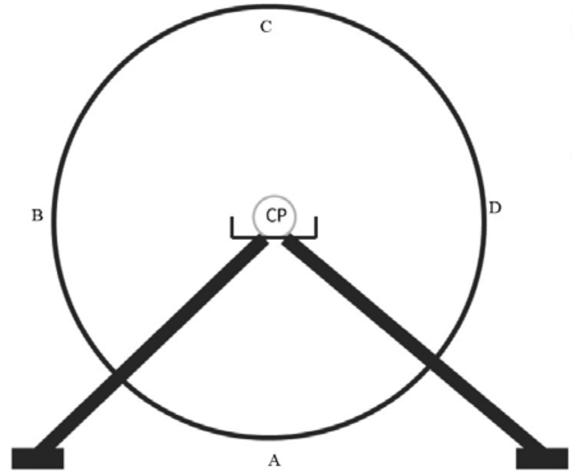
# Giant Wheel

**Ride data available at Giant Wheel entrance.**

- Radius:
- Rotation of 1 revolution / _______ seconds*

**Useful to Know:**

- Radius in meters = ___________
- Circumference = ______________
- Tangential Velocity = ___________
- Approximate mass of 100 lb rider = ________ Kg




**Suppose a person who weighs 100 lbs sits perfectly balanced on a scale as they ride the Giant Wheel so that their feet are off of the floor and their entire weight is on the scale. The wheel rotates at a constant angular velocity in a clockwise direction as it is viewed from the park side of the wheel. Consider the points indicated (A, B, C, D).**

1. At which point(s) would the scale read exactly 100 lbs?

_______________________________________________

_______________________________________________

2. At which point(s) would the scale read more than 100 lbs?

_______________________________________________

_______________________________________________

3. At which point(s) would the scale read less than 100 lbs?

_______________________________________________

_______________________________________________

4. Find the scale reading at each of the points.

_______________________________________________

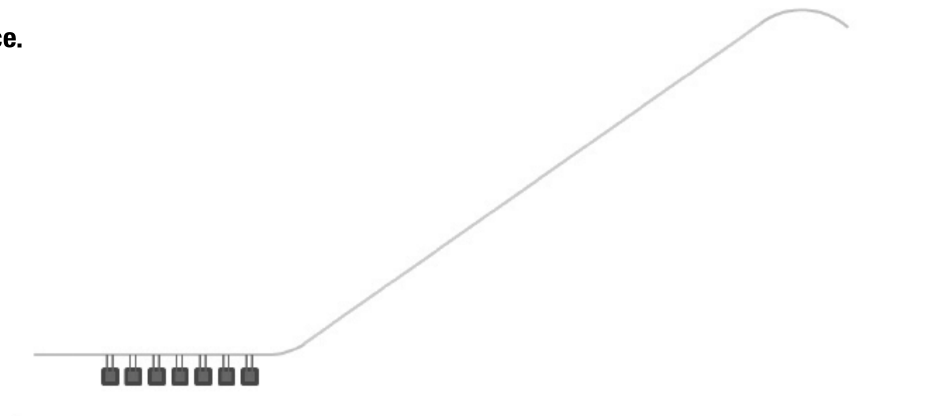
_______________________________________________

*In order to complete this problem, you'll need to know the rotational frequency of the Giant Wheel when it is up to speed. While the use of devices such as cell phone timers is prohibited on rides, you can time the ride while you're waiting in line. The ride stops and starts frequently while loading and unloading, so you'll need to be especially alert for the time when the ride makes one or more complete cycles. Choose your favorite color of gondola and a convenient reference point such as when it moves past one of the support arms to help you get an accurate time. Because of the nature of the ride, you may have to rely on the time for a single revolution, rather than averaging over multiple revolutions. Giant Wheel requires at least two riders per gondola, so you can have a friend help you do your timing while you're waiting in line.

# Iron Dragon

**Ride data available at Iron Dragon entrance.**

- Weight of empty train:
- Capacity of train:
- Lift #1 Data:
  - low point height:
  - overall height:
  - angle of ascent:
  - approximate climb time:
- 1 Horse Power = 746 Watts = 746 J/s



**Lift #1 on Iron Dragon is depicted above (not to exact scale). Use the ride data table above, and the picture, to answer the questions on this page. Before you answer the questions, go ahead and take a ride on Iron Dragon. Pay attention to your experience as the train climbs the first lift, then drops down the first hill.**

1. Overall, does the train ascend the first lift at a constant velocity or is the train accelerating as it climbs the lift?

2. How about on the drop - is the velocity constant or changing as you descend?

3. What is the mechanical advantage (M.A.) of the lift hill track? (Hint: to be accurate, the M.A. will be the ratio of the distance over which the force is applied to the vertical change in elevation of the train.)

4. How much work is done by the lift in bringing an empty train to the top of the hill?

5. What kind of energy does the train have at the top of the lift as a result of the work done by the lift?

6. If the train is filled with passengers weighing an average of 150 lbs, how much work would be done by the lift in bringing the full train to the top of the hill?

7. Given that power is work/time, how much power is being delivered by the lift when a full train is climbing the hill? Give your answer in both watts and horse power.

# Magnum

**Walk along the midway between the Witches' Wheel entrance and the Magnum station, you'll be able to see the base of the lift hill of the Magnum if you look towards Gemini. You should easily be able to find a spot on the midway from where you can see the Magnum trains go into the lift. Go relax a few minutes and watch the Magnum lift mechanism operate while you think about the following questions.**

1. Does the lift hill of a traditionally powered roller coaster such as Magnum represent a simple machine or a compound machine?

2. After the train has engaged the lift hill, does the train ascend the hill with a constant velocity or is the train acelerating up the lift?

3. Describe two methods that you could use to demonstrate that your above answer is correct.

4. Suppose that an engineer wants to rebuild the Magnum lift hill so that it is steeper. The engineer wants to use the same motor, so the mechanical power input to the lift is the same. How would the mechanical advantage of the gear box mechanism have to be changed (would the chain have to move faster or slower)? Why?

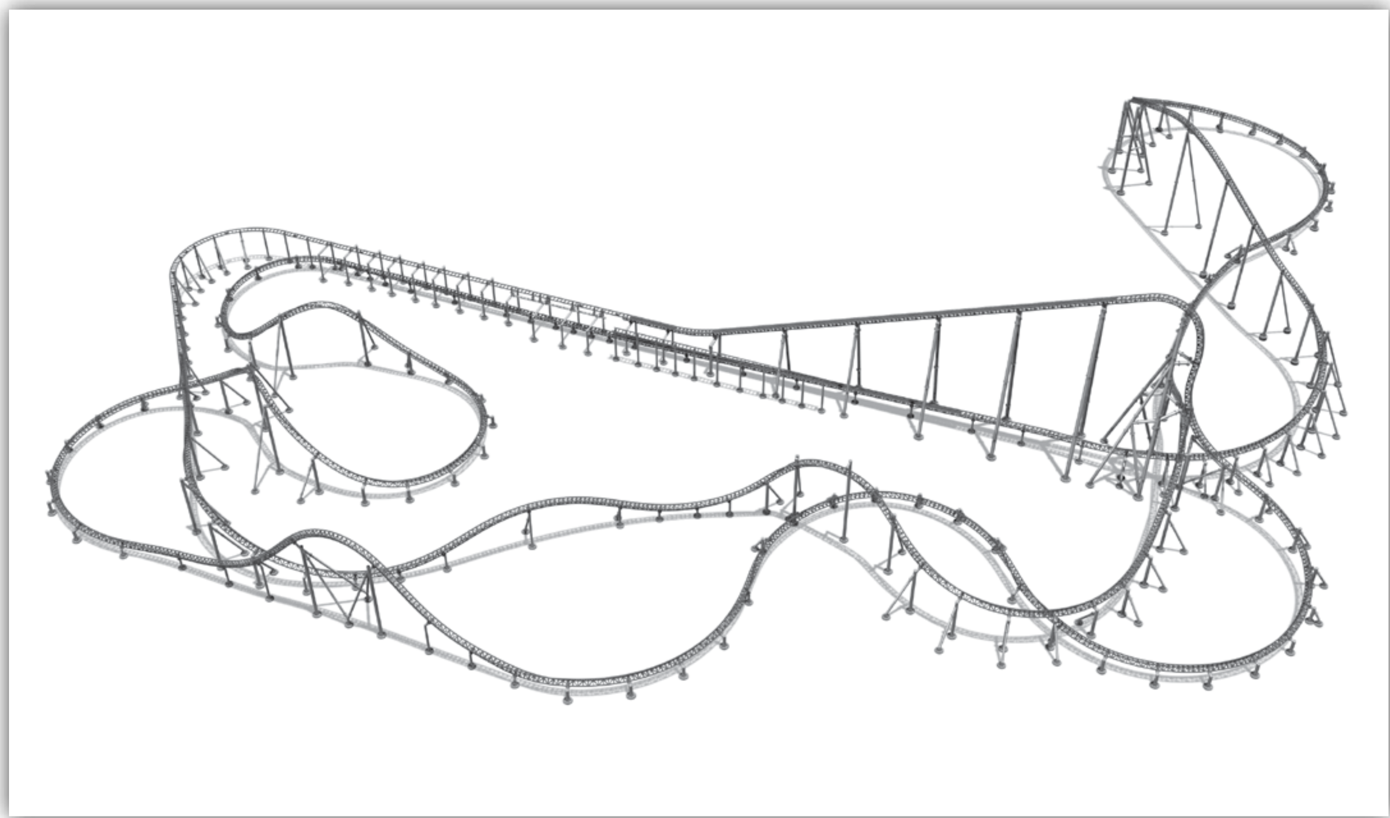
5. As you ride the Magnum, how does the sound inside the tunnels compare to the sound outside? Sure, some of the riders scream more in the tunnel, but what about the sound of the ride itself - is it louder in the tunnel? Why is this likely an example of reflection, refraction, or diffraction of the sound waves?

# Maverick

**At the following coasters you must point out the following points of energy and velocity.**

1. Points of maximum potential and kinetic energy – Label on picture.
2. Points of maximum and minimum velocity – Label on picture.
3. Explain how the shape or position of the track affects the speed.

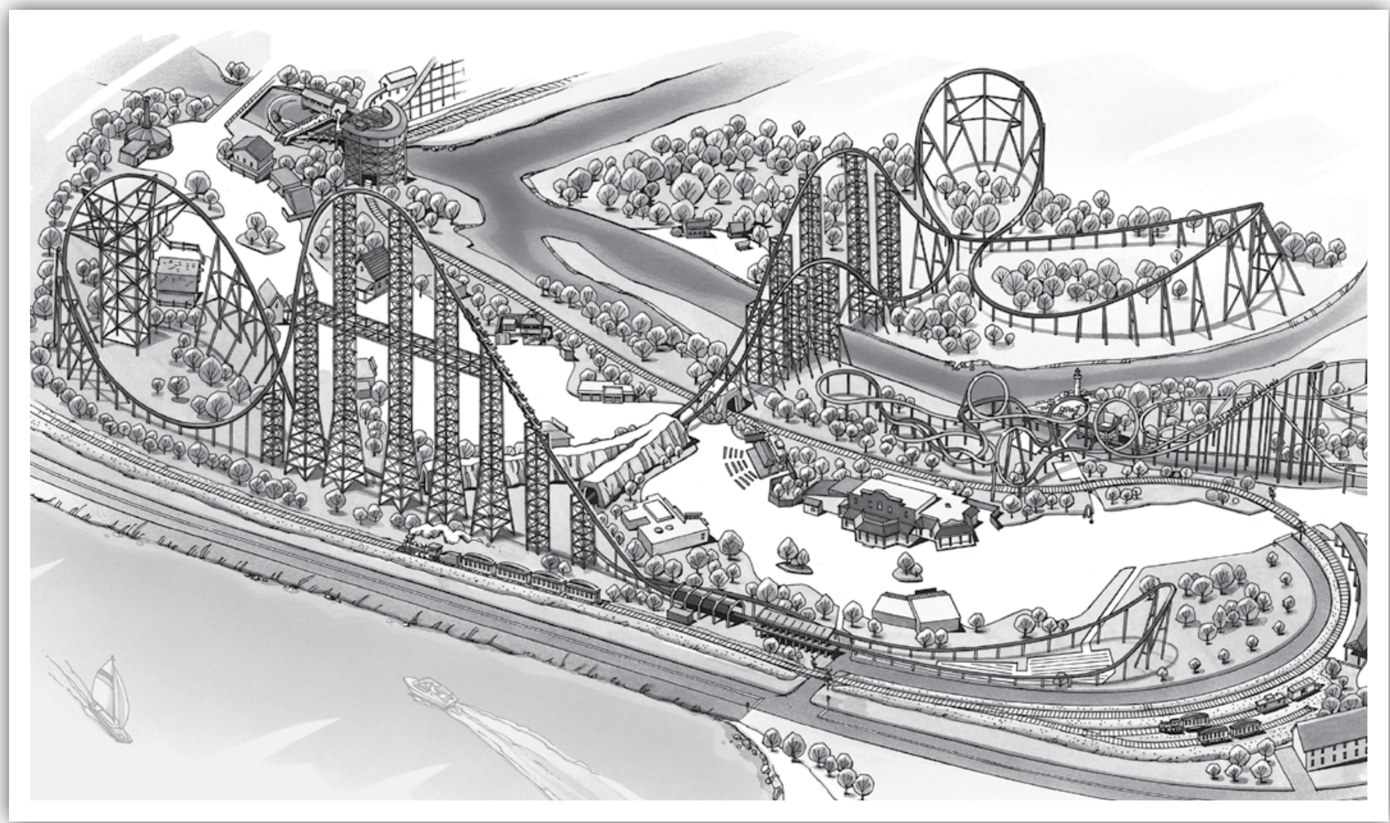
4. Explain where the speed was at its maximum and minimum.



# Millennium Force

1. Points of maximum potential and kinetic energy – Label on picture.
2. Points of maximum and minimum velocity – Label on picture.
3. Explain how the shape or position of the track affects the speed.

4. Explain where the speed was at its maximum and minimum.



# Pipe Scream

**Pipe Scream is like two rides in one. It's a circular ride and it's like a roller coaster too. The two types of motion are independently generated, yet the rider experiences a combination of both simultaneously.**

**Ride data available at Pipe Scream entrance.**

- Speed:
- Rotation:
- Rotation:
- Distance from farthest seat to center of ride:

1. Consider just the circular motion of the ride, and determine the tangential speed of a rider in the back row. Either back row will do (Come to think of it, does Pipe Scream even have a front seat?). Anyway, let's work this in miles per hour and meters per second.

   What is the centripetal acceleration generated by the rotation of the ride in m/s2?

2. Determine the magnitude of the resultant vector formed by the centripetal acceleration and by gravity.

**For the following questions, consider the linear component of the velocity to be directed along the track itself. In other words, don't worry about the exact angle of the track and whether your heading up or down, just look at the motion along the length of the ride.**

3. Under what conditions will your total speed be a maximum and what is the maximum it can be?

4. Under what conditions will your total speed be a minimum and what is the minimum it can be?

5. Describe the conditions under which your total speed would be 24.7 mph.

6. Challenge - Draw a graph of the magnitude of the total velocity of the rider along the length of the track as a function of time. To keep it manageable, work it out as a two dimensional problem, that is, assume the velocity along the length of the track is fairly constant over the hills, except when the ride changes directions at the end. Hints: the resultant velocity is the composite of two independent velocities. Draw these out first. How would the sin function assist you?

# Power Tower

**Use Diagram Below**

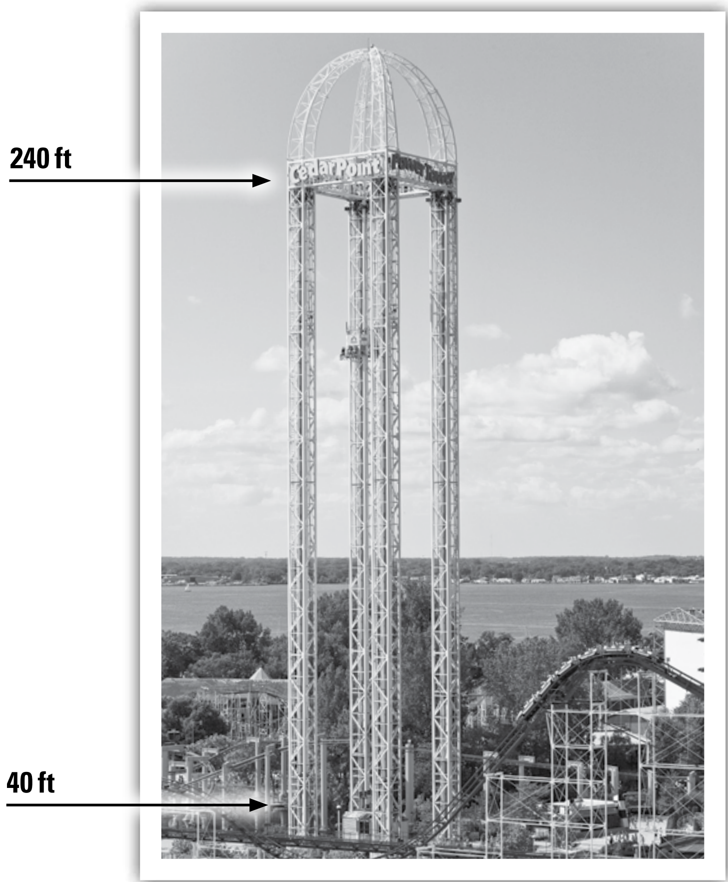
1. How far does Power Tower Drop you?

2. How long *(seconds)* does it take to drop? *(use your stopwatch or cell phone as a timer)*

3. Vertical Change *(Drop Side)*: ***(Ending Point – Starting Point) / Time (Seconds)***

3. Vertical Change *(Thrust Side)*: ***(Ending Point – Starting Point) / Time (Seconds)***

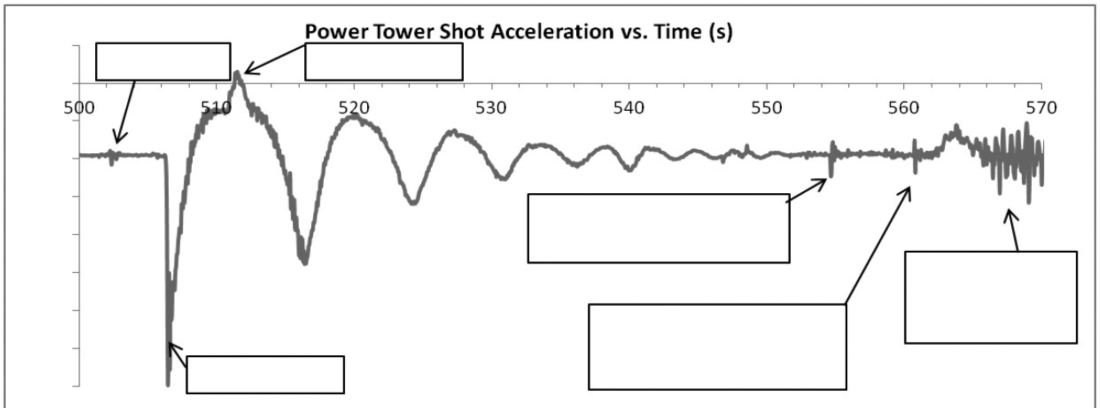
3. Are the two sides the same or different? Explain?

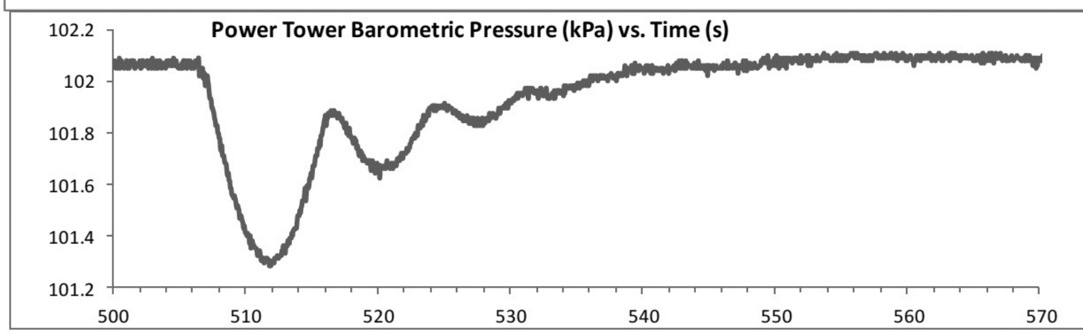


# Power Tower

**Ride data available at Power Tower entrance.**

- Height:
- Vertical Distance Travelled :
- Maximum Speed:




**Watch the drop side of Power Tower in operation. Then answer the questions on this page. When you're done, reward yourself with a ride!**

1. How long does it take for the car to ascend the tower? ____________________

2. How long after the launch does the car begin to slow down? ____________________

3. At what time is the normal force on the rider from the seat the greatest magnitude? ____________________

4. How long after the launch will your apparent weight be equal to your actual weight? ____________________

5. What is the average speed of the car during the ascent? ____________________

6. Is the barometric pressure higher or lower near the top of the tower? Why?

______________________________________________________________________

______________________________________________________________________

7. Is it reasonable to assume that barometric pressure changes linearly with height? Why or why not?

______________________________________________________________________

______________________________________________________________________

8. On the acceleration graph, fill in each annotation box with the event on the ride that is associated acceleration event.

# Raptor

**The Raptor was first opened for operation on May 7, 1994. It is an inverted steel roller coaster that cost approximately twelve million dollars to build. It is 3,790ft long with a maximum speed of 57mph.**

**Ride data available at Raptor entrance.**

- Weight per car:
- Ride Time:
- Lift height:
- Drop of lift hill:

1. Based on your observations of the lift hill, do you think that the speed of Raptor at the top of the lift makes a significant contribution to the total energy of the Raptor train as it travels through the rest of the ride? Why or why not? How would you attempt to answer this quantitatively?

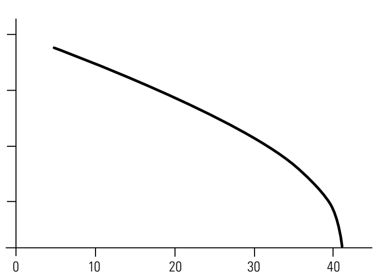
2. What is the kinetic energy of a fully loaded Raptor train at he bottom of the first hill? Assume the average weight of a rider is 150lbs.

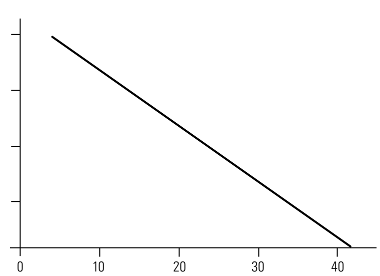
3. Calculate the gravitational potential energy of a train loaded with people at the top of the hill.

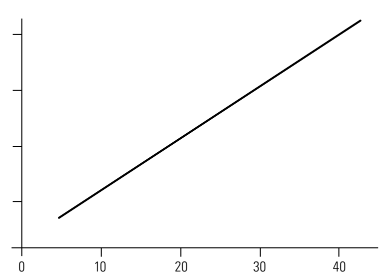
4. Calculate the gravitational potential energy of a train loaded with people at the bottom of the first hill.

5. Why is the potential energy not 0 joules at the bottom of the hill?

6. Consider the following graphs. One depicts potential energy, another depicts kinetic energy, and another velocity. For each graph, the horizontal axis shows the height of the train in meters on the main drop. Label each graph appropriately, and explain why you think your labels are correct. Scale the vertical axis of each graph appropriately.




7. Will the sum of potential and kinetic energy remain constant throughout the entire ride? Why or why not?

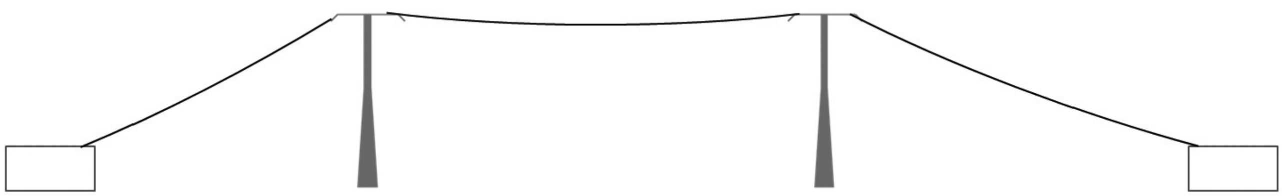
# Sky Ride

**Ride data available at Sky Ride entrance.**

- Distance between towers:
- Weight of empty gondola:
- Weight of passengers in gondola:
- Sag in cable between towers:

1. The Sky Ride is a classic gondola ride supported by a moving cable. The challenge is to calculate the tension on the cable using a combination of simplifications, basic data, reasonable estimates, and basic Physics concepts of forces and vectors. The place to start is with a simplified drawing of the problem. Probably the best way to do that, is to take a ride on Sky Ride, and simply observe carefully how the ride works and how it is put together. Remember that picture taking on rides is prohibited, so you'll need to pay attention carefully and then make your drawing after you have exited the ride and are on the midway at a convenient place.

   Let's sketch one single gondola centered midway between two towers on our simplified rendition of Sky Ride.



2. To complete the problem, you'll need to know the weight of a gondola, and the amount of sag in the cable between two towers. Though the weight of the cable is not insignificant, we'll let it have a mass of zero, and work as though the cable stretches in a perfectly straight line from the gondola to each tower. Draw a free body diagram of the gondola, showing the weight of the car and the tension of the cable resolved into force components. Then solve for the tension.

____________________________________________

____________________________________________

____________________________________________

# Slingshot

**Carefully observe SlingShot in operation. Use your knowledge of physics concepts such as conservation of energy, conversion of energy from one form to another, machines, work, and mechanical advantage to answer the following questions.**

1. What kind of device is used on the SlingShot to change the direction of force? ________________________

2. What other function is such a device used for when used in combinations?

____________________________________________________________________________________________

3. Give a classical name for a combination of pulleys and cable used to provide mechanical advantage. ________________________

4. When is the energy in the springs the greatest?______________________________________________________

5. What kind of energy do the springs have when their energy is greatest?______________________________

6. What happens to this energy as the ride ascends (hint - what kinds of energy does the ride have as it is going up?)

____________________________________________________________________________________________

____________________________________________________________________________________________

____________________________________________________________________________________________

7. During its operation, where is the SlingShot vehicle in relationship to the top of the tower when the springs are at their shortest length?

____________________________________________________________________________________________

____________________________________________________________________________________________

____________________________________________________________________________________________

# Slingshot

**Spring problems are commonly seen where one end of the spring is fixed and with the moveable end being where the energy is put in or taken out. The motion of the load or mass attached to the spring is linearly related to the motion of the spring, such that motion in one direction increases the potential energy in the spring and motion in the other decreases the spring's potential energy. SlingShot is anything but common. As a spring problem, it provides many opportunities for analysis at different academic levels. As a ride experience, it is also anything but common! Carefully watch SlingShot in operation and answer the following questions.**

1. The spring on SlingShot is actually a collection of many springs that act together. Which end of this collective spring is the energy input applied to - the top or the bottom?

   ______________________________________________________________________________

2. What kind of machine stretches the springs in preparation for the ride launch and why do you think this type of machine is used?

   ______________________________________________________________________________

3. For SlingShot to operate, energy must change forms many times. Organize the steps, listed to the right, through which the energy is transferred into the proper order as they are utilized by Slingshot by numbering them from 1 to 7.

   __) Work done by mechanical linear motion (cylinder movement)

   __) PV (movement of pressurized hydraulic fluid

   __) Kinetic energy of ride unit in motion

   __) Electrical Power from First Energy

   __) Mechanical motor turning pump

   __) Gravitational potential energy of ride unit due to increased height

   __) Elastic Potential energy in elongated spring

4. While energy cannot be destroyed, the transformation of energy from one form to another often involves the unavoidable, but undesired generation of heat. Though the heat energy can be accounted for, the unintentional heating of mechanical devices is often considered a loss. Examples include losses due to the resistance in motors and friction in sliding surfaces such as hydraulic cylinders. Even springs exhibit losses, though these are usually very small in comparison to the energy that they store. There is one energy transfer in SlingShot that would be considered conservative. Which one is it?

   ______________________________________________________________________________

   ______________________________________________________________________________

# Slingshot

1. When the SlingShot vehicle is at the very top of its launch, all the way at 360', describe what kind of energy the ride system has, and what two places this energy is at.

2. When Slingshot is all the way up at 360', what forces act on the ride vehicle?

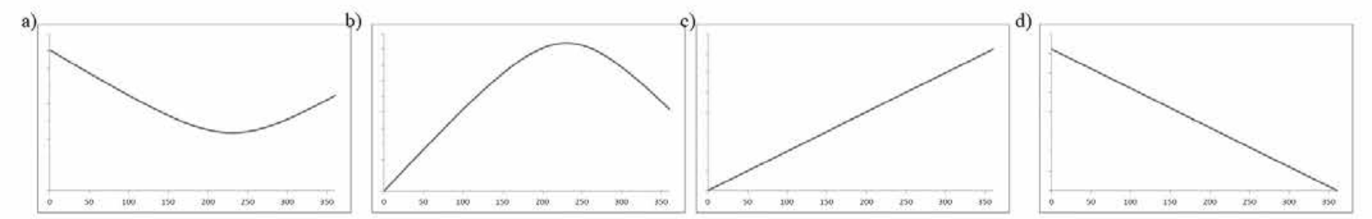
**Two students are discussing SlingShot. One says that your apparent weight will be zero at the very top of the ride's travel, at 360' in the air. The other says that your apparent weight will be zero at a point during the launch when you are in free fall and there is no force from the ride that is pushing you up or down. Another student says that your apparent weight will be zero when you're moving upwards with a constant velocity.**

3. Determine the point at which you would expect to experience no apparent weight on SlingShot. Will this be at the 360' in the air or at some other point and why?

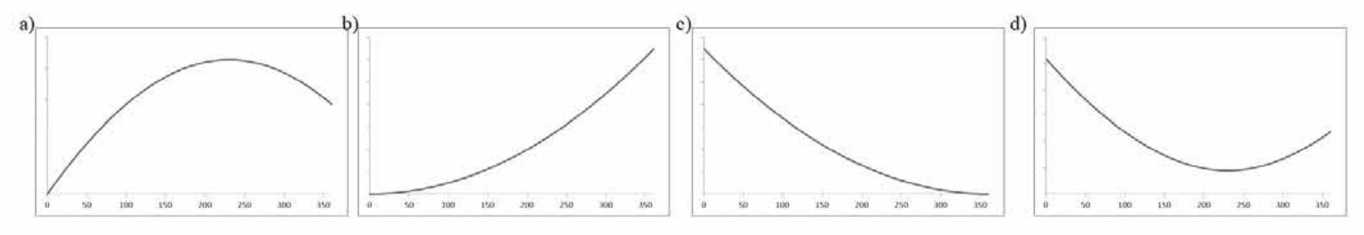
4. Determine the point at which you would expect to experience no apparent weight on SlingShot. Will this be at the 360' in the air or at some other point and why?

# Slingshot

1. After watching the SlingShot in operation, determine which of the following graphs most closely represents the magnitude of the force applied by the spring itself, as a function of the vertical height of the ride during its initial launch from 0 to 360'. Each graph is shown with the origin (0,0) in the lower left hand corner. The horizontal axis is in feet, and the vertical scales are the same, shown in arbitrary units of force.

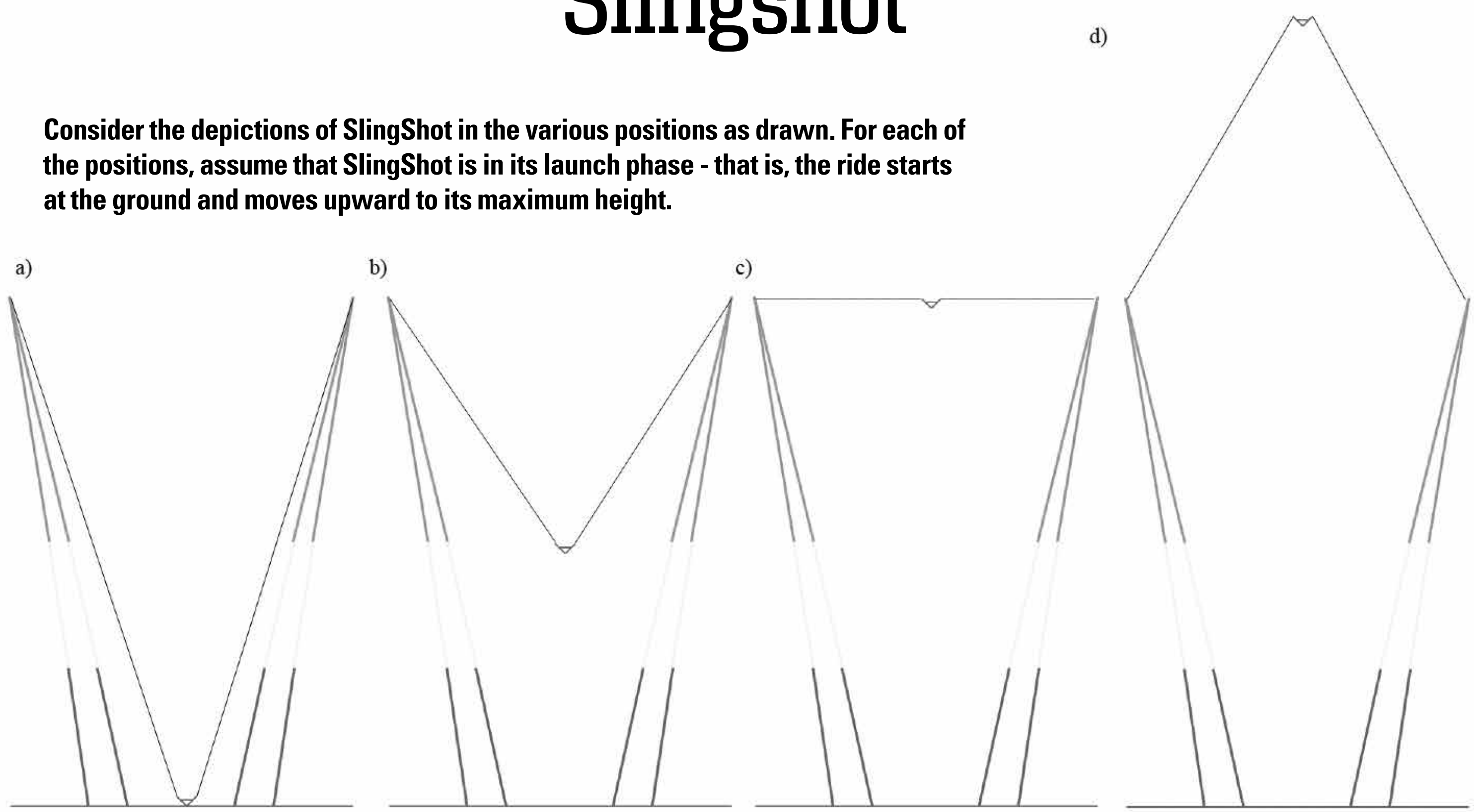



2. Which of the following graphs most closely represents a qualitative representation of the energy stored in the spring as a function of the ride's vertical position during the launch?



# Slingshot

**Consider the depictions of SlingShot in the various positions as drawn. For each of the positions, assume that SlingShot is in its launch phase - that is, the ride starts at the ground and moves upward to its maximum height.**




1. In which position(s) will the gravitational potential energy of the riders be the greatest? __________

2. In which position(s) will the gravitational potential energy of the riders be the least? __________

3. In which position(s) will the kinetic energy of the riders be relatively large? __________

4. In which position(s) will the net force from the ride be directed upwards? __________

5. In which position(s) will the net force from the ride be directed downwards? __________

6. What happens to the vertical force from the ride at position c)?

____________________________________________________________

____________________________________________________________

7. In which position(s) will the net force on the riders have the largest magnitude directed upwards? __________

8. In which position(s) will the net force on the riders have the largest magnitude directed downwards? __________

9. In which direction does the net acceleration on the riders point at position d)?

____________________________________________________________

____________________________________________________________

10. On each depiction, draw vectors to represent the component and resultant forces involved.

11. On each depiction, indicate whether the potential energy of the spring is increasing, decreasing, or staying the same. Remember, the ride unit is in the launch phase, and is moving upward.

# Slingshot

**Ride data available at Slingshot entrance.**

- Maximum height riders ascend to:
- Weight of vehicle:
- Height of towers:
- Length of springs (relaxed):
- Total length of spring when it is stretched out:

1. Find the total effective work done by the springs in launching the loaded vehicle from the ground to the maximum height. In order to do this, you'll need to make an estimate of the weight of the riders. Assume the average rider weighs 150 lbs. You also need to know how many riders SlingShot takes on each trip, which you can find by watching it in action.

2. What is the potential energy of the loaded Slingshot vehicle when it is at its maximum height?
How does this relate to your answer from above?

3. Just prior to launch, the ride vehicle is held down by a powerful electromagnet. Find the minimum amount of force the magnet must exert in order to hold.

# Slingshot

1. Find the speed of the slingshot vehicle as it passes the top of the support towers during it's initial launch.

2. Calculate a reasonable estimate of the effective elastic constant of the spring system by treating the system as one giant spring.

# Top Thrill Dragster

**Useful to Know:**

- Number of passengers per train - can be counted from a variety of guest accessible vantage points

**Ride data available at Top Thrill Dragster entrance.**

- Weight of train:
- Length of train:
- Diameter of cable tension wheel under train launch area:
- Duration of launch acceleration:
- Speed:

**Assume that the Top Thrill Dragster train is fully loaded with passengers weighing an average of 150 lbs. During the launch, the cable system pulls the car with a constant force that accelerates the car to full speed.**

1. What is the acceleration in units of mph/sec? ____________

2. What is the acceleration in units of meters/sec$^2$? ____________

3. What is the distance of the pull (what is the distance travelled during the acceleration of the train)? ____________

4. Draw a plot of position vs. time, and velocity vs. time, during the launch.

5. During the launch, what distance have you travelled when you are going 60 mph (¼ of the launch distance, ½ of the launch distance, or ¾ of the launch distance)? ____________

6. During the launch, how much of the launch time does it take for you to be travelling 60 mph (¼ of the launch distance, ½ of the launch distance, or ¾ of the launch distance)? ____________

7. What is the tension in the cable system during the launch? ____________

8. What is the power needed to produce the acceleration of the train? ____________

# Top Thrill Dragster

**There is a tensioning wheel that is visible underneath the hot launch position (where the train sits when it is ready to take off). The wheel is made of nylatron and has a diameter of 940mm. During the launch, what is the angular acceleration of the wheel? Assume the wheel is sufficiently light, the cable sufficiently tight and that no slipping occurs.**

1. What is the angular speed of the tensioning wheel when the train is released?

________________________________________

________________________________________

2. How many times does the wheel go around during the launch? ________________

3. What is the minimum force which the tensioning piston (see figure) exerts on the axle of the nylatron wheel during the launch?

________________________________________

________________________________________

________________________________________

4. What is the work done by the cable tension on the train during the launch?

________________________________________

________________________________________

________________________________________

5. What is the kinetic energy of the train when it is released?

________________________________________

________________________________________

________________________________________

# Valravn

**Ride Data:**

- Length of track: 3,415
- Speed: 75 mph max
- Overall tallest hill: 223′
- Drop height: 214
- Drop angle: 90°
- Second hill: 131′
- Ride time: 3:23
- Capacity: 1,200 guests / hour
- Structural: 2.99 million lbs
- Riders per train: 24


1. It is common in the roller coaster world to speak casually of a coaster train climbing the lift without regards to the actual mechanisms involved in the motion of the train. The Valravn train is actually pulled up the lift by a chain operated by a gear system which is driven by a motor. Suppose that Valravn train is fully loaded with passengers averaging 150 lbs, and is at the midpoint of the lift hill climbing with constant velocity. If there is no friction and the weight of the chain is negligible, let's try to calculate the tension on the chain that is due to the train. First, make an inventory of the things that we know that would be useful making the calculation.

2. The sine of 47° is 0.731. Explain why this is relevant to this problem.

3. Since the weight of the Valravn train isn't given to us in the problem, we'll need to either find this information or make a reasonable estimate. One way to estimate is by comparison to a similar known object. For example, the Raptor is built by the same manufacturer as Valravn, and an empty Raptor train weighs about 19,000 lbs. Raptor is massive and seats 32 to Valravn's 24 per train, but the Valravn trains are also very sturdily built. Make a reasonable estimate of an empty Valravn train.

4. Now finish the problem. Calculate the tension on the lift chain from a fully loaded Valravn train as the train is climbing the lift at constant speed.

# Valravn

5. Let's take a look at how the ascent velocity affects the tension. If we go back to the original setup, where the angle of ascent is 47° with no friction and 24 passengers weighing 150 lbs each, how would the chain tension be affected if the velocity was still constant, but just happened to be twice what it originally was.

6. If the Valravn lift hill was half as steep, and nothing else changed (same passengers, same constant speed, still no friction, etc.), what would the tension on the chain be ? Again, give your answer in lbs.

7. Think about the Valravn train as it drops down its tallest hill. If the acceleration of Valravn is relatively constant, at what point is the train going half of its final speed?
   a) at the top of the hill
   b) 1/4 of the way down the drop
   c) 1/2 way down the drop
   d) 3/4 of the way down the drop
   e) at the bottom?

8. Determine the overall height of the tallest hill on Valravn in meters.

9. After the Valravn train goes over the first drop, it loses energy to the work done by the friction force as it travels. Wind and other considerations also factor in, but if we neglect those things, it is possible to find the speed of the train as a function of it's elevation. Neglecting friction and other factors show that the basic equation for speed of the Valravn train as a function of its elevation is given by the formula below where h is in meters, $g = 9.81\ m/s^2$, and v is in meters per second.

$$v = \sqrt{2g(68 - h)}$$

Modify the formula so that it takes a height in feet and returns the correct speed in miles per hour.

10. Using the ride data given, determine the average speed of Valravn during the ride and explain the difference between average speed, and maximum speed.

# Wicked Twister

**Ride data available at Wicked Twister entrance.**

- Height:
- Speed:

1. Observe Wicked Twister in operation from a few different vantage points. One good point to watch from would be the area between the Giant Wheel and the long straightaway where the Wicked Twister train heads forward out of its station Draw a nice sketch of the side view of Wicked Twister. Read the following questions, and think about them while you take a ride on Wicked Twister. Then come back and answer the questions.

2. Label the following points on your sketch:
   a) Point where the train has the highest kinetic energy when it is going forward
   b) Point where the train has the highest kinetic energy when it is going backward
   c) Points where the train has the highest potential energy
   d) Areas of the ride where the normal force between the seat bottom and your body is approximately equal to your actual weight.
   e) Areas of the ride where you would be likely to experience significant centripetal acceleration
   f) Areas of the ride where you would experience a sensation similar to free fall
   g) Locations on the ride, and times during the ride, when the force between your body and the seat back is the largest, and why.
   h) Locations on the ride where the kinetic energy of the train would include both a linear part, and rotational kinetic energy (e.g. energy associated with the train rotating approximately around its own center of mass).

3. If the low point of the ride is 6' off the ground, find the approximate height of the center of mass of the train when the train speed is 50 mph, assuming no friction or air drag.

________________________________________

4. Discuss how the shape, and especially distribution of mass, would affect the translational speed of the train as it enters a part of the track that makes it rotate around itself. Do you think this effect will be greatest on Wicked Twister, Raptor, or on Gatekeeper? Ride each one, and compare.

________________________________________

________________________________________

# WindSeeker

**Ride data available at WindSeeker entrance.**

- Diameter of structure supporting the seats:
- Length of seat support arm:
- Weight of empty seat unit:

1. Make a sketch of the ride when the ride is at the top of the tower. Include the radius of the support structure and the length of the seat support arms.

2. How far away from the center of the tower will you be when the seat is at an angle of 40 degrees? Note that the ride swings freely to it's natural angle when it is in operation.

3. When WindSeeker is in operation, what is the speed of the riders when the angle of the seat is 40 degrees off vertical? Give your answer in m/s.

4. What is the angular speed in units of rotations per minute?

# Witches' Wheel

**Stand on the midway in the general area between Joe Cool's Corner Store and the exit of the Witches' Wheel, so that you can observe the operation of the Witches' Wheel from the side. From this vantage point you will see that the ride is pushed up from a horizontal position to nearly vertical by the action of a large device called a cylinder. The cylinder is attached to the center of the ride support structure by a shiny silver colored par called the piston rod, or rod, which extends out from the cylinder body. The rod is the moveable part that exerts the force on the ride support structure that lifts it up. It is moved by fluid (hydraulic oil) that is forced into the cylinder under pressure.**

1. Draw a side view sketch of the ride, depicting it when it is part way up. Include the cylinder. Indicate and label the following parts of the ride in terms of its operation as a lever:

   a) Fulcrum
   b) Effort (or applied force)
   c) Resistance (or load)

   Note what kind of lever system this ride is. ______________________________

2. Does this kind of lever system multiply force, speed, or both? ________________

3. If you apply Pascal's principal and some basic analysis of levers and angles, you could determine how much fluid pressure is needed to lift the ride. What specific information about the ride would you need in order to make such a calculation? Can you predict, qualitatively, how the pressure might vary during the operation of the ride?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

# Witches' Wheel

**This problem requires you to ride Witches' Wheel and make observations. Read the questions below, then while riding, listen closely to the sounds you hear. Pay specific attention to the sound of the motor and hydraulic pump as you ride. After your ride, use the space below to write down your observations and answer the questions.**

1. At which point on the ride is the noise of the motor at it's highest pitch?

_______________________________________________________________________________

_______________________________________________________________________________

2. At which point on the ride did the motor make the lowest pitch noise?

_______________________________________________________________________________

_______________________________________________________________________________

3. What is the scientific name of this phenomenon? ______________________________

4. Explain how this phenomenon works. Draw a diagram and label it as part of your explanation. Show the sound waves, and how the motion of your body interacts with the waves to affect your perception of pitch.

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

# Inequalities of Ride Height Requirement

**Examples:**

| | |
|---|---|
| Blue Streak | **x ≥ 48 inches**<br>*(The height requirement for Blue Streak is greater than or equal to 48 inches)* |
| MAVERICK | **52 inches ≤ x ≤ 78 inches** |

**Now You Try:**

| | |
|---|---|
| WINDSEEKER | |
| maXair | |
| Gemini | |
| ROUGAROU™ | |
| Ocean Motion | |

# Transportation

- **One bus holds 52 students**
- **Cedar Point is open for 150 days**

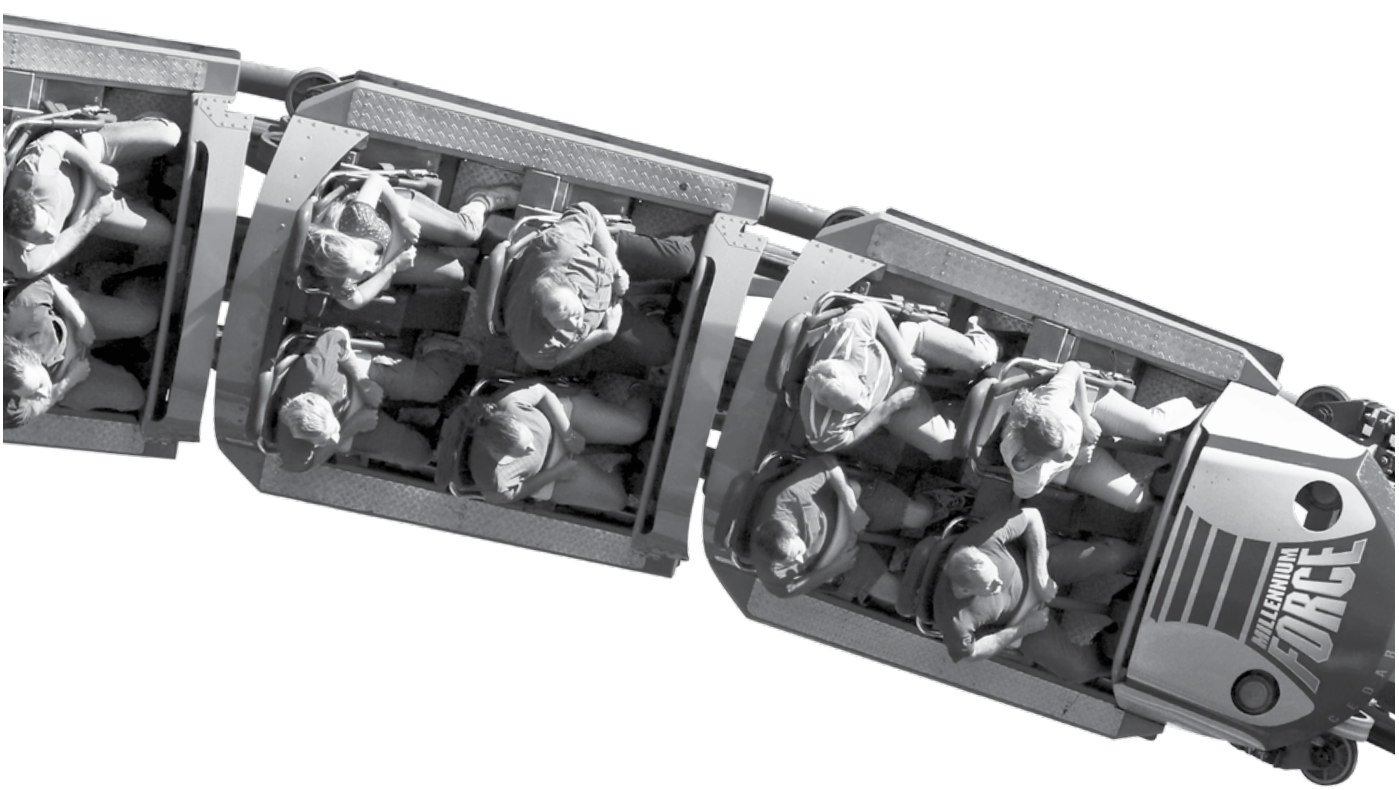
1. If 3,140,000 guests travel to Cedar Point in one year, on average how many guests come to Cedar Point per day?

2. If there are 152 students traveling to Cedar Point on a bus, how many busses would they need to take?

3. If there are 200 students traveling to Cedar Point on a bus, how many busses would they need to take?

4. If there are 3,140,000 guests traveling to Cedar Point on a bus, how many busses would they need to take?

5. If each guest would spend on average $15. How much money would that generate?



# Concession Stand

**Fill out the price per item. Please circle the best unit price.**

| **Toft's Ice Cream** | **Price** | **Unit Price** |
|---|---|---|
| 1 scoop | | |
| 2 scoops | | |
| **Coca-Cola Soft Drink** | **Price** | **Unit Price** |
| Regular 20oz | | |
| Large 32oz | | |

**Directions: Please fill in 5 items that you would buy and their prices.**
**Figure out the total price including tax. Items DO NOT have to be purchased.**

| **Item** | **Price** |
|---|---|
| **1.** | |
| **2.** | |
| **3.** | |
| **4.** | |
| **5.** | |
| **Total cost of all items** | |
| **Tax *(6.75%)*** | |
| **Total cost after tax** | |

# Passenger Capacity

| Ride | Estimated Riders Per Hour | Number of Trains and Passengers per Train | How many times does each train go though each hour |
|---|---|---|---|
| Top Thrill Dragster | 1,500 | 6 Trains,<br>18 Riders per Train | 6 Trains x 18 Passengers = 108 People per Rotation<br>1,500/108 = 13.8 times Each Train Goes By<br>Approximately 13-14 times per Hour |
| Iron Dragon | 2,000 | 3 Trains,<br>28 Riders per Train | |
| Millennium Force® | 1,600 | 3 Trains,<br>26 Riders per Train | |
| Raptor® Rules the Sky | 1,800 | 3 Trains,<br>32 Riders per Train | |
| Wicked Twister | 1,000 | 1 Trains,<br>32 Riders per Train | |
| GateKeeper® | 1,710 | 3 Trains,<br>32 Riders per Train | |

# Kettle Corn

**There is nothing better than fresh kettle corn, especially on a fun day of roller coasters! Let's discuss how kettle corn is made. Step one is to add sugar to the large iron kettle, which caramelizes. Step two is to add popcorn kernels. Popcorn kernels contain a hard shell, starchy interior, and moisture. As popcorn kernels are heated, typically in oil, they pop into a white fluffy edible snack. The following questions will guide you through understanding what happens inside the popcorn kernel as it is heated to turn a hard popcorn kernel into something wonderful.**

**Important Conversion Factors and Equations:**

- Molecular weight of water = 18.016 g/mol
- 1 inch = 2.54 cm
- 1 mL = 1 cm3
- 1 cup = 236 mL

$PV = nRT$ $\quad \frac{P_1}{T_1} = \frac{P_2}{T_2}$ $\quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\quad R = 0.08206 \frac{L\ atm}{mol\ K}$

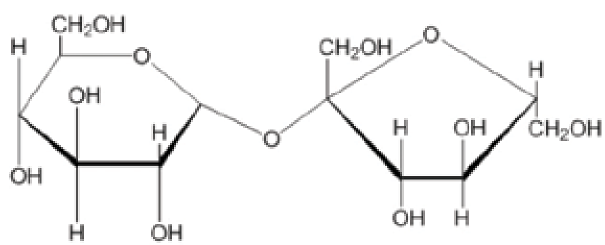
$V = \frac{4}{3}\pi r^3$ $\quad A = \pi r^2$

$°C = \frac{5}{9}(°F - 32)$ $\quad °F = \frac{9}{5}°C + 32$ $\quad K = °C + 273$

**Caramelization process: Sucrose undergoes a pyrolysis process (burning without oxygen in the reaction) at approximately 340°F. The first step in this process is the thermal decomposition of sucrose into fructose and glucose. Fructose and glucose further decompose and recombine to make a variety of molecules that ultimately yield the color and flavor of caramelized sugar.**

1. Calculate the temperature of caramelization in degrees Celsius and in Kelvin. ____________________

2. Given the structure of sucrose below, where is the point of weakness in the molecule? In other words, what bond would you expect to break first? Given this, hypothesize the structures of fructose and glucose? Draw them.




3. Is this process a physical or a chemical change? ____________________

**Note:** Caramel is used for things like caramel apples, and processes like these can be connected to other candies and foods; e.g. "hard crack" vs. soft carmel, etc.

# Kettle Corn

**Popcorn kernels contain moisture inside their hull, or shell. To understand why popcorn kernels pop, we first need to make sure we understand what happens to water when it is heated.**

1. What phase is water in at room temperature? ________________________

2. What phase does water become when heated above 100°C? ________________________

3. This phase change has a special name. What is it? ________________________

4. What happens to the volume of water when this phase change occurs? ________________________

5. Is this phase change a physical or a chemical change? ________________________

6. Initially, due to the hard shell, the volume change cannot occur immediately. Based on Gay-Lussac's gas law relating temperature and pressure, if the volume is held constant as the temperature is elevated, what happens to the pressure? Does it increase, decrease, or stay the same?

____________________________________________________________________________________________

7. To calculate the pressure inside the kernel, we need a little more information. 100 kernels of corn were weighed and found to have a mass of 18.04 g. What is the average mass of a single kernel of popcorn?

____________________________________________________________________________________________

8. Given that each corn kernel has approximately 13.5% moisture. Calculate the mass of water in each kernel.

____________________________________________________________________________________________

9. From the mass found above, determine the number of moles of water in each kernel.

____________________________________________________________________________________________

10. The starchy interior of the kernel retains the majority of the water. Only about 2.5% of the water present inside the popcorn kernel is uncombined and free to boil. What are the moles of free water present inside a single kernel? (3.4 x 10-5 mol)

____________________________________________________________________________________________

11. In another experiment, the volume of the popcorn kernels was determined through water displacement. Using a 10 mL graduated cylinder, the initial volume of water was set at 5.00 mL. 20 popcorn kernels were added and the volume increased to 7.65 mL. What is the average volume of each popcorn kernel?

____________________________________________________________________________________________

12. Using the ideal gas law and the information you've gathered so far, what is the pressure necessary to rupture the hard shell of a popcorn kernel at a popping temperature of 350°F?

____________________________________________________________________________________________

# Kettle Corn

**Now let's compare the density of unpopped popcorn, plain popped popcorn, and kettle corn.**

1. Using the data from previous pages for popcorn kernels, calculate the density of unpopped corn in g/cm3.

___

___

___

2. Plain popcorn was also analyzed in the lab. A half a cup of popcorn weighed 7 g. Calculate the density of plain popcorn.

___

___

___

3. Summary (Fill in the blanks)

So you have learned that popping corn involves the ___________ of water in a confined space. This results in a dramatic ___________ in pressure causing the shell to rupture. You have also learned about the first step in the caramelization process. This is a ___________ change because the bond to the central oxygen in sucrose is broken, resulting in two smaller molecules, ___________ and ___________.

You also calculated the density of popcorn. The density of unpopped popcorn kernels was _________ g/cm3 while the density of plain popcorn was _________ g/cm3. The reduction of density is primarily a result of the _____________________________________. The density of the kettle corn is _________ g/cm3. The increase in density as compared to plain popcorn is largely due to the _____________________________________________.


**Food Section Citations**

http://www.scienceofcooking.com/caramelization.htm; McGee, Harold. On Food and Cooking: The Science and Lore of the Kitchen. Completely Rev. and Updated ed. New York: Scribner, 2004. 656-657. Print.

http://www.popcorn.org/ForTeachers/TeachingGuide/WhatMakesPopcornPop/tabid/88/Default.aspx; McGee, Harold. On Food and Cooking: The Science and Lore of the Kitchen. Completely Rev. and Updated ed. New York: Scribner, 2004. 479-480. Print.

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# Lighting the Midway

**As you walk along the main midway, you'll notice that many trees and structures are decorated with miniature lights. Look around, especially near Cadillac cars and the Pagoda building. These lights are constructed using light emitting diodes (LEDs). They are very energy efficient.**

**LEDs utilize direct current (DC), but line voltage is alternating current (AC). While a precise analysis of practical LED lighting using AC supplies can quickly become a complex problem, there are a variety of useful calculations and approximations that can be done with a basic knowledge of concepts such as current, voltage, and power.**

**Technical Data:**

- Typical light strand
- Line voltage120 VAC
- Current 0.03A
- 25 LED bulbs per strand
- White LED needs 2.7 volts, typical

**Useful to Know:**

- Power = Volts * Amps
- Symbol for an LED
- Voltages add in a series circuit
- Currents add in a parallel circuit

1. How much power is used by one strand of lights?

________________________________________

2. The LEDs in a strand are connected in series. Draw three LEDs connected in series.

3. Is the current through each of the LEDs in series going to be the same, or different?____________________

4. How much total voltage would be expected to be across 25 White LEDs in series?

________________________________________

5. You'll observe that this value is less than line voltage. The remaining voltage appears across devices sometimes called ballasts. There are many types of ballasts, but the general function of a ballast is to interface line voltage to the characteristics needed by the lights. If the ballast is in series with string of LED lights, how much voltage is across the ballast?

________________________________________

________________________________________

6. If the ballast behaves like a resistor in series with the light strand, how much heat will it dissipate?

________________________________________

________________________________________

# Lighting the Midway

1. Though the LEDs in a strand are in series with each other, the strands in a circuit will be in parallel with each other. Even if the strands appear to be connected end to end, the illuminated part of each strand is in parallel with the others due to the construction of the light sets. If the adaptor needed for the light sets allows for 58 strands to be linked, how much current is the adaptor able to supply?

2. If a dimmer is rated at 20 amps, and local codes allow us to use 80% of that, what is the allowable current flow from the dimmer?

3. What would be the maximum number of light strands that could be connected to this dimmer, assuming that we use the appropriate adaptors and configuration?

4. How many LED bulbs would this be

**One common, newer lighting technology is to make a small bulb that contains three LEDs - one red, one green, and one blue - in a single package, but with individual control over the colors. These bulbs can be organized in strands, such as those on the ceiling of the "tunnel" that goes under the Millennium Force track along Frontier Trail. The envelope of the bulb combines the light output of the LEDs and the color you perceive is the composite of the individual components. The idea of color mixing is also the basis of how the lights on the Giant Wheel work.**

5. What LEDs would you illuminate to generate the various colors indicated below?

Red

Yellow

Cyan

# Music for the Midway

**Many venues at the park utilize speakers for sound and music. Speakers are an example of a transducer - a device that converts energy from one form to another, such as electrical energy to sound energy. Speakers operate on various frequencies of alternating current (AC). With alternating current, electrons move back and forth along the conductor, instead of only in one direction as in the case of DC. The opposition to the flow of AC is called impedance. Sometimes an impedance, such as a speaker, can be modeled using a simple resistance, and in fact, the units are the same (Ohms).**

**Technical Data:**

- Typical speaker resistance: 8Ω

**Useful to Know:**

- Ohm's Law: V = I R
- Symbol for resistor
- Power = P = I2R = V2/R
- Resistances add in series
- How to figure parallel resistances?

1. Consider an amplifier channel with a maximum power output of 250 watts connected to a speaker. What would be the current flow when the amplifier is delivering 250 watts to the speaker?

2. What would the voltage be across the speaker in this case?

3. Suppose that two identical speakers are connected in series with each other. What would the total resistance be?

4. If the amplifier was capable of delivering 44.8 volts to the two speakers in series, what amount of power would be delivered to each speaker?

5. Suppose that a set of eight identical 8Ω speakers were to be connected to an amplifier that required a minimum of 2Ω. How could the speakers be connected so that their combined total resistance is a minimum value, but larger than 2 Ohms? Note that each speaker should receive the same amount of power.

# Nuclear Energy

**Steam emanating from the Davis-Besse Nuclear Power Station can be seen from Cedar Point. Davis-Besse uses Nuclear Energy to produce electricity for much of North Western Ohio, including Cedar Point.**

1. What are three subatomic particles that make up an atom?

2. What are their relative masses?

3. Draw and label a general model of an atom.

4. What makes one atom of an element different than another atom of a different element?

5. Nuclear Power Plants utilize atoms of a particular element that undergoes nuclear decay. What causes an atom to decay?

6. When an atom of an element undergoes nuclear decay it emits radiation. What is radiation?

7. List three types of radiation, then describe what each one is.

**This decay process releases thermal energy (heat). The power plant uses this heat energy to heat up water to boiling. The steam is then used to turn generators that produce electrical energy, which is sent through the electrical grid to areas in North Western Ohio, including Cedar Point.**

# Rollercoaster Steel

**Steel is a metal that is used to build with. Steel is called an alloy because it's composed of carbon, iron and other elements that help give it strength. Therefore, there are different types of steel. Steel has grades determined by the SAE organization. One set of steel grades is commonly referred to as "structural steel", and is used for structures such as roller coasters because it is very strong. Still, structural steel needs protection from the weather, as the next set of problems illustrates.**

**Important Conversion Factors:**

- Fe-55.85g/mol
- O-15.99g/mol
- H– 1.01g/mol

$$Density = \frac{Mass}{Volume}$$

**The conversion of Iron to rust is a four part reaction:**

$$2Fe(s) + 2H_2O(l) + O_2(g) \longrightarrow 2Fe^{2+}(aq) + 4OH^{-}(aq)$$

1. Is $Fe^{2+}$ a cation or anion? ________________________

2. Is $OH^{-}$ a cation or anion? ________________________

3. Name this ion: $OH^{-}$ ______________________________

**Consider the following reaction:**

$$Fe^{2+}(aq) + 2OH^{-}(aq) \longrightarrow Fe(OH)_2(s)$$

4. Name the product formed: ______________________________

5. If there are 4 moles of $Fe^{2+}$ , balance the equation

______________________________________________________________

______________________________________________________________

______________________________________________________________

6. What is the limiting reagent? ________________________

7. Name the product. ____________________________

8. What is the molecular weight of this product? ______________________

**Consider the following reaction:**

$$Fe(OH)_3(s) + \text{dehydration} \longrightarrow Fe_2O_3(s) + H_2O(l)$$

9. Name the product. ____________________________

10. What is the molecular weight of this product? ______________________

11. Overall, is the iron changed physically or chemically? ________________________

12. What would happen if the tracks and steel structures of a roller coaster were not painted?

______________________________________________________________

______________________________________________________________

# Rollercoaster Steel

1. Steel is is a combination of iron and a variety of other elements, with the exact composition depending on the type of steel needed. Can you name each of the elements in the following list?

   a) C

   b) Mn

   c) P

   d) S

   e) Si

   f) Cr

   g) Ni

   h) N

   i) Fe

2. Which is the denser of the following:
   175g of Fe2O3 (rust) that displaces 33.4mL of water    OR    140g of steel that displaces 0.0174L of water?

   ______________________________________________________________________

3. Why do you think the answer from above is denser?

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

   ______________________________________________________________________

4. Conclusion (Fill in the Blanks)

   So, steel is a metal ________, meaning that it is composed of different _________. The grade of steel matters because the grade reflects properties such as _____________. Rust is a ____________ part reaction in which a _____________ change occurs. Rust is a corrosive process and can damage structures, so _______ is used to protect the steel.

# Gas Laws

**There are a host of gas laws. The most commonly used gas law is the Ideal gas law, but there are other ones such as Charles's, Boyle's and Avogadro's. Each gas law has a unique calculation that can be done, while making some assumptions. So lets take a look at a piston such as on the Cedar Point Lake Erie Railroad and see what kind of gassy problems we can get ourselves into!**

**Important Conversion Factors:**

- $O2=31.98g/mol$
- $P1V1=P2V2$
- $K=273.15+°C$
- $PV=nRT$
- 1 mol gas at STP= 22.4L
- $V1/T1=V2/T2$
- $P1/N1=P2/N2$
- R= 0.082057 L*atm/Mol*K
- 1 atm= 14.7 psi
- $F-32/1.8=°C$
- 1mmHg=0.0013 atm

1. In order to complete the following gas law problems, we have a slight problem. The engineers on the railroad got carried away and measured the amount of oxygen in the piston. There is 176.31g of O2 in the piston and we need to know how many L of O2 there are! Can you calculate this?

**Boyle's Law: Boyle's Law (P1V1=P2V2) tells us that pressure and volume are related. If we change the original pressure and volume, we directly change the volume and pressure on another. This gas law assumes that the number of moles of gas along with the temperature remain constant.**

2. From the problem above, lets say that the pressure of the piston was originally at 1 atm. If the steam engine needs to move forward, it requires that the piston have a pressure of 113.1 lbs per square inch (psi). Convert psi to atm and then solve for the new volume of the gas using Boyle's Law.

3. Therefore Boyle's Law helps to show us that pressure and volume are proportionally effected by one another! But what if we wanted to look at the volume and temperature?

**Charles's Law: Charles's Law (V1/T1=V2/T2) tells us that volume and temperature are inversely proportional to one another. If we change the volume on the left side of the equation, we directly effect the volume on the right or inversely effect the temperature.**

4. Let's say it is a nice summer day out at Cedar Point and you want to measure the temperature of the piston along with the volume of O2! The temperature on this beautiful day is 82°F while the volume of O2 in the piston is 123.49 L . You come back a couple months later in November and retake your measurements. The temperature is a bit nippy at 54°F. For some reason, you forgot to measure the volume of O2 in the piston and you need that number for your school report. Can you solve this problem using Charles's Law? Remember, chemists love to use temperature in Kelvin!

# Gas Laws

1. So as it got cooler out, the volume of the gas__________?
2. Can you explain why the volume of the gas changed as you described above?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

**Avogadro's Law: Avogadro's Law ( P1/N1=P2/N2) tells us that pressure and number of moles are inversely proportional to one another. If we change the pressure on the left side of the equation, we directly effect the pressure on the right or inversely effect the number of moles.**

3. By now, you are really getting the hang of these gas laws! In the Cedar Point Lake Erie Railroads piston, we can use Avogadro's Law to figure this next problem out. 123.49L of O2 are in the piston with a pressure of 7.69atm at rest. However, you go to the park on a rainy day where the pressure is 22.57mmHg and you need to find the volume of O2!

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________

4. So as the air pressure decreased, the number of moles of gas__________?

**Ideal Gas Law: The Ideal Gas Law (PV=nRT) is a all together different gas law from any of the above, however, it uses all of their properties. In the Ideal Gas Law, we can calculate the change of temperature, pressure, volume, or even the number of moles in one single equation. This equation is great to use when not using a standard temp or pressure deemed "STP" at normal operating procedures. Remember that your units are important, i.e. K, atm etc.**

5. This piston at Cedar Point has a rough life! Today, the piston has O2 at a temperature of 82°F, 123.49L, 7.69atm. How many moles of O2 are in the piston?

______________________________________________________________________

______________________________________________________________________

6. Conclusion (fill in):

So, you have learned a bunch of gas laws and how to successfully apply all of them! Boyle's Law allowed you to relate the _____________ and __________ while Charles's Law allowed you to compare __________ and ______________. You also got to use _______________ Law which allowed you to calculate the pressure in relation to the number of moles. Finally, you used the ideal gas law which uses the ___________, _________________ , _________________ , a rate constant and __________________!