Physics Is Fun
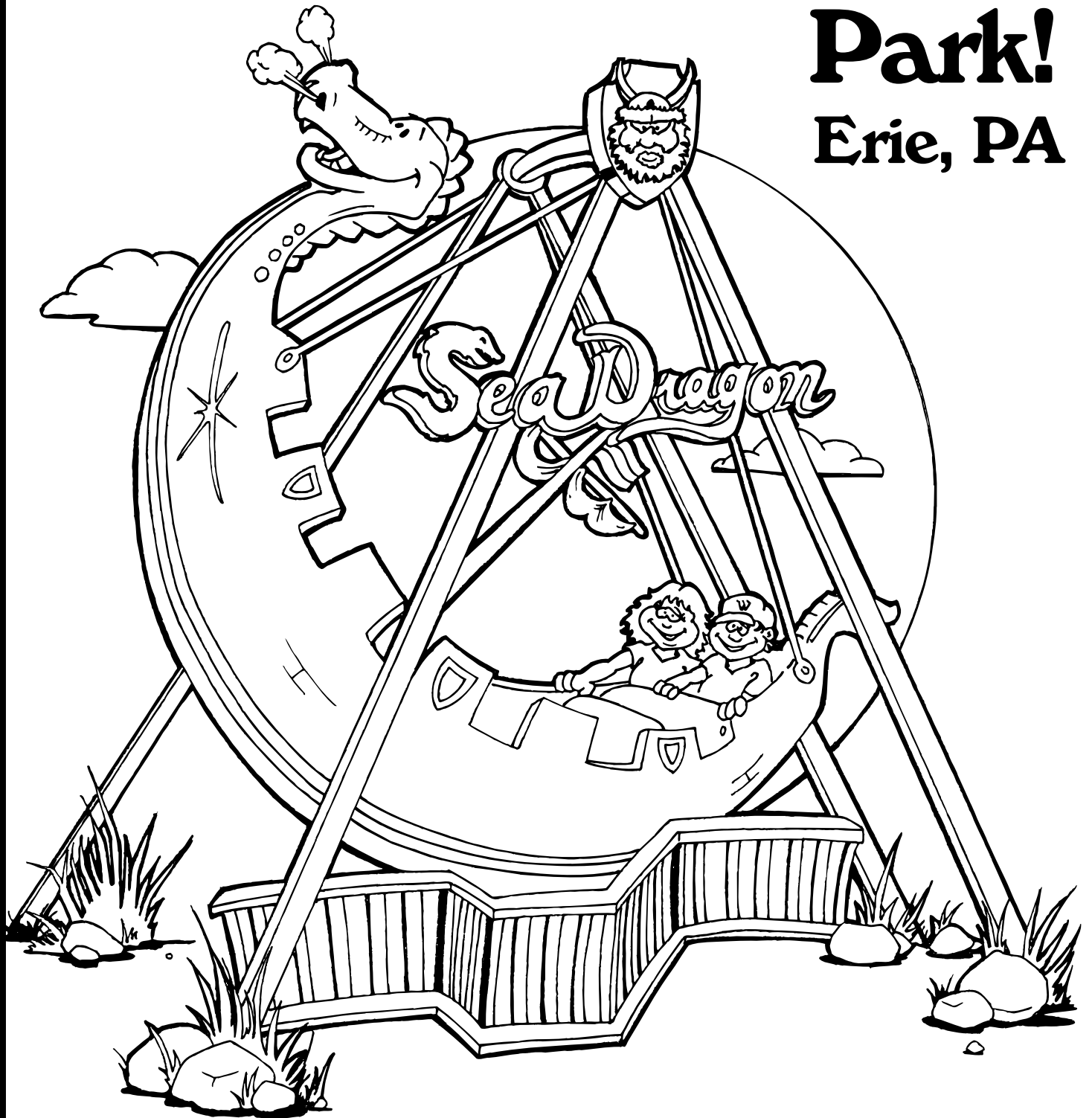## At Waldameer Park!
Erie, PA

AMUSEMENT PARK PHYSICS

THINGS TO BRING:

Bring a pencil
Bring a calculator
Don't forget to bring this assignment packet
Bring a stop watch, a digital watch, or a watch with a sweep second hand

CRITICAL SAFETY NOTE:

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

MAKING MEASUREMENTS:

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

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

> **PACING:** Determining the length of your stride by walking at your normal rate over a measure distance. Dividing the distance by the number of steps and you can get the average distance per step. Knowing this, you can pace off horizontal distances.
>   My pace = _____ M

Physics

MAKING MEASUREMENTS: (cont.)

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

$$V_{AVE} = \frac{\blacktriangle D}{\blacktriangle T}$$

In circular motion, where speed of rotation is constant:

$$V_{AVE} = \frac{\blacktriangle D}{\blacktriangle T} = \frac{2\pi R}{\blacktriangle T}$$

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

$$V_{AVE} = \frac{\blacktriangle D}{\blacktriangle T} = \frac{length\ of\ train}{time\ to\ pass\ point}$$

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

$$V_{AVE} = \frac{\blacktriangle V}{\blacktriangle T} = \frac{V2 - V1}{T2 - T1} = \frac{change\ in\ speed}{change\ in\ time}$$

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

Physics
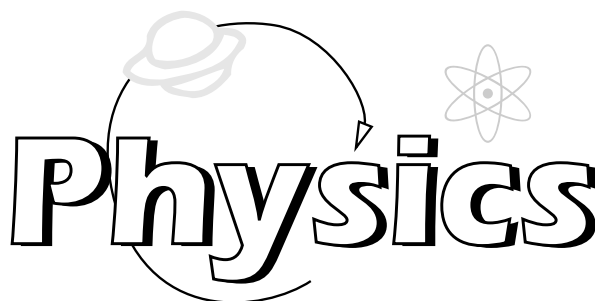
USEFUL FORMULAE

$F = ma$

$a = \dfrac{v^2}{r}$

$vf^2 = v_i^2 + 2ad$

$E_k = 1/2\ mv^2$

$v = \sqrt{2\ gh}$

$a = \dfrac{4\pi^2 r}{t^2}$

$F = \dfrac{mv^2}{r}$

$\lambda = \dfrac{h}{p}$

$mgh = 1/2\ mv^2$

$m = \sqrt{\dfrac{m_0}{1 - \dfrac{v-}{c-}}}$

$F = \dfrac{m4\pi^2 r}{t^2}$

$t = \sqrt{\dfrac{t_0}{1 - \dfrac{v-}{c-}}}$

$g = 9.8\ m/s^2$

$E_p = mgh$

$w = F\cdot d$

$p = m\cdot v$

$v_f = v_i + at$

$P = \dfrac{w}{t}$

$d = \left(\dfrac{v_i + v_f}{2}\right) t$

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

TRAIN

OBSERVATIONS:

_____ M, How long is the train?

_____ S, How long does it take the train to complete one loop?

_____ KG, Estimate the mass of the train.

CALCULATIONS:

1. What is the average velocity? _____ M / SEC

2. What is the maximum velocity? _____ M / SEC

3. What is the acceleration during the first 10 seconds? _____ M / SEC^2

4. What is the kinetic energy when at maximum velocity? _____ KG - M / S^2

5. Determine the maximum number of riders during a 3 hour period. _____ Riders

MERRY GO ROUND

MEASUREMENTS:
Diameter of inner ring = 5M
Diameter of outer ring = 8M
Number of Horses = 58
Number of Sea Dragons = 2
Numbers of Chariots = 2
Passengers per Chariot = 4
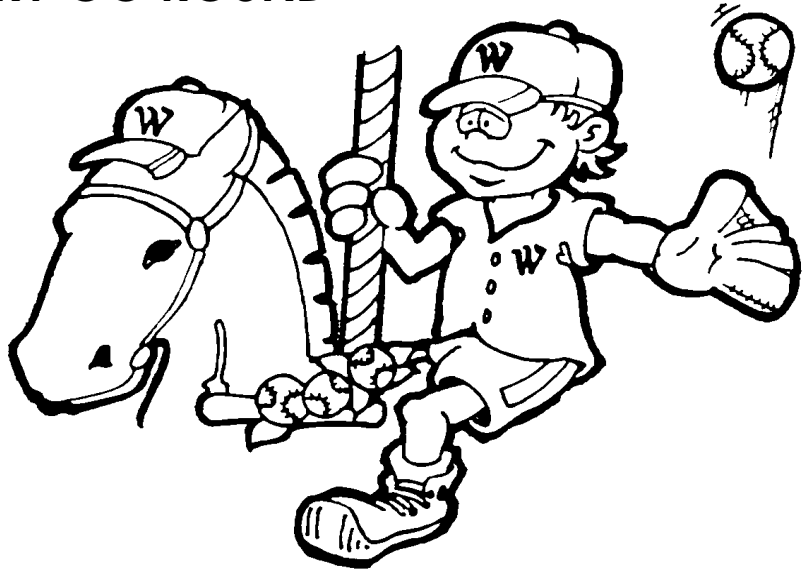
### OBSERVATIONS:
Circumference of inner ring of horses = _____ M
Circumference of outer ring of horses = _____ M
Period in seconds per revolution   = _____ S

CALCULATIONS:

1. Which horse has the greatest speed?
   Inner, outer or same   _____

$$V = \frac{C}{T} = \frac{\pi D}{T}$$

2. Calculate the speed of the inner
   and outer horses.   _____ M/ SEC inner
                        _____ M/ SEC outer

3. If you were to throw a ball from position A on the diagram
   to someone at position B, while the ride was turning, where
   would you aim the ball?

4. Draw the path of the ball as seen by someone
   standing on the ground.

5. Draw the path as seen by a person on the ride at point B.

6. What is the duration of the ride cycle? _____ MIN.

7. How many people could ride the carousel if it held the
   maximum number of riders for 3 hours? _____ Persons
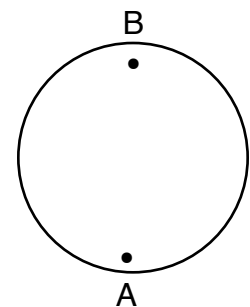
THUNDER RIVER LOG FLUME

Ride Measurements:
Distance Boat travels in tunnel
= 36 Meters
Height of "Big Thunder" hill
= 14 Meters
Angle of "Big Thunder" hill
= 45 Degrees
Length of a log boat
= 3 Meters

Time for boat to travel in tunnel = _____ Seconds
Time for boat to travel down "Big Thunder" hill = _____ Seconds
Time for boat to travel its length after the splash is over = _____ Seconds

CALCULATIONS:

1. Calculate the average speed of the boat in the tunnel. _____ M/S

2. Calculate the final speed of the boat at the bottom of "Big Thunder" hill. before it starts to splash. Assume that the speed of the boat at the top is zero and there is no friction losses (hint: PE = KE). _____ M/S

3. Use the given angle and height to calculate the length of "Big Thunder" hill. _____ M

4. Use the length of the hill and the time you recorded for the boat to travel down the hill to calculate the final speed of the boat at the bottom of "Big Thunder" hill. (Assume that Vf = 2d/t, since Vav = d/t and Vav = (Vi + Vf)/2 and we assume Vi = 0). _____ M/S

5. Do the speeds calculated in #2 & #4 agree? Explain your answer.

6. Calculate the speed of the boat after the splash is over. _____ M/S

7. Calculate the loss in kinetic energy of the boat during the splash. Where did this energy go?

Physics
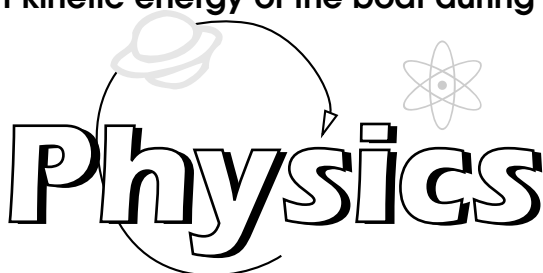
The Waldameer Classroom
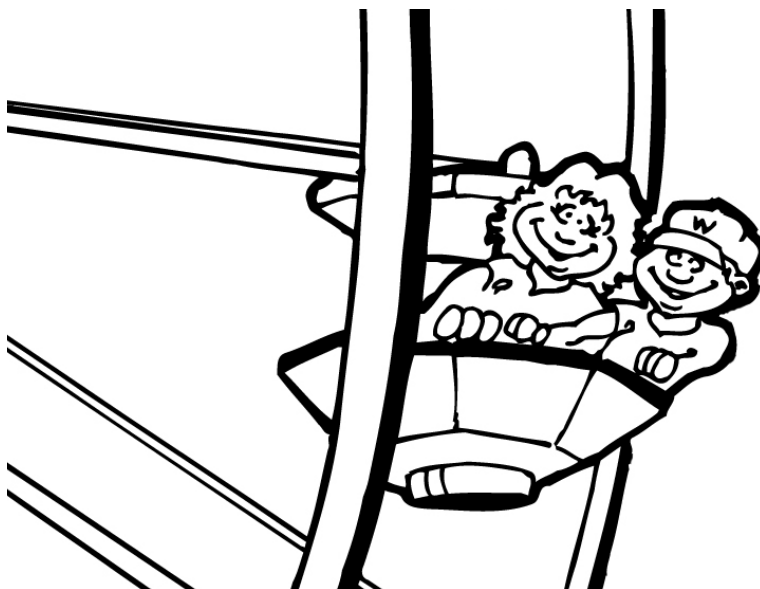
FERRIS WHEEL

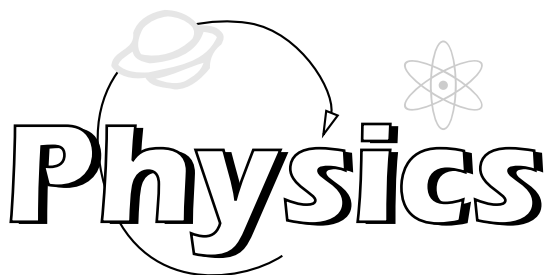### Ride Facts:
Radius: 12 Meters
Length of Ride: 3 Minutes
Number of Gondolas: 20
Maximum Passengers per Gondola:
   6 adults or 8 children

1. Measure the time for one revolution (period). T = _____ Seconds

2. What is the rotational speed of the ride in revolutions per minute?
      _____ RPM

3. Calculate the circular tangential speed using v = 2 π r/T   _____ M/S

4. What total distance does each gondola travel during one complete ride?
      _____ Meters

5. If the wheel broke loose from its mooring, how much time would elapse
    before it reached Lake Erie? (Assume it is a flat 500 meters to Lake Erie,
    and do not account for friction.) _____ Seconds

6. How many rotations would it take to reach Lake Erie? _____Rotations

7. Calculate the gravitational potential energy of a 75 kg passenger stopped at
    the top, assuming zero elevation at the bottom. PE = _____Joules

Physics

SEA DRAGON

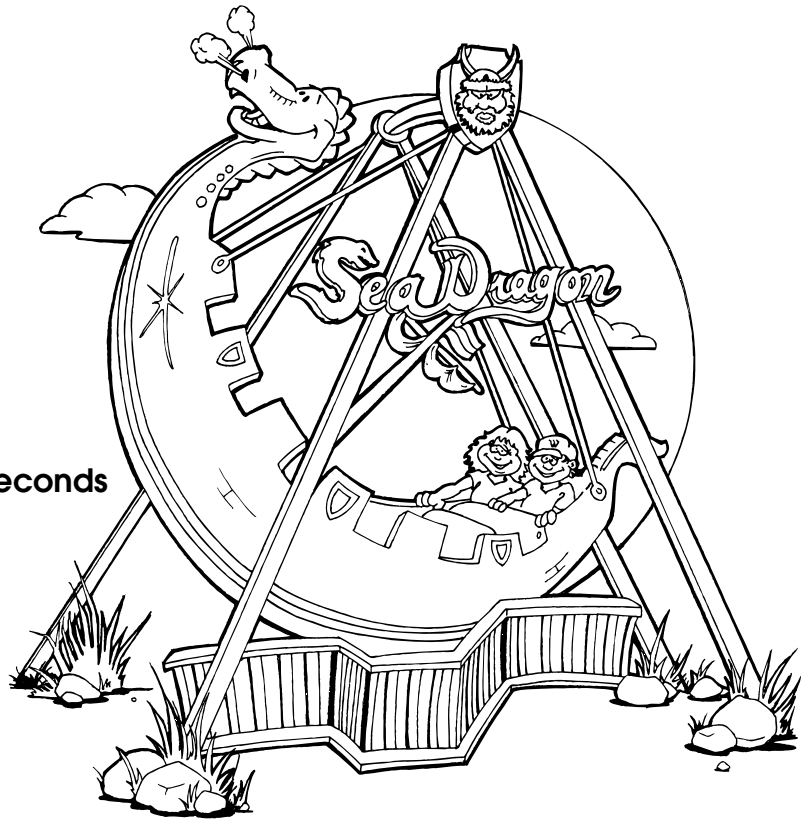### RIDE FACTS:

Number of Rows: 10
Number of Seats per Row: 4
Length of Ride: 2 minutes
Length of Time Between Rides: 60 seconds
Lenght of Pendulum: 12 Meters
Maximum Swing Angle: 65 degrees
   from center

SUGGESTED ACTIVITIES:

1. What types of forces are at work on you as you ride this ride?

2. At what point does your body feel the greatest amount of force pushing it downward?

3. At what point does your body feel the least amount of force pushing it downward? Explain this sensation of weightlessness.

4. Ride the ride with your eyes closed. In what way does it feel different then when you ride with your eyes open? What does this say about the input that your sight has on the total sensation of the Sea Dragon?

5. Why do you feel more weightless when you ride in a row near the end of the boat than when you ride in the center of the boat?

SEA DRAGON (continued)

1. Estimate the highest elevation that a rider in the end row is lifted. Assume zero elevation when the ride is at the lowest position. _____ M

2. Measure the period of the ride after it reaches full swing. T = _____ Seconds

3. Calculate the frequency of the pendulum.
    f = _____ Cycles/Second

4. Calculate the gravitational potential energy of a 75 kg rider (sitting in the end row) when he is at the highest elevation. PE = _____ Joules

5. How much work was done to lift this rider to the highest elevation?
    W = _____ Joules

6. Calculate the speed of this ride at the lowest position, assuming that there are no friction losses (hint: PE = KE). _____ M/S

7. Calculate the speed of this rider at the lowest position, using the formula for circular tangential speed $v = 2 \pi r/T$ _____ M/S

8. How do your answers for #6 and #7 compare? Explain.

Physics
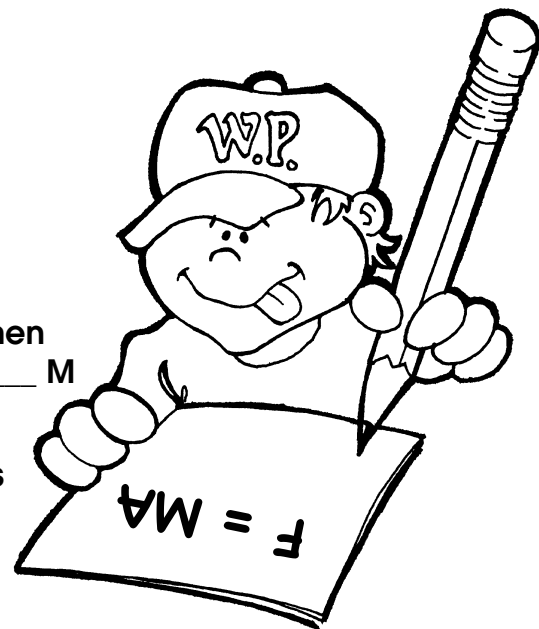
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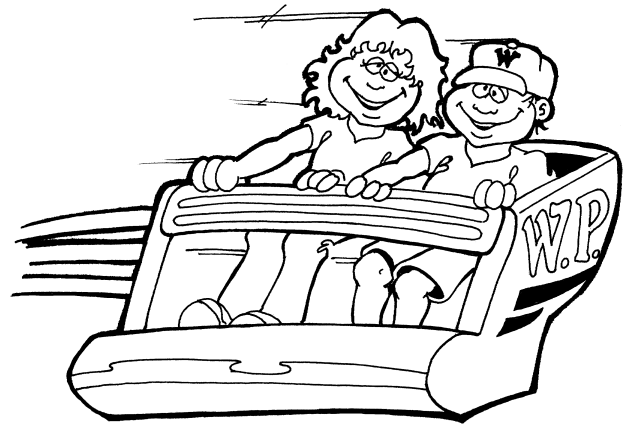
SCRAMBLER

Ride Facts:
Number of seats: 12
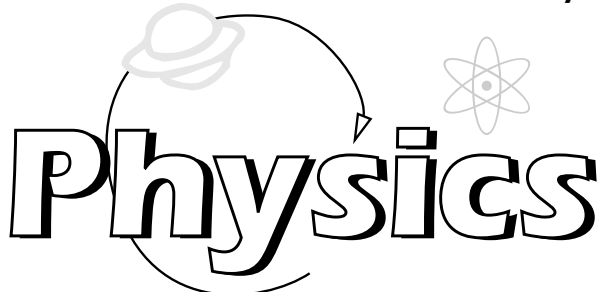Seat capacity: 3 persons
Length of Ride: 1.30 minutes
Length of time between rides:
1.00 minute

SUGGESTED ACTIVITIES:

1. Try to count the number of rotations the ride makes from start to finish. How many did you count?

2. What forces are at work on your body as you ride this ride? (see physics facts).

3. Draw the path a Scrambler ride takes in one revolution of the center arm.

4. How many revolutions does the ride make from the start of one ride to the finish?

5. Describe the sensations you felt during the ride. (movement side to side, etc.)

6. Compare your responses on this ride to another ride of your choice. How do they compare?

Physics

SCRAMBLER

A. DATA

1. Estimated radius of primary axis
   (center of ride to center of cluster)
   _____ M

2. Estimated radius of secondary axis
   (center of cluster to rider)
   _____ M

3. Turning rate around primary axis
   _____ Rev / Min

4. Clockwise or counter-clockwise rotation
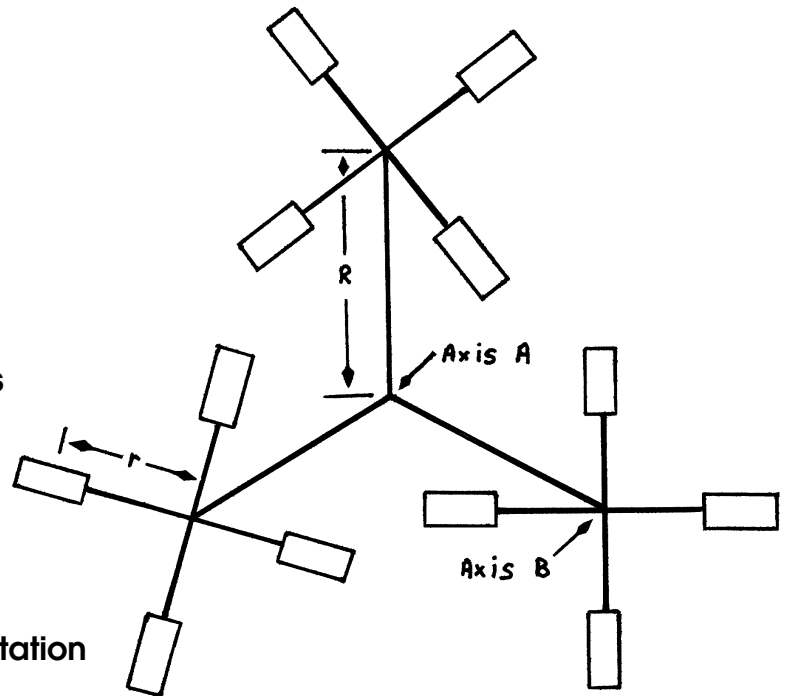   around primary axis? _____

5. Turning rate around secondary axis
   _____Rev / Min

6. Clockwise or counter-clockwise rotation around secondary axis

   _____

7. Concentrate your attention on one rider and follow this single rider's motion for at least one full rotation of the ride around the primary axis (put yourself in a frame of reference outside the ride), Draw the path of the rider for one turn on the primary axis. Try to mentally eliminate any vertical aspects of the ride and consider the ride to be running flat. Your sketch should be what you would see the rider do if you were looking down on the rider from above.

Physics

SCRAMBLER (cont.)

B. QUALITATIVE TASKS:

1. Describe the sensations you felt during the ride.

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

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

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

5. What is the period of the ride? _____ s

6. Where was your speed the greatest? _____

7. Where was your speed the least? _____

Physics
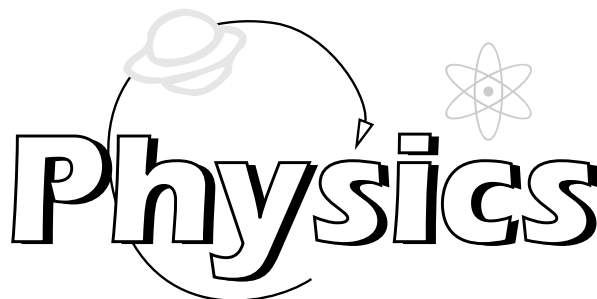
ROLLER COASTER

<u>DATA:</u>

MEASUREMENTS WHILE STANDING IN LINE:

Time for Ride: _____ S
Length of Train: _____ M
Capacity per Hour: _____ Persons

<u>MEASUREMENTS FROM OBSERVATION AREA:</u>

Distance from hill to observation area ____ M

Angle: _____ °

Calculated height of hill: _____ S

Time for train to go from bottom to top of first hill: _____ S

Time for train to pass point at top of hill: _____ S

Time for train to pass point at bottom of hill: _____ S

Time for train to go from top of hill to bottom of hill: _____ S

<u>QUALITATIVE OBSERVATIONS:</u>

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

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

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

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

ROLLER COASTER (CONT.)

SPEED OF A FALLING ROLLER COASTER
(Assumes a free fall parabolic arc)

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

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

What is the speed after falling:
5M _____ 10M _____ 20M_____

How far does the coaster have to fall to be traveling:
20KM/H_____ 40KM/H_____ 60KM/H_____

In a roller coaster, part of the gravitational potential energy is converted into the heat of friction and the kinetic energy of moving air particles pushed by the moving roller coaster. Since this is the case, are actual speeds greater or less than those shown on the graph? _____
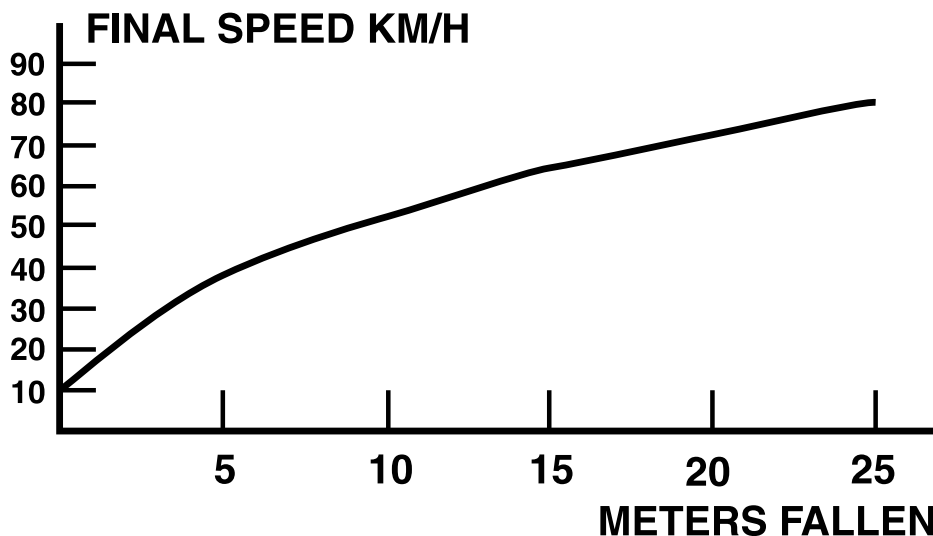
What does the shape of this graph tell you about the relationship between the variables graphed (speed vs. meters fallen)? Explain why the shape of the graph makes sense.

ROLLER COASTER (CONT.)

QUALITATIVE CALCULATIONS:

1. Average speed of the train for total ride (M/S & KM/H)

2. Speed at top of first hill (M/S)

3. Speed at bottom of first hill (M/S)

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

5. If each car has a mass of **2500** KG, and assuming the coaster is filled with riders whose average mass is the same as yours, how much total work is done getting the filled coaster to the top of the first hill? (Joules)
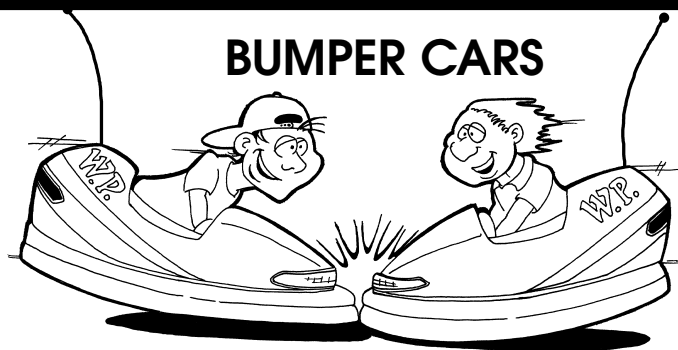
$$W = F \times \triangle D \qquad F = M \times A$$

6. How much power does the motor have to put out in order to lift the loaded coaster to the top of the first hill (answer in both Watts and Horsepower: 746 Watts = 1 HP)

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

Physics

The Waldameer Classroom

BUMPER CARS
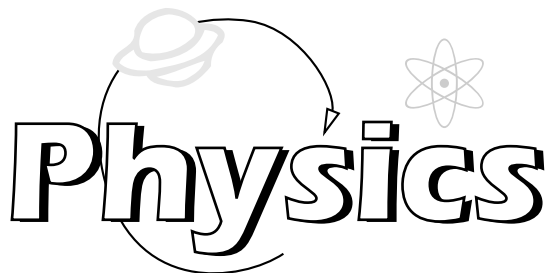
QUALITATIVE TASKS:

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

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

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

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

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

5. Answer these questions using the concepts of energy, impulse and Newton's Laws of Motion. Don't use vague terms like "shock."

   A. What is the reason for having the rubber bumpers around the cars?

   B. Why should you not design a bumper car with very soft bumpers?

   C. Why should you not design a bumper car with no bumpers at all?

BUMPER CARS (cont.)

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

7. Under what conditions do the following happen?
   A. Driver will feel the strongest jolt?

   B. Driver will be thrown forward?

   C. Car will accelerate at the crash?

   D. Driver will be thrown backward?

   E. Car will change direction at crash?

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

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

Physics