May 17, 2002
Schedule Of Events

Time	Event	Location
9:30	Lagoon Park opens	
9:30 - 11:00	School & teacher registration	Main Gate
9:30 - 11:00	Contest registration & safety approval inspections	Davis Pavilion
11:00 - 1:30	**Colossus' Colossal G-Forces Contest**	
2:00	Entry forms due	Davis Pavilion
10:00 - 4:00	**Physics Bowl Competition**	
10:15 - 10:45	Preliminary Qualification Round	Davis Pavilion
11:00 - 12:30	Round of thirty-two	Davis Pavilion
1:00 - 2:00	Round of sixteen	Davis Pavilion
2:00 - 2:30	Quarter-final round	Davis Pavilion
2:30 - 3:00	Semi-final round	Davis Pavilion
3:00 - 3:30	Consolation round	Davis Pavilion
3:30 - 4:00	Championship round	Davis Pavilion
11:00 - 3:00	**Physics Demonstration**	Davis Pavilion
	Lagoon: 2001 Ride Design and Physics Day Logo Design Contests	
10:00 - 3:00	**Student Workbook**	
3:30	Entry forms due	Davis Pavilion
12:00 - 1:00	Faculty and staff complimentary lunch	Canyon Terrace
3:30	All contest entry forms due at registration desk	Davis Pavilion
4:30	All rides close	
4:15 - 4:45	Awards and closing ceremony	Davis Pavilion
4:45	Park closes	

WIN FREE DAY PASSES AND SEASON PASSES TO LAGOON OR SPACE POSTERS!!!

All students who turn in their workbook to the table at Davis Pavilion by 3:30 have a chance to win fabulous prizes by random drawing.

Workbooks must be turned in by 3:30!!

Utah State University

High School Student Workbook

PHYSICS DAY AT LAGOON
May 17, 2002

ARTIST: *Mike Leishman, Box Elder High School*
ADVISOR: *Ron Cefalo*

STUDENT ______________________________

TEACHER ______________________________

HIGH SCHOOL ______________________________

WELCOME TO PHYSICS DAY AT LAGOON!!!

Thank you for coming to Lagoon for a day of physics and fun!

You are one of more than 4000 physics students from more than 100 schools here to enjoy a fun day experiencing Amusement Park Physics first hand.

This Student Workbook is for use in one of six activities that you can participate in today:

Student Workbook
Physics Bowl Contest
Colossus' Colossal G-Forces Contest
Physics Demonstration Design Contest
Lagoon: 2001 - A Ride Design Contest
Physics Day Logo Design Contest

The Physics Department at Utah State University, the NASA Rocky Mountain Space Grant Consortium, and the Idaho National Engineering and Environmental Laboratory are running today's activities. The contests are sponsored by Hansen Planetarium; Idaho National Engineering and Environmental Laboratory; Lagoon; Thiokol Corporation; NASA Rocky Mountain Space Grant Consortium; US Holographics, Logan; E-Systems, West Valley; Montgomery Watson Engineering, Salt Lake City; the USU College of Science, and the USU Office of School Relations.

If you have questions or would like to find out more about physics at Utah State University, stop by the Davis Pavilion.
We will be glad to see you!

ABOVE ALL, HAVE A FUN AND SAFE DAY!!!

Table of Contents

KINETIC ENERGY: The energy of a body associated with its motion.

LONGITUDINAL WAVE: A wave that vibrates or oscillates in the same direction that the wave pattern is moving (example: sound wave).

MASS: The amount of material a body contains. A quantitative measure of the inertia of a body.

MOMENTUM: The product of mass times velocity.

NEWTON'S LAWS OF MOTION: Physical laws governing the motion of bodies (at speed much less than the speed of light) expressed in terms of force, mass, and acceleration.

PERIOD: The amount of time for one complete wave oscillation to pass a point in space.

POTENTIAL ENERGY: Energy of a body associated with its position.

POWER: Rate of work done per unit time.

SPEED: The magnitude of velocity.

TRANSVERSE WAVE: A wave in which the vibration or oscillation is perpendicular to the direction that the wave pattern is moving (example: stadium wave football cheer).

VELOCITY: The magnitude and direction of the time rate of change of position.

WAVELENGTH: The distance between successive crests or troughs of a wave.

WEIGHT: A force proportional to the mass of a body. Measurement of the gravitational attraction of a body to the Earth.

WEIGHTLESSNESS: A condition under which a body feels no net force proportional to its mass.

WORK: Product of the magnitude of force on a body times the distance through which the force acts.

Useful Conversion Factors

1 in = 2.54 cm	1 J = 2.78 x 10^{-7} kw hr = 9.5 x 10^{-4} BTU
1 km = 0.621 miles	1 W = 1J/s = 1.3 x 10^{-3} horsepower
1 liter = 0.264 gal	1 W = 1.3 x 10^{-3} horsepower
1 hr = 3600 sec	1 g = 9.8 m/s^2 = 32 ft/s^2
1 fortnight = 1.728 x 10^6 sec	1 N = 0.225 lbf
1 m/s = 3.6 km/hr = 2.24 mi/hr	1 atm = 1 x 10^5 Pa = 14.7 lb/in^2
1 Calorie = 1 kcal = 1000 cl = 4186J	1 kg/liter H_2O = 8.35 lb/gal H_2O

FERMI QUESTIONS

Enrico Fermi was one of this country's greatest physicists. Among his accomplishments were the 1938 Nobel Prize for nuclear and particle physics and the title "Father of the Atomic Age" for his role in building the first nuclear reactor. He had a rare talent as both a gifted theorist and experimentalist. One of his legacies is the "Fermi Question," an insightful question requiring both an understanding of physics principles and estimation skills.

ENRICO FERMI

1901-1954

The Fermi Questions given below require information gathered for this workbook, estimation and some clever thinking. The additional questions provide hints for *one possible* way to figure out the answer.

1. How many times do you have to ride Colossus to pay for your Lagoon entrance ticket? Assume an electric motor is 30% efficient, lifts a fully loaded Colossus roller coaster (7200 kg) up the first hill on Colossus.

   a. Calculate the power necessary to raise the train.

   b. If Utah Power and Light charges 10 cents per kilowatt-hour, determine the cost of the electricity used to power this ride for one hour. Assume the ride to be operating at maximum capacity of a new train every two minutes.

   c. So, how many times do you have to ride Colossus?

2. Go check out the Skyscraper Ferris Wheel. This is one big, bright ride! Is it bigger or brighter?

   a. How much mechanical power is required to turn the Ferris wheel? Estimate the radius, mass and angular velocity to calculate the power needed to form the Ferris wheel. Assume the wheel turns 50% of the time and that the electric motor is 30% efficient.

   b. How much power is required to run the lights? They are 40 W. bulbs.

   c. Does it take more power to turn the Ferris wheel or light it?

BUMPER CARS

1. What happens in a collision to each car when:

   a. one bumper car is not moving?

   b. a rear-end collision takes place?

   c. a head-on collision takes place?

   d. bumper car hits a stationary object, i.e. the wall?

   e. cars sideswipe each other?

2. What is the difference between two pieces of clay that collide and two marbles that collide? Do bumper cars behave more like clay or marbles?

3. When will a driver:

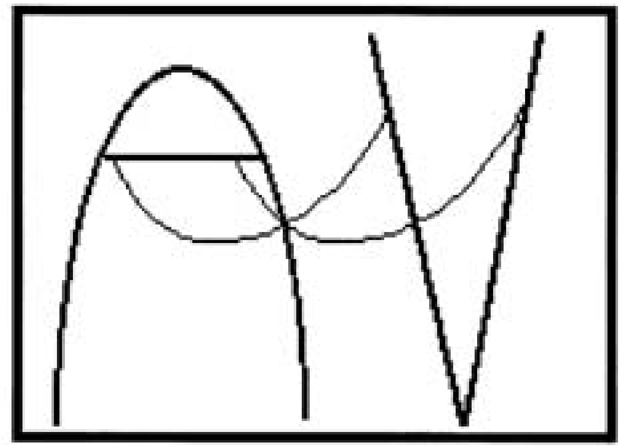
   a. feel the strongest jolt?

   b. be thrown forward?

   c. be thrown backward?

   d. be accelerated?

SKY COASTER



1. Measure the half-period (T/2) of motion for the first half-cycle, second half-cycle, etc., until the ride comes to a stop. Does the period change as the amplitude of the motion decreases?

2. Provide an explanation for the change in half-period T/2 measured in (1).

3. If there were no air resistance, would the period T be longer or shorter? Can you support your answer by observing the ride with different numbers of riders?

4. From the period T for the smallest oscillations estimate the height of the ride. (Remember that $T = 2\pi (L/g)^{1/2}$ where L is the length of the pendulum and $g = 9.8\ m/s^2$ is the acceleration due to gravity.)

5. Would the ride take longer on the surface of the moon? Why or why not?

FLYING ACES

MEASUREMENTS:

1. What is the time for a single revolution at top speed?_________ s/rev

2. What are the maximum and minimum radii of the planes and their angles with respect to vertical?

   Maximum: ________ m________ °   Minimum:________ m________ °

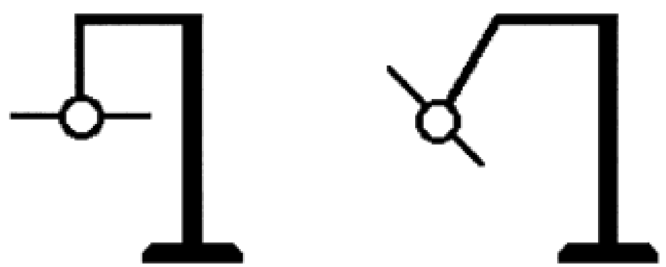
QUESTIONS

1. Planes move (toward, away from) the middle as they turn faster.

2. What causes this to happen?

3. Although the center hub rotates at a constant rate, it does not feel that way. Why?

4. Diagram vector forces acting on the planes shown below.



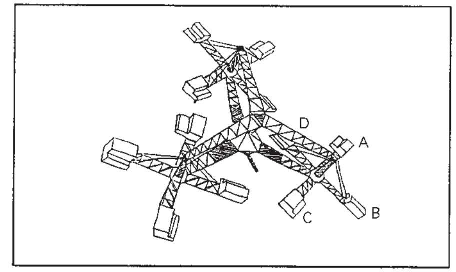
Plane at Rest

Plane in motion at maximun angle from vertical

5. Calculate the speed of the planes in the two figures above.

   _________m/s   _________m/s

SCRAMBLER



Indicate the direction of rotation of the ride cars about the main and secondary axes on the adjacent figure.

Sketch the path of the ride car.

How many rotations does the rider make about each axis?

Main ___________

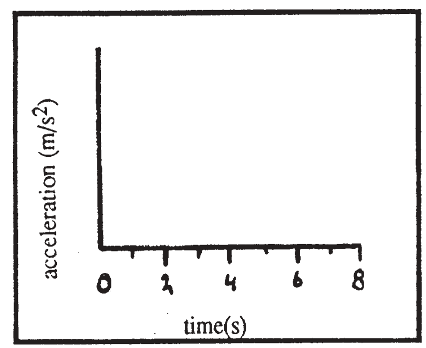
Secondary ___________

Ride Car Path

At which position (A, B, C, or D) was the speed (and force) of the ride car a maximum?

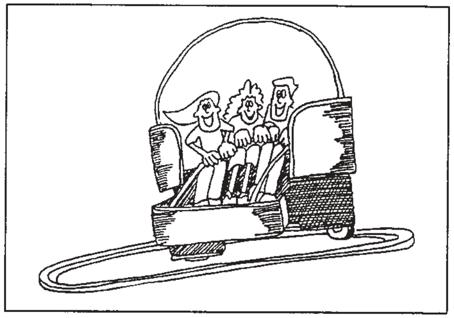
At which position (A, B, C, or D) was the speed (and force) of the ride car a minimum?

Calculate the total distance traveled by riding the Scrambler.



Graph the acceleration versus time for one main revolution of the Scrambler.

TILT-A-WHIRL -- CHAOS IN ACTION!!



When you hang a stone from a string, pull it aside, let go, and the stone swings back and forth in an almost exactly repeating way. These repetitions are so regular that you can keep pretty good time with such a simple toy. In fact, if you look inside a grandfather's clock, you'll see that the thing that "ticks" is a lot like a stone hanging from a string.

The repetitive swinging of a stone hanging from a string is very predictable. After you watch it for awhile, it gets kind of boring. There are many things in nature that repeat like a swinging stone. For example, the sun comes up every day, the moon is full every month, the temperature gets hot every summer, your heart beats about once every second (at least, if you are sitting still and not watching a horror movie). Those things, just like the swinging stone, are predictable.

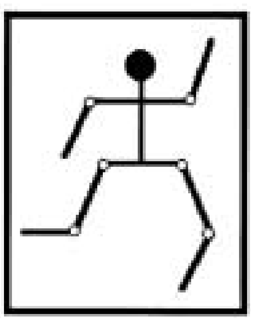
On the other hand, there are lots of other things that don't repeat in such a nice fashion and are very unpredictable. Some examples are the gurgling ripples in a rushing stream, the stretching and puffing of clouds blown by the wind, the flickering of a candle's flame, and the faces of a pair of dice that come up when you roll them.

Why do you suppose that some things are so regular and others so unruly? Maybe some parts of nature are governed by rules and are tame while other parts are run by luck and chance and are wild. Maybe.

But, hold on a second. If you make a gurgling stream slow down enough, the gurgles go away. And if you make the flame burn in just the right way, it becomes as smooth and regular as can be. Hmm.

But, the situation's more complicated still. The summer is hot every year, all right, but never quite the same — sometimes boiling, sometimes okay. And if you time your heartbeat very carefully you'll find it isn't regular either — sometimes it's a little fast, sometimes a little slow.

There are good reasons to believe that tame and wild behaviors are both governed by rules — they are opposite sides of the same coin. People are beginning to realize that some things that appear to be run by chance and to be unpredictable (streams and flames and hearts are all examples) actually march to the same kind of rules as the swinging stone. We call such unruliness "chaos."

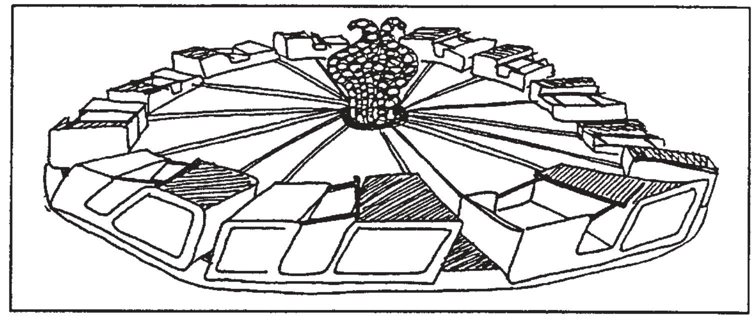


You may have seen a toy like the one pictured in the box. Its arms are free to flail about, as are its legs. The whole body rotates around a pivot in its chest. When you give the toy a good spin around its pivot, the arms and legs go every which way without any seeming rhyme or reason. If you give it a gentle spin, the arms and legs swing back and forth in a regular, repetitive manner. In both cases, the arms and legs go where rigid rules tell them to go. The wild, unpredictable behavior in this toy isn't due to chance. It's chaos.

The Tilt-a-Whirl ride at Lagoon is similar to this toy. Notice how unpredictable the ride feels. Pick a spot on the ground. Every time you pass that spot, jot down (if you can) which way you're facing. Later, after you can think straight again, look at your record. Does it seem repetitive or irregular? The irregularity of the Tilt-a-Whirl is not due to some genie playing chance with you. This ride obeys rigid rules. The unexpected whips and turns you just experienced are chaos.

(So here's an interesting question for you to ponder when you have nothing better to do: When you have an accident or you have a little good luck or it rains when it isn't supposed to or you decide to eat a hot dog instead of a piece of pizza, is that because of chance, or are you doing a chaotic dance just like the toy?)

MUSIK EXPRESS



QUESTIONS

1. As you go over the high point you feel (heavier, lighter, no change).
2. When loading each car, the (more massive, less massive) rider should be seated on the outside. Why?
3. The more massive rider requires (a larger, a smaller, the same) force to hold on the inside.
4. The centripetal acceleration on a large rider is (more than, less than, the same) as on a small rider.
5. Explain how the ride would be different without the hills and valleys.
6. Does the pitch of the music remain constant during the ride? Explain.

Collect the following data for use with later calculations:

1. Estimated radii for inside and outside riders: _________ m ________ m
2. Height of high point: _________ m
3. Time for one revolution at the maximum speed: _________ s
4. Total number of revolutions in one ride: _________
5. Time for one ride: _________s

CENTENNIAL SCREAMER

Ride Facts:

Number of carriers: 20
Number of people per seat: 2
Length of ride: 1.30 minutes
Length of time between rides: 2.00 minutes
Radius: 6 to 8 m
Minimum rotational period: 4s
Maximum angle of tilt: 85°

1. Calculate the minimum speed necessary to stay in your seat at the top of the ride.

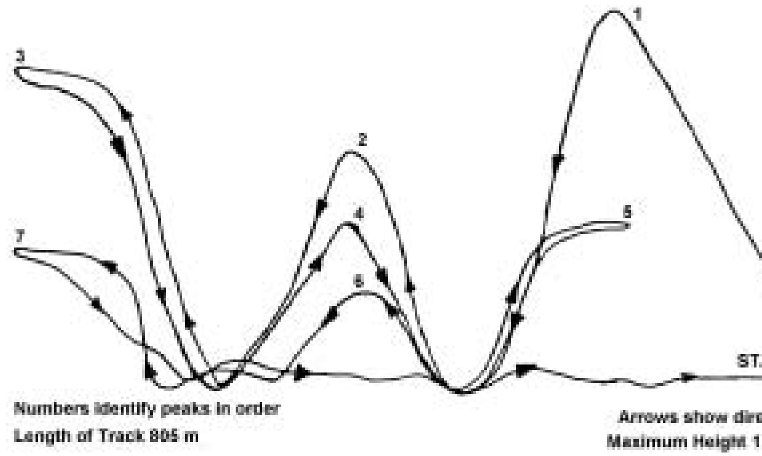
2. Calculate the frequency of the ride at full speed.

3. Measure the angle each car makes with the vertical as the wheel approaches full speed while still rotating horizontally. Is each car uniformly the same angle, regardless of its position around the wheel?

4. Calculate the circumference of the ride.

5. Determine the tangential speed of the ride.

WOODEN ROLLER COASTER



1. Determine the angles of ascent and descent of the first hill.

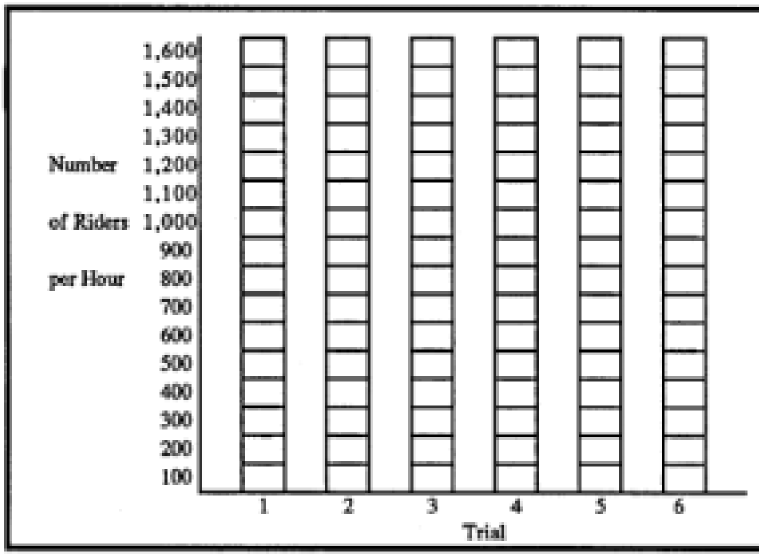
2. Identify at least 3 sources of friction in this ride.

3. Complete the diagram by putting in the proper labels. Label the following, minimum potential energy, G; maximum potential energy, X; maximum kinetic energy, K; minimum kinetic energy, M; weightless sensation, W; heavy sensation, H.

4. What is the average speed from the beginning to the end of the ride? What is the average velocity?

MEASUREMENT AND STATISTICS

1. Estimate the number of people per hour that ride the Sky Tram. Count the number of riders passing a certain point in one minute, and then multiply by 60. Enter your result as Trial 1 on the histogram below. Repeat your measurement. Find two friends and “borrow” their results. Finish the histograms and calculate the average number of riders per hour and the standard deviation. The standard deviation tells you how well all the measurements agree with each other.



Average $\left(N_{avg} = \frac{N_1 + N_2 + N_3 + N_4 + N_5 + N_6}{6}\right)$: ______

Standard deviation $= \sqrt{\frac{1}{6}\sum_{i=1}^{6}(N_i - N_{avg})^2}$: ______________

2. Now measure the number of riders passing your special point for 3 minutes. Which gives the most precise result: a) the 3-minute measurement; b) Trial 1; or c) the average value from Part 1? Why?

3. Imagine you measure the length of the Sky Tram using three devices: 1) a meter stick; 2) pacing the distance; and 3) a car odometer. Which will give you the most precise value? Why?

AMUSEMENT PARK PHYSICS GLOSSARY

Here are some physics concepts that you will encounter today. Most of them should be familiar to you after the exciting physics class you’ve been in this year.

ACCELERATION: Time rate of change of velocity (either speed or direction) of motion.

ACCELEROMETER: A device to measure acceleration.

AIR RESISTANCE: Force resisting motion of a body through air due to the frictional forces between the air and body.

AMPLITUDE: The maximum height of the wave above or below zero level.

ANGULAR ACCELERATION: Time rate of change of angular velocity.

ANGULAR VELOCITY: Time rate of change of angular position.

CENTRIPETAL FORCE: A force on an object pulling or pushing the object towards the center of its curved path.

CONSERVATION OF ENERGY: Basic tenet of physics stating that energy can neither be created nor destroyed in any process, though it may change form.

CONSERVATION OF MOMENTUM: The total momentum of a system is constant whenever the net external force on the system is zero.

ELASTIC COLLISION: A collision in which kinetic energy is the same before and after the collision.

FORCE: A push or pull. The time rate of change (direction and magnitude) of momentum.

FREQUENCY: The number of waves that pass a particular point in one second.

FRICTION: A retarding force that resists the motion of a body.

G-FORCE: Ratio of the magnitude of acceleration on a body to the acceleration of gravity at sea level on Earth ($g = 9.8\ m/s^2$).

GRAVITY: Attractive force between two bodies, proportional to their masses.

IMPULSE: Product of the magnitude of a force on a body times the time over which the force acts on the body.

INELASTIC COLLISON: A collision in which kinetic energy decrease as a result of the collision.

INERTIA: Tendency of a body to remain at rest or in uniform motion in a straight line.