## Schedule of Events

<table>
<thead>
<tr>
<th>TIME</th>
<th>EVENT</th>
<th>LOCATION</th>
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<tr>
<td>8:45</td>
<td>Lagoon Autopark (parking lot) opens</td>
<td>Main Gate</td>
</tr>
<tr>
<td>9:30</td>
<td>Lagoon Main Gates to rides opens</td>
<td>Main Gate</td>
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<tr>
<td>9:00 - 11:00</td>
<td>School &amp; teacher registration Main Gate</td>
<td>Main Gate</td>
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<tr>
<td>9:30 - 11:00</td>
<td>Contest registration &amp; safety approval inspections</td>
<td>Davis Pavilion</td>
</tr>
<tr>
<td>10:00-11:00</td>
<td>Utah/Idaho FIRST Robotics Grudge Match—Semifinals</td>
<td>Davis Pavilion</td>
</tr>
<tr>
<td>10:00-2:00</td>
<td>Mindstorm Activities</td>
<td>Maple Terrace</td>
</tr>
<tr>
<td>10:00-2:00</td>
<td>Wind Energy Challenge MESA Contest Activities</td>
<td>Oak Terrace</td>
</tr>
<tr>
<td>12:00 - 1:00</td>
<td>Faculty and staff complimentary lunch</td>
<td>Canyon Terrace</td>
</tr>
<tr>
<td>2:30 - 3:30</td>
<td>Contest winners are posted as judging is completed</td>
<td>Davis Pavilion</td>
</tr>
<tr>
<td>2:00-2:45</td>
<td>Utah/Idaho FIRST Robotics Grudge Match—Finals</td>
<td>Davis Pavilion</td>
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<tr>
<td>2:30-3:45</td>
<td>Mindstorm Competitions</td>
<td>Maple Terrace</td>
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<tr>
<td>3:30</td>
<td>Awards Ceremony in Davis Pavilion</td>
<td>Davis Pavilion</td>
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<tr>
<td>4:30</td>
<td>All rides close</td>
<td></td>
</tr>
<tr>
<td>4:45</td>
<td>Park closes</td>
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### Sky Drop Contest
- 10:00-11:30 Registration for the Sky Drop is open
- 11:30-1:30 Eggs can be dropped from the Sky Coaster.
  - Line will close at 1:00, or as soon as the line is finished.
- 2:30 Winners will be announced as soon as the contest is judged.

### Colossus’ Colossal G-Forces Contest
- 9:30-10:30 Contest registration & safety approval inspections
- 10:30-12:30 Colossus open for measurements
- 2:00 Entry forms due

### Physics Bowl Competition (Bighorn Pavilion)
- 9:30 - 10:30 Contest registration
- 10:30 - 11:00 Preliminary Qualification Round in
- 11:00 - 11:45 Round of thirty-two
- 1:15 - 1:45 Round of sixteen
- 1:45 - 2:15 Quarter-final round
- 2:15 - 2:45 Semi-final round
- 2:45 - 3:00 Consolation round
- 2:45 - 3:00 Championship round
- 3:30 Scholarships and prizes awarded

### Physics Demonstration, Lagoon: Ride Design and Physics Day Logo Design Contests
- 9:30 - 11:00 Contest registration & safety approval inspections
- 11:00 - 3:00 Judging
- 11:00-2:00 Meet with Judges by appointment as arranged during registration

### ARDUSAT
- 10:00 - 2:00 Monitor G-Force wearing ARDUSAT’s gear

### Student Workbook
- 10:00 - 3:00 Workbooks Collected
- 3:30 All entry forms due. Teachers can pick up solutions.

All students who turn in their workbook to the table at Davis Pavilion by 3:30 can enter a random drawing to Win Fabulous Prizes
Thank you for coming to Lagoon for a day of physics and fun!

You are one of more than 7000 physics students from more than 100 schools from five states here to enjoy a fun day experiencing Amusement Park Physics first hand.

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

- Student Workbook Physics Bowl Contest
- Colossus’ Colossal G-Forces Contest
- Sky Drop (Egg Drop) Contest
- Physics Demonstration Design Contest
- Lagoon Ride Design Contest
- Physics Day Logo Design Contest

The Physics Department at Utah State University and the Idaho National Laboratory are running today’s activities.

The contests are sponsored by Apogee, ARDUSAT, ASI, ATK Launch Systems, Boeing, Campbell Scientific, Eastern Idaho Regional Medical Center, Embry-Riddle, Exelis, Hill Air Force Base, Idaho Virtual Academy, IM Flash Technologies, Lagoon, Micron, Ophir-Spiricon, Parker Aerospace, Portage Environment, Rocky Mountain NASA Space Grant Consortium, Space Dynamics Laboratory, US Navy, USU College of Science, USU Emma Eccles Jones College of Education & Human Resources, USU Admissions Office, Utah Virtual Academy, and WiTricity.

More information about Physics Day is available at physicsday.usu.edu. If you have questions or would like to find out more about physics at Utah State University (www.physics.usu.edu), please stop by the Davis Pavilion. We will be glad to see you at Lagoon!

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1. When a roller coaster is at the top of a hill, it has the most ______________ energy?
2. ______________ of an object refers to its speed and direction.
3. When on a curve on Cannibal or on spinning rides, the riders feel an inward force known as ______________ force.
4. To measure the acceleration throughout the Cannibal ride, riders can take an ______________ on the ride.
5. The attractive force between two massive bodies, which causes Lagoon’s roller coasters to run, is called ______________.
6. Rides at Lagoon are all slowed down by this force: ______________.
7. Riders on Cannibal experience ______________, a type of frictional force, due to our atmosphere.
8. Cannibal riders have the same ______________ both here on Earth and on the Moon, but their ______________ is less on the Moon.
9. A push or pull felt on the Cannibal ride is known as a ______________.
10. ______________ is felt when rapid changes in speed or direction occur.
11. If two Cannibal cars collide and the net external force acting on the cars is zero, the total momentum is ______________.
12. ______________ causes Cannibal riders to lean when going around a bend because their bodies resist changing direction.
13. As the Cannibal riders descend down the top of the hill, their ______________ energy is rapidly converted to ______________ energy.
14. The ______________ on Cannibal cause riders to feel heavier than normal when they ride through the loops.
15. The ______________ of ______________ states that within the boundaries of a problem, ______________ cannot be created nor destroyed, though it may change form.
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.

The Fermi Questions given below require information gathered for this workbook, estimation, and some clever thinking.

1. Estimate the length of Cannibal and explain your reasoning.

2. What fraction of the weight of the moving parts (car and riders) of Cannibal do the passengers comprise? What fraction of the total weight of Cannibal do the riders account for?

Hints: How many riders are there? What does an average person weigh? How many cars are there? How big (long, wide, and high) is each car? What fraction of each car is air and what fraction is the rest? What is the average density of the stuff the cars are made of (see page 5 for common densities)? Use the same logic for the cars on the whole Cannibal ride.
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.

**ANGLULAR ACCELERATION**: Time rate of change of angular velocity.

**ANGLULAR 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/s²).

**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 COLLISION**: 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.

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

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**Angry Birds** – Projectile motion, acceleration, force, and many more fun physics principles tested with this series of games.

**Coaster Physics** – Build and ride your own roller coaster. See real-time potential and kinetic energy, speed and acceleration, and the g-forces felt during the ride.

**Convert Units for Free** – Feet to meters, miles per hour to kilometers per hour? Convert many units with this application.

**Flashcards+** – Build your own flashcards or use premade decks to keep on top of your physics game.

**Footsteps – Pedometer Free** – Use this to measure your own velocity or get velocity of rides using distance per unit time.

**IBPhysics Definitions** – Test your physics definitions using the innovative flashcard style application.

**Roller Coaster RushFREE** – Use the accelerometer to gain speed, get points, and master each level.

**Paper Toss** – Throwing paper into the trash has never been so fun especially with a blowing fan and other obstacles.

**SPARKvue** – Acceleration data application. Measure and log each x, y, or z axis individually or all three at the same time.

**Tone Generator** – Produce a wide range of tones for fun or to test the hearing of those around.

**Vernier Video Physics ($4.99)** – Real-time video analysis of motion. Plot and chart the positions as well as determine the velocity.

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**Angry Birds** – Projectile motion, acceleration, force, and many more fun physics principles tested with this series of games.

**Angular Velocity** – Up for a challenge? Try this app to test your physics reasoning abilities. Tilt the phone to control gravity and to swing your way through each level.

**Sound Meter** – Walk around Lagoon and determine the loudest locations. Displays waveform and frequency spectrum.

**Cardio Trainer** – Use this to measure your own velocity or get velocity of rides using distance per unit time.

**Unit Converter – ConvertPad** – Feet to meters, miles per hour to kilometers per hour? Convert many units with this application.

**Flash Cards** – Build your own flashcards or use premade decks to keep on top of your physics game.

**Grav-O-Meter** – Measures real-time acceleration felt and logs the maximum.

**Instant Heart Rate** – What is your heart rate before and after the ride? Test it out to see!

**Paper Toss** – Throwing paper into the trash has never been so fun especially with a blowing fan and other obstacles.

**Smart Measure** – Use the built in camera to measure the distance and height of objects.

**Surveyor** – Use the built in camera to measure the distance of objects.

**True Tone** – Produce a wide range of tones. Test this out with the Audalyzer application to see what cool designs can be generated.
This year, one of our sponsors is providing you with the opportunity to make measurements in real time – riding on the Rocket!! ARDUSAT provides these interactive opportunities for students to get this hands on experience. Visit the ARDUSAT table by the Rocket sometime between 10:00 and 2:00 to put numbers to those feelings in the pit of your stomach!

For your chance to wear their gear, answer the following questions!

1. What is the size and weight of a cubesat satellite?

2. What is the acceleration of gravity?

Now that you have the answers to these questions, step up and strap in! Answer the question below when you get back from space for a chance to enter the ARDUSAT drawing!

3. What is maximum G force on the ride The Rocket? How does this compare to the force astronauts experience in a launch to the International Space Station?

4. What is the minimum G force on The Rocket? How does this compare to the force USU Get Away Special students experienced during their experiments on the NASA Vomit Comet? (Talk to the GAS Team members in Davis Pavilion for more information!)

Useful Conversion Factors

<table>
<thead>
<tr>
<th>Conversion</th>
<th>Common Densities (g/cm3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 m = 3.28 ft</td>
<td>air</td>
</tr>
<tr>
<td>1 hr = 3600 sec</td>
<td>water</td>
</tr>
<tr>
<td>1 m/s = 3.6 km/hr = 2.24 mi/hr</td>
<td>aluminum</td>
</tr>
<tr>
<td>1 g = 9.8 m/s2 = 32 ft/s2</td>
<td>iron</td>
</tr>
<tr>
<td>1 in = 2.54 cm</td>
<td>lead</td>
</tr>
<tr>
<td>1 km = 0.621 miles</td>
<td>plastic</td>
</tr>
<tr>
<td>1 kg = 2.2 lbs</td>
<td>wood</td>
</tr>
<tr>
<td>1 N = 0.225 lbs</td>
<td></td>
</tr>
<tr>
<td>1 Cal = 1 kcal = 1000 cal = 4184 J</td>
<td></td>
</tr>
</tbody>
</table>
The height of the first hill of a roller coaster is very important. Roller coasters use the acceleration due to gravity to complete its course. Thus, the height of the beginning of the coaster determines the energy and therefore the kinetic energy and _____ of the roller coaster. Thus, the height of the Cannibal tower is critical to rest of the ride!

Height of Cannibal track as it exits the tower \( (h_{\text{track}}) \): 63 m (208 ft)

Questions

1. Fill in the blanks of the above statement.
   a. ________  b. ________

2. Stand in a location where you can see the track exit the tower.
   a. Measure the angle \( (\theta_{\text{track}}) \) from where you are to the point the track exits the top of the tower using the iPhone or iPod “Multi Protractor” or Android “Advanced Protractor” application (see page 13).
      \[ \theta_{\text{track}} = \text{________ degrees} \]
   b. Calculate the distance \( (d_{\text{calc}}) \) from the base of the Cannibal tower to where you are standing, using \( \theta_{\text{track}} \), the trig functions below (determine which function is relevant), and the \( h_{\text{track}} \), given above.
      \[ d_{\text{calc}} = \text{________ m} \]
   c. Measure the angle \( (\theta_{\text{tower}}) \) from where you are to the top of the tower.
      \[ \theta_{\text{tower}} = \text{________ degrees} \]
   d. Using angle \( \theta_{\text{tower}} \), the distance \( (d_{\text{calc}}) \) and the trig functions, calculate the height \( (h_{\text{tower}}) \) of the Cannibal track at the top of the tower.
      \[ h_{\text{tower}} = \text{________ m} \]
   e. Good scientists always check their work. Pace the distance, \( d_{\text{meas}} \), from your measurement point to the base of Cannibal tower. How well does this agree with your value from (b)?
      \[ d_{\text{meas}} = \text{________ m} \]
      \[ \text{percent difference} = \frac{d_{\text{meas}} - d_{\text{calc}}}{\frac{1}{2}(d_{\text{meas}} + d_{\text{calc}})} \times 100 = \text{________ \%} \]

\[ \sin(\theta) = \frac{h}{f} \]
\[ \cos(\theta) = \frac{d}{f} \]
\[ \tan(\theta) = \frac{h}{d} \]
There are many more things we can measure and calculate with respect to this new ride, Cannibal. Using the things you learned and calculated on the previous pages, complete this worksheet to learn more about Cannibal.

Questions
1. Fill out the table using the same technique from page 6. You may have to move to new locations and recalculate d.

<table>
<thead>
<tr>
<th>Location on Cannibal</th>
<th>d (m)</th>
<th>θ (deg)</th>
<th>h (m)</th>
<th>PE (J/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
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<tr>
<td>C</td>
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</tr>
<tr>
<td>D</td>
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</tr>
<tr>
<td>E</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
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</table>

2. If all of the potential energy of cars and riders at the top of Cannibal was converted into kinetic energy, what would the riders’ velocity at the bottom of the tower be?

When you get in the Cannibal roller coaster car, an elevator lifts the car to the top of the tower. From here, the car exits the tower and begins the thrilling ride.

Useful Equations
‘h’ is the height of the tower or track, found on page 6
‘m’ is the mass
‘g’ is the acceleration due to gravity
‘PE’ is the potential energy

\[ PE = m \times g \times h \]

Questions
1. What provides the potential energy for Cannibal?

2. What would be the potential energy of a Cannibal car if the track started at the top of the tower (leave mass as a variable, m, so that answer is in terms of a number times m, for example as 40 x m Joules)?

3. What is the potential energy of a Cannibal car where track actually exits the tower (leave mass as a variable, m, so that answer is in terms of a number times m, as above)?

4. What is the potential energy at the bottom of the tower (leave mass as a variable, m, so that answer is in terms of a number times m, as above)?
KINETIC ENERGY

You survived the first drop of Cannibal and are well on your way to the end of the ride. This ride is a great example of kinetic energy, which you will be calculating below. Here, we assume that the initial velocity is zero and it’s a frictionless coaster.

Useful Equations

\[ v_{\text{final}} = g \times t_{\text{avg}} \]
\[ KE = \frac{1}{2} m \times v^2 \]

Questions

1. Watch Cannibal run 3 times. Using the iPhone or iPod “Stopwatch Analog+Digital” or the Android “StopWatch and Timer” application, measure the time it takes for the car to travel from the top of the tower to the bottom for each of those runs. Determine the average time.

\[ t_1 = \_\_\_\_\_\_ s \quad t_2 = \_\_\_\_\_\_ s \quad t_3 = \_\_\_\_\_\_ s \quad t_{\text{avg}} = \_\_\_\_\_\_ s \]

2. Now that ‘t_{avg}’ is known, calculate the velocity of the car at the bottom of the tower?

\[ v_{\text{final}} = \_\_\_\_\_\_ m/s \]

3. Use the velocity found in Question 2 to calculate the kinetic energy of the car at the base of the tower (leave mass as a variable, m, so that answer is in terms of a number times m, as on page 7).

CONSERVATION OF ENERGY

The conservation of energy means that within the boundaries of the problem, energy cannot be created or destroyed. In other words, the energy that is available at the beginning of the problem, or in our case the beginning of the Cannibal ride, must be equal to the energy at the end.

Questions

1. Describe what happens to the potential and kinetic energies as the cart falls from the top to bottom of the tower.

2. Restate the values of potential energy (see pg. 7) at the top of the tower and kinetic energy (see pg. 8) at the bottom of the tower here.

Estimated PE = \_\_\_\_\_\_ J/m
Estimated KE = \_\_\_\_\_\_ J/m

3. Are the values from Question 2 equal? If not, why? Where is the energy lost? What is the percent energy lost (see last question on page 6)?