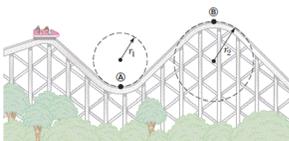




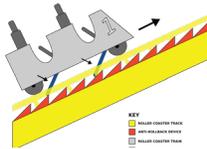
## Grades 4-6

- 1 A rider will feel weightless at 14 different times while riding Wicked Cyclone. How many pounds would a 100-pound rider weigh after riding Wicked Cyclone?
- 2 Wicked Cyclone has a new smooth steel track in comparison to the original Cyclone. What force is reduced when coaster trains ride over a smoother track?
- 3 Wicked Cyclone uses the force of gravity to move riders throughout the twisted track. Would gravity be considered "biotic" or "abiotic" (with reference to Wicked Cyclone)? Why?
- 4 The top speed reached on Sky Screamer is 43 miles per hour. If a rider were able to stay on the revolving ride for 2 hours at the top, how many miles would the rider travel during that time?
- 5 The Sky Screamer operates by utilizing multiple forces. What force is always pulling on the chairs even when the ride hasn't begun to operate?
- 6 The trains on Batman are made of mainly steel and fiberglass. Using materials like fiberglass make it easy to shape complex designs as well as reduce the \_\_\_\_\_ of the ride?
- 7 What shape is modeled to make one Superman's many turns?



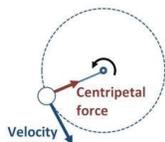


- 8 One of Superman's trains weighs nearly 37,000 pounds! What is needed to move one of these heavy trains?



- 9 While riding the Teacups, it is so hard to watch other people riding because they are always changing \_\_\_\_\_.

- 10 Which way does each Teacups push on its riders?



- 11 Thunderbolt was built in 1941 and has 2,200 feet of wooden track. If we replace 400 feet of the track each year, how many years will it take us to replace the whole track?

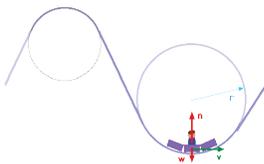
- 12 Thunderbolt is a wooden roller coaster that was built in 1941. Why aren't all roller coasters still built with wood?

- 13 Describe the different ways Pandemonium's car moves during the ride (give at least 3).



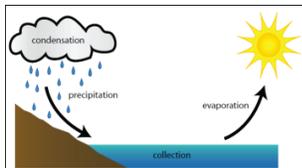
## Grades 7-9

- 1 How many Joules of work are required by the Wicked Cyclone train to lift a 445-Newton person (100 pounds) to the top of its 33.2-meter drop hill?
- 2 A Wicked Cyclone rider has a mass of 44.5 kilograms. When that rider is sent through one of the ride's Zero-G rolls to induce the feeling of weightlessness, how much mass would the rider have during the roll?
- 3 There are two primary forces acting upon a rider's swing during a flight on Sky Screamer. What are these two forces and in which direction does each pull (or push)?
- 4 Since the Sky Screamer is the tallest ride at Six Flags New England, it also gives riders the most \_\_\_\_\_ energy due to gravity?
- 5 Batman is a unique ride that allows riders' legs to swing freely. This means that if you sit in the front row, your legs will be exposed and will now feel the force of \_\_\_\_\_ .
- 6 It is this force that causes riders of Superman to feel nearly 4.5 times heavier at the bottom of the first drop.



**7** One of Superman's trains weighs nearly 37,000 pounds! This translates to nearly 164,500 Newtons. How many Joules of work are required to lift 164,500 Newtons to the top of Superman's 63.4-meter drop hill?

**8** Superman has two mist tunnels. The addition of mist to the tunnel would be best classified as which physical change?



**9** Up to 60 riders can enjoy the Teacups with no worries of wearing a seat belt. This is because there are two primary forces keeping all the riders anchored into their seats. What are those forces?

**10** Why is the first hill on the Thunderbolt Roller Coaster the highest hill on the ride?

**11** Thunderbolt's track is 2,200 feet long. If the ride takes 113 seconds, what is the average speed for the ride in feet/second?

**12** Which will spin more on Pandemonium, a car with passengers of a lesser or greater mass?



## Grades 10-12

- 1 Wicked Cyclone was designed to give riders 14 different points of “weightlessness” during the ride. At such a point, what would be the mass (in kilograms) and weight (in Newtons) of 44,500-gram rider?
- 2 One of Wicked Cyclone’s trains weighs nearly 36,000 pounds! This translates to nearly 160 kilo-Newtons. Using scientific notation, how many Joules of work are required to lift 160 kilo-Newtons to the top of Wicked Cyclone’s 33-meter drop hill?
- 3 Centripetal force is the force pulling each swing towards the center of the Sky Screamer. What is the name of the apparent force that is equal and opposite of centripetal force? (Hint: it is the term most commonly used for the feeling of being “pushed into your seat”)
- 4 The peak speed reached on the Sky Screamer is 43 miles per hour (19 meters per second). If a rider weighs 660 Newtons, what would be their value of momentum during the highest reached speed on Sky Screamer? (Assume that the acceleration due to gravity is  $10 \text{ m/s}^2$ )
- 5 You may notice that the large loop incorporated into the design of Batman is not a perfect circle. Instead the loop is designed to be a “Clothoid Loop.” What is the primary benefit to riders experiencing a Clothoid Loop versus a circular loop?
- 6 Batman: The Dark Knight is a unique ride in the sense that it is a “floorless coaster.” In other words, if you are sitting in the front row, your legs are now exposed. Engineers must account for increased levels of \_\_\_\_\_ when designing such a ride using the scientific study of fluids moving over surfaces known as \_\_\_\_\_.
- 7 Batman uses brake pads (that open and close) to bring the riders into the station at the end of the ride. Which set of pads would you expect to undergo the most wear-and-tear? Why?



## Grades 10-12

- 8** At the bottom of the first drop of Superman can cause a G-Force spike of nearly 4.5. Knowing that one of Superman's trains weighs 37,000 pounds, at minimum how much force must Superman's track be able to support at the bottom of the first drop?
- 9** One of Superman's trains weighs nearly 37,000 pounds! This translates to nearly 164,500 Newtons. Using scientific notation, how many Joules of work are required to lift 164,500 Newtons to the top of Bizarro's 63.4 meter drop hill?
- 10** While riding the Teacups, where would you expect to obtain the highest linear velocities? Use the radius of the large turntable as your reference.
- 11** The first hill on Thunderbolt is 25.9 meters (85 feet). If the cars each have a mass of 450 kg (about 1000 pounds) and six people with average weights of 670 Newtons (about 150 pounds), how many Joules of work must be done to get the car to the top? (assume the acceleration due to gravity is  $10 \text{ m/s}^2$ )
- 12** At the top of the first hill, the cars and passengers on Thunderbolt have potential energy. However, not all of this energy is converted into kinetic energy. Where does this "lost" energy go?
- 13** Parts of Pandemonium's track look level. Why is the cart able to keep moving?
- 14** Pandemonium has a maximum speed of 15m/s. If the car has 4 riders each with a mass of 80kg, what is the kinetic energy of the riders?



## Grades 4-6

# Answer Key

### 1 100 pounds

The ride cannot physically change your resting weight unless mass is added or removed from the rider.

### 2 Friction

Friction is an opposing force to motion. Therefore, a smoother track reduces the amount of opposing forces.

### 3 Abiotic

Gravity is not a living thing. Although gravity may seem to be alive (biotic), it is nothing but a force. Therefore gravity must be abiotic.

### 4 86 miles

At 43 miles per hour, an object will travel 86 miles in 2 hours.

### 5 Gravity

This force is always acting upon objects with mass here on Earth. In fact, the force of gravity combined with the tension force of the cables is what creates the angle at which the chairs swing.

### 6 Weight

Fiberglass is much lighter material than steel.

### 7 Circle

The turn in a track stems from a circular design.

### 8 Force

A force is defined simply as a push or pull. Therefore in order to move Superman's large train, a combination of the chain-lift pulling force and the force of gravity are required.

### 9 Position

### 10 Towards the center of the cup

Riders will tend to say that they feel pushed against the walls of the cup when indeed it's the wall pushing them towards the center of the cup (represented by the red arrow) during rotation.

### 11 5½ Years

$2,200 \text{ feet} \div 400 \text{ feet/year} = 5.5 \text{ years}$

### 12 Steel is more durable and/or requires less maintenance (accept either answer)

### 13 Fast, round and round/circular, forward, downhill, straight



# Grades 7-9

## Answer Key

### 1 14,774 Joules

The equation necessary is work ( $W$ ) = force ( $F$ ) x distance ( $d$ )

Therefore  $W = 445 \text{ Newtons} * 33.2 \text{ meters}$  which calculates out to 14,774 Joules. You may get a different result from a student who understands the concept of significant figures and therefore may give a result of 14,800 Joules (also can be displayed as  $1.48 \times 10^4$  Joules), which is an acceptable answer as well.

### 2 44.5 kilograms

The common misconception is that when "weightless" an object has no mass. However, mass cannot be created nor destroyed so therefore the rider's mass does not change during any element of the ride.

### 3 1. Gravity (down); 2. Cable's tension force (in the direction of the cable towards the base)

Gravity is always pulling masses towards the center of the Earth (e.g. down) and cables are used to hold swinging objects in place.

### 4 Potential Energy

As a mass on is pulled away from the Earth's surface, it gains a greater "potential to fall." Therefore the higher the ride, the more potential energy the rider gains.

### 5 Friction (Air Resistance is an acceptable answer as well)

Friction is basically any force that resists motion.

### 6 Centripetal Force

The common misconception for roller coaster riders is that they feel like they're being "pushed" into their seats at the bottom of a drop. What they are actually feeling is the force of the coaster track pushing on them. When the track turns, the "pushing" sensation is caused by the centripetal force of the track literally pushing the train around the curve.

In the diagram, the force represented by "n" would represent the centripetal force.

### 7 10,429,300 Joules

The equation necessary is work ( $W$ ) = force ( $F$ ) x distance ( $d$ )

Therefore  $W = 164,500 \text{ Newtons} * 63.4 \text{ meters}$  which calculates out to 10,429,300 Joules.

You may get a different result from a student who understands the concept of significant figures and therefore may give a result of 10,400,000 Joules (also can be displayed as  $1.04 \times 10^7$  Joules), which is an acceptable answer as well.



## Grades 7-9

# Answer Key

### 8 Condensation

This question relates to the water cycle. The basic idea is that a mist tunnel is supposed to create the sensation of being in a cloud. The best way to form a cloud is to cool water vapor until it condensates to form a visual fog.

A common misconception is that condensation is a chemical change. A phase change is always it a physical change.

### 9 Gravity and Centripetal Force

Gravity is the force keeping the riders anchored to their seats so they don't drift away. Centripetal force is what riders feel pushing on their backs by the wall as the ride rotates. It is centripetal force that keeps the riders sitting upright.

### 10 At the highest point, the maximum amount of potential energy required to make it through the entire roller coaster is reached

### 11 19.5 feet/second

$2,200 \text{ feet} \div 113 \text{ seconds} = 19.5 \text{ feet/second}$

### 12 Cars of lesser mass should spin faster (if not more) due to less rotational inertia



# Grades 10-12

## Answer Key

- 1 Mass = 44.5 kilograms; Weight = 0 Newtons**  
**Mass = 44,500 Kilograms ÷ 1000 = 44.5 kilograms.**

During a point of weightlessness, the net acceleration on the body would be 0 and therefore the weight too must be zero.

- 2 5.28 x 10<sup>6</sup> Joules**

The equation necessary is work (W) = force (F) x distance (d)

Therefore W = 160,000 Newtons \* 33 meters which calculates out to 5.28 x 10<sup>6</sup> Joules.

You may get a different result from a student who understands the concept of significant figures and therefore may give a result of 5.3 x 10<sup>6</sup> Joules, which is an acceptable answer as well.

- 3 Centrifugal Force**

This question is very in depth as many students are familiar with centripetal force. It is the centripetal force that pulls the riders towards the center of the Sky Screamer. However, there is a name for the "apparent" force that riders feel while on the ride and that simulation is known as centrifugal force.

- 4 125,400 (kg)\*(m/s)**

**130,000 would also be an acceptable value** (if students understand the concept of significant figures)

Since momentum (p) = mass (m) x velocity (v), then p = (660N/10m/s<sup>2</sup>)\*(19m/s)

- 5 The riders experience less of a centripetal force on their bodies**

A Clothoid Loop is designed similar to a Venn Diagram where the center of two overlapping circles is where the "loop" comes from. The design keeps the most intense turn at the top of the loop where the train's speed is the least.

- 6 Friction (or Air Resistance); Aerodynamics**

Friction is the resistance to motion while Aerodynamics is the study of fluids moving over surfaces.

- 7 The set closest to the last leg of the ride path.**

This is where the train enters at its highest speed during the breaking process and requires the most friction to slow the ride down.

- 8 166,500 lbs.**

37,000 pounds x 4.5 = 166,500 pounds. You may get a different result from a student who



## Grades 10-12

# Answer Key

### 9 $1.04293 \times 10^7$ Joules

The equation necessary is work ( $W$ ) = force ( $F$ ) x distance ( $d$ ) Therefore  $W = 164,500$  Newtons \*  $63.4$  meters which calculates out to  $1.04293 \times 10^7$  Joules.

You may get a different result from a student who understands the concept of significant figures and therefore may give a result of  $1.04 \times 10^7$  Joules, which is an acceptable answer as well.

### 10 **The greater the radius from the center of the large turntable, the higher the linear velocity.**

In other words, when the cup is furthest away from the teapot in the center, the greatest linear velocities will be achieved.

### 11 **220,668 Joules**

Work = Force  $\times$  Distance

Force = total weight =  $(450 \text{ kg})(10 \text{ m/s}^2) + (6)(670 \text{ N}) = 8520 \text{ N}$

Work =  $(8520 \text{ N})(25.9 \text{ m}) = 220,668 \text{ J}$

Some students that understand the concept of significant figures will come up with an answer of  $221,000 \text{ J}$

### 12 **Energy is primarily lost to friction forces opposing the motion of the coaster.**

### 13 **The law of inertia-an object in motion tends to stay in motion until acted on by an outside force. Eventually the cart would stop if there were no more drops (simply due to friction).**

### 14 $KE = \frac{1}{2}mv^2$

$KE = \frac{1}{2}(80 \text{ kg} * 4 \text{ riders})(15 \text{ m/s})^2$

$KE = \frac{1}{2} (320)(225)$

$KE = 36,000 \text{ Joules}$