I-X Indoor Amusement Park
We've got the fun covered!

Amusement Park Physics

You've bought your ticket and boarded the roller coaster. Now you're barreling down the track at 60 miles per hour, taking hairpin turns and completing death-defying loops. Your heart is in your throat and your stomach is somewhere near your shoes. The only thing separating you from total disaster is a safety harness   but are you really in danger?

The designers of the roller coaster carefully crafted this thrilling ride to be just that, but you're actually in less danger than you think. You face a greater threat of injury playing sports or riding a bike than you do on a park ride. Amusement park rides use physics laws to *simulate* danger, while the rides themselves are typically very safe.

Read on to see how physics laws create excitement in your favorite amusement park rides.

Roller Coaster

How does a roller coaster work?
What you may not realize as you're cruising down the track at 60 miles an hour is that the coaster has no engine. The car is pulled to the top of the first hill at the beginning of the ride, but after that the coaster must complete the ride on its own. You aren't being propelled around the track by a motor or pulled by a hitch. The conversion of potential energy to kinetic energy is what drives the roller coaster, and all of the kinetic energy you need for the ride is present once the coaster descents the first hill .

Once you're underway, different types of wheels help keep the ride smooth. Running wheels guide the coaster on the track. Friction wheels control lateral motion (movement to either side of the track). A final set of wheels keeps the coaster on the track even if it's inverted. Compressed air brakes stop the car as the ride ends.

Lesson
There is 1 roller coaster at the I-X Indoor Amusement Park.
Explain how you felt when riding it.
Does the mass of the roller coaster riders affect the speed of the ride?

Carousel

Carousels are not considered “thrill machines” by any stretch of the imagination. Still, carousels are as reliant on the laws of motion as their more exciting cousins, the roller coasters. It's theoretically possible that, allowed to spin out of control, a carousel could gain enough speed so that the riders would be thrown off. Thankfully, runaway carousels are not the least bit common.

Are some horses moving faster than others?
With all of its beauty and seeming simplicity, the carousel is a delicate balance of motion and forces. All of the horses move through one complete circle in the same amount of time. The horses on the outside of the carousel have to cover more distance than the inside horses in the same amount of time. This means that horses on the outside have a faster linear speed than those at the hub.

What if they're galloping?
On some carousels, the horses go up and down in a galloping motion simulating what it might be like to ride a real horse. For these carousels, the ride designer had to approach the problem of movement around the central axis differently. In a normal carousel, each horse maintains a constant acceleration, radius, and tangential speed (speed tangent to the circular path of the carousel). If you add a gallop to some of the horses, you must consider the forces needed to change that horse's position upward or downward as it goes around the track. In designing with these forces in mind, you also need to take into account the mass of the horse and its rider.

How do you tell the lead horse on a carousel?
According to carousel legend, the lead horse of any carousel is always the biggest, most decorative horse. In many instances, this horse is a military or war horse. If a chariot is included in the carousel, the first horse right behind the chariot on the outside is the lead horse.

Lesson
Ride the carousels. List the different motions that are experienced as you ride.
Give the name of one of the carousels you rode.
Try to find the lead animal and identify it.
Tell why you think it is the lead.

Bumper Cars

Newton's third law of motion comes into play on the bumper cars. This law, the law of interaction, says that if one body exerts a force on a second body, the second body exerts a force equal in magnitude and opposite in direction on the first body. It's *the law of action-reaction*, and it helps to explain why you feel a jolt when you collide with another bumper car.

How do bumper cars work?
Bumper car rides are designed so that the cars can collide without much danger to the riders. Each car has a large rubber bumper all around it, which prolongs the impact and diffuses the force of the collision.

The bumper cars run on electricity, carried by a pole on the back of the car that leads up to a wire grid in the ride's ceiling. This grid carries the electricity that runs the car. Electrical energy carried to the cars from the grid is converted to kinetic energy, some of which is converted to heat.

What happens to the drivers?
When bumper cars collide, the drivers feel a change in their motion and become aware of their inertia. Though the cars themselves may stop or change direction, the drivers continue in the direction they were moving before the collision. This is why it's important to wear a seat belt while driving a real car, since otherwise you could suffer injury being thrown forward in a collision.

The masses of the drivers also affect the collisions. A difference in mass between two bumper car riders will mean that one rider experiences more change in motion than the other (or more of a jolt). The type of collision, velocity of the cars, and mass of the individual drivers all come into play in bumper car collisions.

Lesson
Ride the bumper cars.
They are called "The Scooter"
Tell how the collisions you experience differ from each other.
Why are the collisions different?

Free Fall

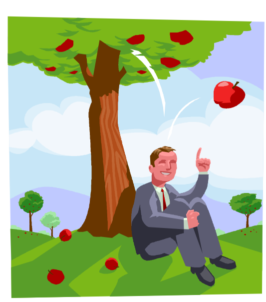
Galileo first introduced the concept of free fall. His classic experiments led to the finding that all objects free fall at the same rate, regardless of their mass. According to legend, Galileo dropped balls of different mass from the Leaning Tower of Pisa to help support his ideas.

A freely falling body is an object that is moving under the influence of gravity only. These objects have a downward acceleration toward the center of the earth. Newton later took Galileo's ideas about mechanics and formalized them into his laws of motion.

How do free-fall rides work?
Free-fall rides are really made up of three distinct parts: (1) the ride to the top, (2) the momentary suspension, (3) and the downward plunge. In the first part of the ride, force is applied to the car to lift it to the top of the free-fall tower. The amount of force that must be applied depends on the mass of the car and its passengers. The force is applied by motors, and there is a build-in safety allowance for variations in the mass of the riders.

After a brief period in which the riders are suspended in the air, the car suddenly drops and begins to accelerate toward the ground under the influence of the earth's gravity. The plunge seems dramatic. Just as Galileo and Newton explain in their theories of free fall, the least massive and most massive riders fall to the earth with the same rate of acceleration. If the riders were allowed to hit the earth at that speed, coming to a sudden stop at the end of the ride, there would certainly be serious injuries. Ride designers account for this by building an exit track. The car is attached to this track, which gradually curves toward the ground. A stretch of straight track allows the car to slow down and brake, producing a controlled stop at the bottom, that keeps passengers from getting injured.

The free fall ride at the I-X Indoor Amusement Park is the "Super Shot".
Ride the Super Shot and tell how it felt to be free-falling.



Pendulum

Pendulum rides are a little like the swing sets you might remember from your childhood. Swings give you a feeling of flying in a controlled manner. You pump your legs to provide enough force to increase the height of the swing's arc, and enjoy the increased velocity of the downward swing. When you stop pumping, the swing gradually slows and then stops.

What causes the feeling of "weightlessness" on pendulum rides?
Riders often experience near-weightlessness as they approach the top of a pendulum ride. If the ride is the type that makes a complete 260-degree circle, they experience a feeling of complete weightlessness.

Feelings of weightlessness are not due to a decrease in forces of gravitation; people do not feel forces of gravity. What you feel is the force of a seat (or other external object) pushing on your body with a force to counteract gravity's downward pull. A 100-pound person at rest in his or her chair experiences the seat pushing upwards on their body with a force of 100 pounds. Yet at the top of a pendulum ride, the same 100-pound person will feel less than this normal sensation of weight. At the very top of the pendulum ride, riders begin to all out of their seats. Since a 100-jpound person is no longer in full contact with her seat, the seat is no longer pushing on her with 100 pounds of force. Thus, the rider has a sensation of weighing less than her or her normal weight.

Why do riders experience high g-forces on pendulum rides?
As riders pass through the bottom of the circular arc, they often experience high g-forces. Once again, these g-forces are not evidence of increasing forces of gravitation, but the result of increases in the amount of force applied by the seat upon their bodies. Understanding this demands a little information about circular motion.

The motion of an object in a circle requires that there be a force directed toward the center of the circle (sometimes called a "centripetal force"). This means that at the bottom of the circular swing, there must be an upward force (since the circle's center is upward). Gravitational forces are always directed downward upon a rider's body; thus, gravitational forces cannot meet this centripetal force requirement. The seat must supply the centripetal force, pushing upwards on the rider with a force greater than gravity's downward pull. This is twice the usual amount experienced by our 100-pound rider. For this reason, we would say the rider experiences 2 g's of force (a seat force that is 2 times the gravity force).

Ride the "Skater", "Pharaoh's Fury", or "Yo-Yo".
Tell how the gravitational pull felt at different points of the ride.

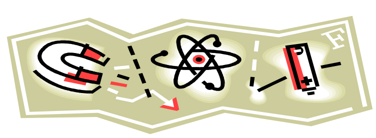
Acceleration
Objects that are changing their speed or their direction are said to be accelerating. The rate at which the speed or direction changes is referred to as acceleration. Some amusement park rides (such as roller coasters) are characterized by rapid changes in speed and or direction. These rides have large accelerations. Rides such as the carousel result in small accelerations; the speed and direction of the riders change gradually.

Balanced and Unbalanced Forces
A balanced force results whenever two or more forces act upon an object in such a way as to exactly counteract each other. As you sit in your seat at this moment, the seat pushes upward with a force equal in strength and opposite in direction to the force of gravity. These two forces are said to balance each other, causing you to remain at rest. If the seat is suddenly pulled out from under you, then you experience an unbalanced force. There is no longer an upward seat force to balance the downward pull of gravity, so you accelerate to the ground.

Centripetal force
Motion along a curve or through a circle is always caused by a centripetal force. This is a force that pushes an object in an inward direction. The moon orbits the earth in a circular motion because a force of gravity pulls on the moon in an inward direction toward the center of its orbit. In a roller coaster loop, riders are pushed inwards toward the center of the loop by forces resulting from the car seat (at the loop's bottom) and by gravity (at the loop's top).

Energy
Energy comes in many forms. The two most important forms for amusement park rides are *kinetic* energy and *potential* energy. In the absence of external forces such as air resistance and friction (two of many), the total amount of an object's energy remains constant. On a coaster ride, energy is rapidly transformed from potential energy to kinetic energy when falling and from kinetic energy to potential energy when rising. Yet the total amount of energy remains constant.

Force
A force is a push or a pull acting upon an object. Forces result from interactions between two objects. Most interactions involve contact. If you hit the wall, the wall hits you back. The contact interaction between your hand and the wall results in a mutual push upon both objects. Bumper cars experience mutual forces acting between them due to contact during a collision. Some forces can act from a distance without actual contact between the two interacting objects. Gravity is one such force.



Friction
Friction is a force that resists the motion of an object. Friction results from the close interaction between two surfaces that are sliding across each other. When you slam on your brakes and your car skids to a stop with locked wheels, it is the force of friction that brings it to a stop. Friction resists the car's motion.

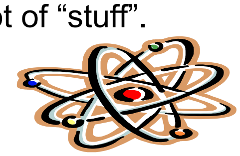
G's
A g is a unit of acceleration equal to the acceleration caused by gravity. Gravity causes free-falling objects on the Earth to change their speeds at rates of about 10 m/s each second. That would be equivalent to a change in speed of 32 ft/s in each consecutive second. If an object is said to experience 3g's of acceleration, then the object is changing its speed at a rate of about 30 m/s every second.

Gravitational force
Any two objects with mass attract each other with a type of force known as a gravitational force. The strength of this force depends upon the mass of the two objects and the distance between them. For objects with masses as large as the earth and the sun, these forces are sizeable and have tremendous influence upon the subsequent motion. For objects such as tow people sitting in a theater the force of gravitation attraction is so small that it is insignificant. Objects on the earth experience noticeable attractions with the earth due to the earth's large mass.

Inertia
Inertia is a tendency of an object to resist change in its state of motion. More massive objects have more inertia; that is, they have more tendency to resist changes in the way they are moving. An elephant has a lot of inertia, for example. On the other hand, a pencil has a small amount of inertia. It's easy to move a pencil from its state of rest. More massive objects have more inertia and thus require more force in order to change their state of motion.

Kinetic energy
Kinetic energy is the energy possessed by an object because of its motion. All moving objects have kinetic energy. The amount of kinetic energy depends upon the mass and speed of the object. A roller coaster car has a lot of kinetic energy if it is moving fast and has a lot of mass. In general, the kinetic energy of a roller coaster rider is at a maximum when the rider reaches a minimum height.

Mass
The mass of an object is a measurement of the amount of material in a substance. Mass refers to how much "stuff" is there. Elephants are very massive, since they contain a lot of "stuff".



Momentum
Momentum pertains to the quantity of motion that an object possesses. Any mass that is in motion has momentum. In fact, momentum depends upon mass and velocity, or in other words, the amount of "stuff" that is moving and how fast the "stuff" is moving. A train of roller coaster cars moving at a high speed has a lot of momentum. A tennis ball moving at a high speed has less momentum. And the building you area in, despite its large mass, has no momentum since it is at rest.

Newton's First Law of Motion
An object at rest or in uniform motion in a straight line will remain at rest or in the same uniform motion unless acted upon by an unbalanced force. This is also known as the law of inertia.

Newton's Second Law of Motion
The acceleration of an object is directly proportional to the total unbalanced force exerted on the object, and is inversely proportional to the mass of the object (in other words, as mass increases, the acceleration has to decrease). The acceleration of an object moves in the same direction as the total force. This is also known as the law of acceleration.

Newton's Third Law of Motion
If one object exerts a force on a second object, the second object exerts a force equal in magnitude and opposite in direction on the object body. This is also known as the law of interaction.

Period
A motion that repeats itself in cyclic fashion is said to be periodic. The time for one complete cycle is known as the period of motion. The motion of a second hand has a period of 60 seconds. The periodic rotation of the earth about its axis is 24 hours. The periodic motion of an amusement park pendulum ride may have a period as high as 10 or 15 seconds.

Potential energy
Potential energy is the energy possessed by an object because of its height above the ground. The amount of potential energy possessed by an object depends on its mass and its height. A roller coaster car is initially hauled by a motor and chain system to the top of a tall hill, giving it a large quantity of potential energy.

Speed
Speed is a measurement of how fast an object is moving. Fast-moving objects can cover large distances in a small amount of time. They are said to have a high speed. A roller coaster car moving at 60 miles per hour would be able to cover a distance of 60 miles in one hour if it could maintain this pace.

Velocity
The velocity of an object refers to the speed and direction in which it moves. If you drive north to your work place and your speedometer reads 35 miles per hour, then your velocity is 35 miles per hour in a northward direction. Velocity is speed with a direction and is important in understanding bumper car collisions.

Weight
Weight is a measurement of the gravitational force acting on an object. The weight of an object is expressed in pounds in the United States. A 120 pound person is experiencing a force of gravitational attraction to the earth equal to 120 pounds.

Weightlessness
Amusement park rides often produce sensations of weightlessness. These sensations result when riders no longer feel an external force acting upon their bodies. At the top of the tower of a free-fall ride, a 100-pound rider would feel 100 pounds of force from the seat pushing as an external force upon her body. The rider feels her normal weight, yet, as she falls from the tower, the seat has fallen out from under her. She no longer feels the external force of the seat and subsequently has a brief sensation of weightlessness. She has not last any weight, but feels as though she has because of the absence of the seat force. In this context, weightlessness is a sensation and not an actual change in weight.

Lesson

Choose one listing from the physics glossary.
List the name of a ride you went on at the I-X Indoor Amusement Park.
Use this listing to describe how this ride at the I-X Indoor Amusement Park uses the laws of physics.