## Things to Consider When Designing Your Coaster

### Acceleration[1]

The rate of change in velocity (the speed of an object in a certain direction) is known as acceleration. Whether an object is speeding up, slowing down, or changing direction, it is accelerating. Most amusement park rides involve acceleration. On a downhill slope or a sharp curve, a ride will probably increase in velocity or positively accelerate. While moving uphill or in a straight line, it may decrease in velocity or negatively accelerate. The force of gravity pulling a roller coaster down hill causes the roller coaster to go faster and faster, it is positively accelerating. The force of gravity causes a roller coaster to go slower and slower when it climbs a hill, the roller coaster is negatively accelerating or going slower. The acceleration of a roller coaster depends on its mass and how strong is the force that is pushing or pulling it.

### Centripetal Force[2]

When the coaster is moving through the loop centripetal force comes into play. This is the force that causes an object to move in a circle. It literally means the "center-seeking" force. For example, when you go down a curved slide on a playgroud, Gravity makes you go down the slide in a straight line but because the slide curves, centripetal force makes you slide along the curve. You think you are being thrown to the outer edge of the slide but gravity is just trying to make you go straight on a curved slide. The coaster will behave in the same way.

To travel in a circle, a force pointing to the inside of the circle, or curve, is needed. The force pointing to the inside is called the centripetal force.

### Energy[3]

Energy is the ability of a body (for example, the roller coaster) to do work.

- Kinetic energy – energy that is being used, the energy caused by motion.
- Potential energy – energy that is stored for later use.
- Law of Conservation of Energy – Energy can change from one form to another but cannot be created or destroyed.

When you ride a roller coaster a motor does the work to get you up the first hill. As the coaster is being pulled up the hill by the motor it is storing more and more potential energy. That potential energy is turned into kinetic energy as gravity pulls you down the first hill. The farther you go down the hill, the more potential energy is changed into kinetic energy, which you feel as speed. The ride goes fastest at the bottom of the hill because more and more of the potential energy has been changed to kinetic energy.

As you go up the next hill, kinetic energy is changed into potential energy and the ride slows down. The higher you go, the more energy is changed and you feel the car slow down. This conversion of kinetic energy to potential energy and vice versa continues as you go up and down hills for the rest of the ride. The total energy does not increase or decrease; it just changes from one form to the other. Notice that the first or lift hill is the highest point in the coaster. Why is that?

However, some of the energy is changed into friction. Wind resistance, the rolling of the wheels, and other factors all use some of the energy. Coaster designers know that friction plays a part in the ride. Therefore, they make each successive hill lower so that the coaster will be able to make it over each peak.

A roller coaster works because of two things: gravity and the law of conservation of energy. A roller coaster is similar to a slide except it is longer and you ride in a train car rather than on the seat of your pants. The wheels reduce friction: it's easier to let something roll than to let it slide.

**Forces**[4]

Force is a push or pull. Balanced forces are equal forces that are applied in opposite directions and result in no change in velocity. Unbalanced forces are forces that are not equal and opposite, and they result in a change in velocity.

If objects have to touch for the force to be applied, the force is a contact force. If force can be applied without objects touching, the force is a noncontact force.

## Friction[5]

Friction is a force that works in the opposite direction of an object that is moving along a surface. Friction can come in many forms, but it always resists motion. The amount of friction depends mainly on the materials involved.

Accompanying all motion is friction[6], the resistance produced when two surfaces rub together. No surface is perfectly smooth. The tiny ridges in a "smooth surface or the larger bumps and hollows in a rough one, catch and resist when the surfaces rub together. Surface pressure is another condition that affects friction. A heavy object has more friction than a lighter one.

However some of the energy is changed into friction. Coaster designers know that friction plays a part in the ride. Therefore, they make each successive hill lower so that the coaster will be able to make it over each peak.[7] Coaster designers also take advantage of friction to slow the coaster and bring it to a safe stop when breaks are applied at the end of the ride.

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## Gravity[6]

The most interesting and significant force that acts on a roller coaster is the force of gravity. Gravity is the force that pulls all objects in the universe toward one another. The effective acceleration or deceleration due to gravity depends on the inclined angle of the track relative to ground; the steeper the slope is the greater the effective acceleration.

## G's[7]

A unit that is commonly used to describe forces we feel is the g. One g is equal to the force of earth's gravity. When the space shuttle takes off, the astronauts feel about 3 g's of force (three times the force of earth's gravity).[9] The astronaut feels this increased g force because he/she is moving against gravity. As a result, he/she feels very heavy or the sensation of being pulled back to Earth.

## Inertia[10]

If a body, for example a roller coaster, is standing still, it won't want to move unless some force pushes or pulls it. This resistance of the roller coaster to move is called inertia. The more mass a body has the more inertia it has.

If the roller coaster is moving, it will want to keep moving, along the direction of motion, unless something causes it to speed up or slow down. This resistance of the moving roller coaster to changing its velocity is another example of its inertia. Again, the greater the mass of the body, the more inertia it has.

## Momentum[13]

An object's momentum is its mass multiplied by its velocity. If its mass or velocity is large, an object will have a large momentum. The more momentum an object has, the harder it is to stop the object or change the object's direction. Objects' momentums increase or decrease when changes in speed occur.

## Sir Isaac Newton[14]

Newton was one of the most influential scientists of the seventeenth century. He discovered three basic laws that explain all aspects of motion. To build a roller coaster it is very useful to know something about these famous laws.

Newton's first law of motion states that objects at rest tend to stay at rest, and objects that are moving tend to continue moving. This tendency of objects to resist changes in motion is called inertia.

Newton's second law of motion states that when an unbalanced force is applied to an object the object accelerates. The law goes on to say that the amount of acceleration depends on the mass of the object and the amount of force applied to it. A greater force applied to an object results in greater acceleration. Increases in mass result in less acceleration.

Newton's third law of motion states that for every force there is an equal and opposite force. These forces are called action forces and reaction forces.

Simply stated Newton's three laws of motion are[15]

1. An object moving in a straight line will keep moving in that direction unless acted on by an outside force.
2. If an object is moved by a force, it will move in the direction of the force. Also the greater the force, the faster the object moves.
3. For every action there is an equal and opposite reaction.

**Weightlessness[19]**

There are two ways to experience weightlessness. (1) Move far enough away from the planets and sun to where their pull is nearly zero. [Gravity acts over infinite distance. One can never completely escape it.] (2) Fall down at a rate equal to the pull of gravity. In other words, accelerate to the Earth speeding up 22 mph every second in the air. In order for a person to feel weight, a person must sense the reaction force of the ground pushing in the opposite direction of gravity.

In the absence of the reaction force a person will sink through the ground. Many amusement park rides generate the weightless sensation by accelerating down at close to 22 mph every second.