Excerpt from “How RollerCoasters Work” from essortment.com

Roller coasters are a classic example of "what goes up must come down." How these scream machines operate, however, is far more complex.

Types of Roller Coasters

There are two basic types of roller coasters: steel and wooden. The type of coaster is determined by the type of track it runs along. A steel roller coaster runs on tubular steel rails. Usually hollow, the rails may be filled with sand or another dense material to help dampen the sound, especially in metropolitan areas with restrictions on noise level. Steel coasters typically have a steel support structure, but there are coasters with steel rails that have wooden supports. It is still the type of running rail, however, that defines the coaster as steel.

A wooden coaster runs on strips of laminated wood track topped with a steel strap. The most common types of wood used for coaster construction are Douglas fir and southern yellow pine because they readily accept the pressure treatment necessary to make the wood more durable. Most wooden coasters have a wooden support structure, but it is possible to build a steel support structure and still use the wooden rails that define the type of coaster.

Because wood is naturally less durable than steel, a wooden coaster cannot have such tight turns or steep hills. Wooden coasters have a different type of appeal, however, due to the shaky, out-of-control feel of the ride. No wooden coaster can have any inversions, however, because of the nature of the track. Only one wooden coaster, Son of Beast at Paramount's Kings Island in Ohio, has an inversion - a vertical loop - but the loop is constructed out of steel and the coaster is designed to transition between the two types of track.

Wooden coasters have two basic layouts: out-and-back and twister. An out-and-back coaster travels along its course, makes a one-hundred-eighty degree turn, and returns to the station parallel to the outbound course. A twister design weaves throughout the structure of the ride, often traveling above and below portions of its own track.

Physics of Roller Coasters

Despite the differences between steel and wooden coasters, each style operates under the same laws of physics, applying them in different ways to achieve the ultimate thrill.

Gravity is the primary force that drives all roller coasters. Once a coaster has crested the highest point along its course, usually a tall hill at the beginning of the circuit, gravity provides the force that controls the speed of the ride.

When a coaster is at the highest point of its track, it has high potential energy (energy of position). As the coaster accelerates down the hill, that potential energy changes into kinetic energy (energy of motion). Each time the coaster goes up another hill, the kinetic energy becomes potential energy again, and the cycle continues. Ideally, the total amount of energy would remain the same, but some is lost to friction between the wheels and the rails, wind drag along the train, and friction applied by the brakes. Because of this energy loss, each successive hill along a coaster track must be smaller than the previous hill in order for the train to continue along the course.

Roller coasters rely heavily on inertia to thrill riders. Inertia is the reluctance of a body (such as a coaster train) to change its state of motion. For example, a coaster train that is accelerating down a steep hill will resist the change in direction to head up the next hill, through an inversion, or around a curve. Riders feel that resistance as g-force, making their bodies feel heavier. Similarly, a coaster train that is racing up a hill is resistant to the change in direction that forces it down the hill, and that resistance can be felt as a negative g-force, or what coaster enthusiasts call "airtime" - momentary weightlessness as the coaster travels over the crest of the hill.

Using the Laws of Physics

Engineers design roller coasters to take advantage of the laws of physics whenever possible. Most coaster stations, or platforms, are slanted to take advantage of gravity to begin the ride: when the station brakes are released, the coaster will succumb to gravity and begin rolling out of the station. That provides the initial velocity needed for the coaster to reach the lift hill, where the real ride begins.

The most common type of lift hill is the chain lift. Coaster trains have small metal protrusions, called chain dogs, beneath two or more cars. When the train reaches the lift hill, the chain dogs fit into the sprockets of the chain, and the train is lifted up the hill. At the top of the hill, the chain dogs disengage as the chain wraps underneath the lift hill, and the train begins to coast along the track. A number of coasters prolong the ride by using a second chain lift midway through the course.

Engineers carefully use the concepts of inertia, g-forces, and airtime to create a ride that delivers safe thrills while still feeling out-of-control. For example, if a hill is shorter than necessary, the coaster will have more inertia at the crest, and more airtime will be felt. Tighter turns also create higher g-forces, pushing riders side-to-side. Use of these forces, however, must be carefully balanced with rider safety and ride maintenance. Engineers are always developing smoother transitions between different sections of the track to minimize any hazards.

Fighting the Laws of Physics

By its very design and the nature of the laws of physics, a roller coaster wants to fly off the track. The wheel design on coaster trains, however, prevents any such accident. There are three types of coaster wheels: running wheels, guide wheels, and upstop wheels.

Running wheels are the largest wheels on the coaster, and they support the weight of the train. They may be flanged or rimmed wheels, or else grooved to fit snugly along the rails.

Guide wheels are arranged on the sides of the coaster train, and provide stability during tight turns, keeping the coaster train from rubbing the structure of the ride. Depending on the construction of the track, these wheels may be positioned either outside or inside the rails.

Upstop wheels are smaller wheels on the underside of the rails that keep the train locked to the track. These wheels allow coasters to have more airtime because they eliminate any danger of the train leaving the track. Older coasters may use an upstop bar rather than an actual wheel, but the purpose is the same.

There are times when a coaster is subjected to too much gravity for a safe ride. A rollback can occur when a coaster fails to crest a hill and instead begins to move backward. Coaster trains, however, are equipped with anti-rollbacks paired with the chain dogs. One set of the metal protrusions functions to engage the chain, while the other set is parallel to the chain and can engage ratchets to prevent a rollback. If a lift chain were to break, the anti-rollbacks would hook into those ratchets and stop the train from moving backward. Similarly, many coasters have sets of anti-rollback ratchets at the crests of hills throughout the track, in case a train may not have enough speed to complete the course. These ratchets create the familiar clackety-clackety sound a coaster makes when going up a lift hill or crossing over these safetydevices.

Hitting the Brakes

Naturally, every coaster ride has to come to an end. There are two types of braking systems that bring coasters to a smooth, safe finish: sled brakes and fin brakes. In addition, block brakes and trim brakes help to control a coaster's speed throughout the course of the ride.

Sled brakes, also called skid brakes, are long, flat bars positioned between the rails of the track. Usually operated manually by a long lever, they are raised to make contact with brake shoes on the underside of the coaster train.

Through friction, the train is brought to a safe stop. These types of brakes are more prevalent on older wooden coasters and have largely been replaced by more modern systems in recent decades.

Fin or squeeze brakes are the most common types of brakes on coasters today. Long metal fins are attached either beneath or on the sides of the coaster train, and pneumatic (air pressure) clamps are used to grip them and bring the train to a halt.

Block brakes are used on many coasters as a safety feature along the course. These brakes operate the same as either the sled or fin brakes in the station, and are capable of fully stopping the train in case of an emergency.

Many coasters employ trim brakes to literally trim excess speed from a coaster train as it travels along the course. These brakes cannot completely stop a train, but they do help control the spacing of multiple trains along the track and reduce wear and tear that would ultimately increase maintenance costs.