Roller coaster physics

Business, Industries

Individuals love to go to the amusement parks and try out the rides that are available. The most common and thrilling ride is the roller coaster. An amusement park is not an amusement park if it does not contain a roller coaster. What makes these roller coasters so fun that every amuse parks has one. A lot of people would say it is their extreme high speeds that makes it very exciting. That is a valid answer, but it is the wrong answer. The speed has nothing to do with the excitement.

It is more than likely that most people travel faster on their ride along the highway on the way to the amusement park than they would in a roller coaster. Basically the thrill all comes from the acceleration and the feeling of weightlessness that they produce. Roller coasters thrill people because of their ability to accelerate them downward one moment and upwards the next; leftwards one moment and rightwards the next. How does this thrill machine work? There are two ways that this question will be answered. First, through the basic principles and then through a more advanced explanation.

Roller coaster rides involve a great deal of physics. The ride often begins with a chain and motor which exerts a force on the train of cars to lift the train to the top of a tall hill. Once the cars are lifted to the top of the hill, gravity takes over and the rest of the ride works on energy transformation. There is no motor or engine that takes a train around the track. The law of physics is basically the engine of the train. At the top of the hill, the cars possess a large amount of potential energy because they are elevated very high above the ground.

The potential energy depends on the mass and the height of the object. As the cars are released they lose a lot of their potential energy but they gain kinetic energy because all of the potential energy is transferred into kinetic energy. The kinetic energy depends on the mass of the object and the speed of the object. As the cars lose speed, they also lose kinetic energy, but that does not stop the whole thing, inertia is what keeps the cars moving. While the cars might slow down when they approach a new hill, it is inertia which moves it forward.

Once cars go through loops, turns and smaller hills, the only forces that act upon the cars are the force of gravity, the normal force and dissipative forces such as air resistance. The force of gravity is an internal force and any work done by it does not change the total mechanical energy of the train of cars. The normal force of the track pushing up on the cars is an external force and it always times acts perpendicular to the motion of the cars and it is unable of doing any work to the train of cars.

Air resistance if a force capable of doing work on the cars and taking away a bit of energy from the total mechanical energy which the cars possess. Due to the complexity of this force and the small role that it plays on the large quantity of energy possessed by the cars, it is often neglected. By neglecting air resistance, it can be said that the total mechanical energy of the train of cars is conserved during the ride. That is to say, the total amount of mechanical energy possessed by the cars is the same throughout the ride. Energy is not gained or lost, only transformed from kinetic energy to potential energy and vice versa.

Now that the basics are understood, we can get into more complex things, such as the physics of making a roller coaster amusing. We have said that it is the acceleration that makes it exciting. The most exciting part of a roller coaster is when it approaches the loops, and centripetal acceleration occurs within those loops. The most common loop of a roller coaster ride is the loop that looks like a tear drop, it is not a perfect circle. These loops are called clothoid loops. A clothoid is a section of a spiral in which the radius is constantly changing, unlike a circle where the radius is constant.

The radius at the bottom of a clothoid loop is much larger than the radius at the top of the clothoid loop. As a roller coaster rider travels through a clothoid loop, he/she will experiences an acceleration due to both a change in speed and a change in direction. A rightward moving rider gradually becomes an upward moving rider, then a leftward moving rider, then a downward moving rider, before finally becoming a rightward-moving rider once again. There is a continuing change in the direction of the rider as he/she will moves through the clothoid loop. A change in direction is one thing of an accelerating object.

The rider also changes speed. As the rider begins to climb upward the loop, he/she begins to slow down. What we talked about suggests that an increase in height results in a decrease in kinetic energy and speed and a decrease in height results in an increase in kinetic energy and speed. So the rider experiences the greatest speeds at the bottom of the loop. The change in speed as the rider moves through the loop is the second part of acceleration which the riders experiences. A rider who moves through a circular loop with a constant speed, the acceleration is centripetal and towards the center of he circle. In this case of a rider moving through a noncircular loop at non-constant speed, the acceleration of the rider has two components. There is a component which is directed towards the center of the circle (ac) and relates itself to the direction change and the other component is directed tangent (at) to the track and relates itself to the car's change in speed. This tangential component would be directed opposite the direction of the car's motion as its speed decreases and in the same direction as the car's motion as its speed.

At the very top and the very bottom of the loop, the acceleration is primarily directed towards the center of the circle. At the top, this would be in the downward direction and at the bottom of the loop it would be in the upward direction. Inward acceleration of an object is caused by an inward net force. Circular motion or curved path such as a clothiod requires an inwards component of net force. If all the forces which act upon the object are added together as vectors, then the net force would be directed inwards.

Neglecting friction and air resistance, a roller coaster car will experience two forces which I have mentioned earlier. The normal force is always acting in a direction perpendicular to the track and the gravitational force is always acts downwards. We will discuss the relative magnitude and direction of these two forces for the top and the bottom of the loop. At the bottom of the loop, the track pushes upwards upon the car with a normal force. However, at the top of the loop the normal force is directed downwards because the track is above the car, it pushes downwards upon the car.

The magnitude of the force of gravity acting upon the passenger (or car) can easily be found using the equation Fgrav = m*g where g = acceleration of gravity (approx. 10 m/s2). The magnitude of the normal force depends on two factors which are the speed of the car, the radius of the loop and the mass of the rider. The normal force is always greater at the bottom of the loop than it is at the top. The normal force must always be of the appropriate size to combine with the force of gravity in a way to make the required inward or centripetal net force.

At the bottom of the loop, the force of gravity points outwards away from the center of the loop. The normal force must be sufficiently large to overcome this force of gravity and supply some excess force to result in a net inward force. Basically the force of gravity and the force of normal are playing a tug of war and force of normal must win by an amount equal to the net force. At the top of the loop, both forces are directed inwards. The force of gravity is found in the usual way using the equation Fgrav = m*g. Once more the normal force must provide sufficient force to produce the required inward or centripetal net force.