Kristiyan Kurtev
Teammate #1
Teammate #2
Teammate #3
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Roller Coaster Journal and Report

NOTE: This is a shortened version of the original text

Roller Coaster

Introduction

Roller coasters have become the heart of amusement parks around the world. Numerous thrill-seekers enjoy riding modern roller coasters consisting of bends along the tracks and even loops where the riders hang upside down. The roller coaster industry has traveled a long way since the first commercial roller coaster was constructed - the Switchback Railway, which debuted at Coney Island on June 13, 1884 (*First Roller Coaster in America Opens - HISTORY*). This roller coaster had a meager top speed of 6mph, in sharp contrast with modern roller coasters, the fastest of which is the Formula Rossa in Abu Dhabi, which reaches a top speed of 149 mph. (*Ferrari World, Home of the World's Fastest Roller Coaster*, n.d.)

In the twentieth century, roller coasters have evolved a long way from the old and slow Switchback Railway. Nowadays, roller coasters have acquired various thrilling elements, some of which include the vertical loop, the saxophone, the corkscrew, the helix, and many

others. And with the constantly transforming new developments in roller coasters, roller coaster manufacturers changed as well. For instance, the legendary rides manufacturer - Arrow Dynamics, which dominated the roller coaster industry for over 30 years, went bankrupt, only to be replaced by S&S Arrow (Later, S&S Worldwide), the current leader in roller coaster manufacturing. (*Legacy of Arrow*, n.d.)

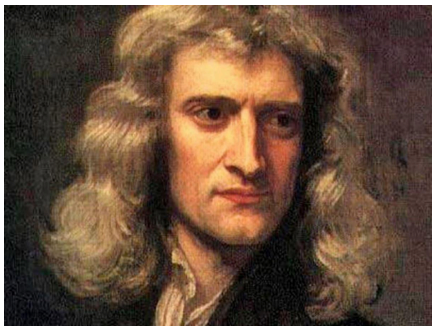
Our group designed and manufactured the Shockwave - a unique roller coaster model. Let's check out how it works!

Describe your Roller Coaster:

The roller coaster is going to start at ground level, a mechanism will lift it to the top of the roller coaster. From there, the track curves, and then descends until it reaches a loop (an inversion). Finally, the track curves to the right, and reaches the beginning of the roller coaster closing the loop. As the marble circles back to the beginning of the loop, one of the "seats" (ledges made out of popsicle sticks and toothpicks) will carry the marble back to the peak of the roller coaster and start the cycle again.

Body / Science: Explained

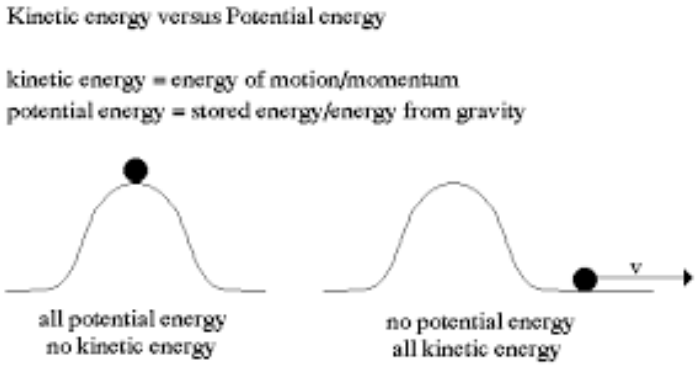
In order for us to achieve our goal of building a model roller coaster, we had to be knowledgeable regarding physics concepts such as interia, centripetal acceleration, gravitational force, potential energy, transformation of energy, kinetic energy, velocity, force, magnetic forces, and Newton's Laws of Motion.



Isaac Newton was an English mathematician, physicist, astronomer, alchemist, and author. "He was widely recognised as one of the greatest mathematicians and physicists of all time and among the most

influential scientists." His book Mathematical Principles of Natural Philosophy was first published in 1687 establishing "classical mechanics".

When the marble is at the top of a hill, the marble possesses potential energy. When the marble is released, it will convert that potential energy into kinetic energy (the energy of motion), causing the marble to start rolling downhill, and when the marble starts rolling uphill, kinetic energy is lost and some potential energy is gained (energy cannot be created or destroyed). This example demonstrates potential and kinetic energy. And following the same example, in order for the moving marble to climb the next hill, the amount of potential energy that it possessed would have to be enough for it to be able to roll along the roller coaster and climb the next hill. (*Potential and Kinetic Energy Explained | Education Overview*, n.d.)



In addition, our research also shows that the main driving force of the roller coaster is gravity, since the coaster has no engine. This is actually the reason roller coasters tend to be short - the boost provided by the largest drop is not infinite. When gravity is pulling the marble toward the ground, it is causing the marble to increase its speed (acceleration), and when the marble is climbing up a hill, the marble decreases its speed (deceleration).

The first scientific studies of gravity were performed by an Italian astronomer Galileo Galilei. He discovered that when objects fall, gravity imposes a constant acceleration on all objects regardless of their mass. The size of the object doesn't matter, it will fall at the same rate of acceleration. This claim disproved Aristotle's idea that heavier objects will fall faster than

lighter objects. Galileo's principle only holds true in a vacuum, since there isn't any air resistance to slow the objects down, and air resistance exerts different amounts of force on different objects. For example, in a vacuum, a feather and a metal ball will fall at the same time, while in the air, air resistance will put more force into the feather, making it fall slower.

Around the same time as Galileo, an astronomer named Johannes Kepler studied celestial objects, and proposed three laws that described the positions and movements of the planets as they traveled around the Sun.

Scientist Issac Newton said that the gravity that makes objects fall towards the ground and that the force that keeps the Moon in Earth's orbit are the same. In his book Mathematical Principles of Natural Philosophy, Newton explained that both Galileo's observations and Kepler's laws could be described by a single law - the law of universal gravitation.

What is the law of universal gravitation?

“The force of gravity between two objects increases as their respective masses increase; the greater the mass, the greater the gravitational force exerted.”

“The gravitational force between two objects decreases as the distance between them increases. That is, the more distant two objects are from each other, the less their mutual gravitational attraction; conversely, the closer two objects are, the greater the attraction between them.”

Also in the Mathematical Principles of Natural Philosophy Newton mathematically defined the concept that any force is equal to the mass of the object on which the force is applied, times the acceleration that results from the force. Looking at the formula below, F stands for force, m stands for mass, and a stands for acceleration:

$$\vec{F} = m\vec{a}$$

This shows that the force of gravity increases proportionately to the mass of the object that is accelerated, and that acceleration remains the same. This confirmed Galileo's observation that all objects on Earth, regardless of mass, are accelerated by Earth's gravity to the same extent.

Friction is also present in roller coasters – it occurs when the marble rubs with the track. The friction works in the opposite direction that the marble is trying to move. Coasters are sometimes oiled to reduce friction, but eliminating friction completely is not desirable. Friction causes the speed of the marble to decrease, since part of the kinetic energy is transformed into heat, and because friction is the force that resists the motion of the object that it touches, the total amount of kinetic and potential energy lost due to friction can never exceed the initial potential energy in the beginning of the hill due to the law of conservation of energy. Roller coasters can be stopped with friction brakes, or more modern eddy-current brakes.

There are two types of friction - static and kinetic. Static friction occurs when two surfaces aren't moving relative to each other, while kinetic friction occurs when two

objects are in motion. Kinetic friction is present within our roller coaster when the ball rubs with the track (the ball is moving).

Inertia is the tendency of objects to remain in motion until acted upon by forces such as friction. The concept of inertia is undoubtedly present within our roller coaster. When the marble travels along the track, it exhibits this property, since the object is in motion. In addition, inertia can connect with Newton's first law of motion, which states that "an object at rest remains at rest, and an object in motion remains in motion at [a] constant speed and in a straight line unless acted on by an unbalanced force."(*Examples of Inertia*, n.d.)

Centripetal acceleration occurs when objects travel in a circular path, such as our inversion. The acceleration alters due to the direction it is going in, which is shown within the routes of our roller coaster, since there are circular or round paths for the marble to travel along. Sharp turns and angles can change the direction and energy of the ball. (*Centripetal Acceleration | Definition, Formula, Units, & Facts*, n.d.)

Conclusion

In conclusion, using the research about physics and science that we made, we were able to produce a working model of a rollercoaster. This project as a whole, including the journal as well as the physical build of the rollercoaster, took more than three weeks to complete. Additionally, when we worked on our roller coaster, we were surprised at how delicate the mechanism was. If the pressure of more than a couple marbles was applied to the lifting

mechanism, the whole device would start to shudder. This happens because the weight was too much for the motor to handle.

Due to our experience with handling our roller coaster, we were able to make the necessary adjustments in order to fulfill the amount of gravity, potential and kinetic energy, inertia and velocity needed to make the roller coaster work.

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