FORCES IN A ROLLER COASTER

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The roller coaster, a thrilling, modern invention that is a great example of Newton's Laws of Motion. Roller coasters, with their twists, turns, and loops seem to defy everything we know about how people and objects move. Roller coaster designers, however, simply use Newton's laws to push people past their usual limits for an exciting ride. Some early roller coasters, like Coney Island's Flip Flap, even caused whiplash and broken necks due to abrupt high g-forces (force of gravity). Today roller coasters thrill us, because of their ability to accelerate us downwards one moment and upwards the next, then left, then right and then left again, and all while keeping us safe due to the hard work of engineers that employ and understand the mathematics behind Newton's Laws of Motion.

Newton's First Law is the Law of ***Inertia***. This states that an object at rest stays at rest, or an object in motion stays in motion until acted on by unbalanced force(s). Roller coasters are ruled by the Law of Inertia. Since an object at rest, stays at rest, at the beginning of the ride a stationary roller coaster is at rest and will need to be pushed or pulled along to get it started. Most are pulled up a large hill called a lift hill. The first hill in a conventional roller coaster is always the biggest hill. As the cars go uphill, they store potential energy. Once the cars are put into motion (potential is allowed to be converted into kinetic energy), they will not stop again until the brakes are applied at the end of the ride. The cars are slowed (negative acceleration) eventually to a stop, because of unbalanced forces due to friction acting on them.

The riders, which have inertia, are also acted on by unbalanced forces throughout the ride causing them to change their motion. At the top of hills riders rise up in their seats and at the bottom of hills are pushed down deeper into their seats. Inertia might throw a passenger from a car even, but thankfully, the seats belts or safety bars act as an unbalanced force too, on the riders and holds them down to the seat. When a rider gets to the bottom of a hill, the body is still moving downwards, but the seat starts pushes back holding your body in place. Going around turns the riders are acted on by the cars and seat belts, and again overcome inertia to halt the motion of the body from side to side.

Newton's Second Law is that of ***Force*** equaling *mass* multiplied by *acceleration* (F=ma). The law states that the acceleration of an object depends on the object's mass and magnitude (strength) or the ***force*** acting upon it. You feel this second law when you start going down the hills. Coaster cars and your body have mass. Gravity exerts a force on that mass, which can then cause it to accelerate. The rider feels that force as one moves along the coaster track. The track directs this force on the cars as you race along. The mass of the cars and your body are a *constant*, thus remain the same from start to finish. The amount of ***force*** a rider experiences, varies only with the acceleration of the cars along the track. As the roller coaster speeds up (positive acceleration) racing downhill or turning abruptly, the amount of force a rider fells increases. As the roller coaster slows down (deceleration) due to friction between the wheels and the track or air rushing by, the forces a rider feels ease off. Variables an engineer might consider to change the force experienced by the rider include, heightening the coaster, added loops, and sharp turns or increasing the mass of the cars. Regardless of the coaster design aspects or variables one may consider, all of these variables fall into the category of acceleration or mass when calculating the *force* experienced by a rider.

Newton's Third Law is that of ***Action-Reaction*** which states that for every action there is an equal and opposite reaction. This means that as you are pushed down, further and further in your seat, the seat is pushing back at you. This law comes into play with newer roller coasters too that expose riders to higher G-forces. "G-forces" relate to the acceleration on a body to due to gravity. What happens to your body in a 2 G-force turn? Your body accelerates so rapidly that it experiences *forces* twice that of the normal force of gravity. Older coasters did not expose riders to very many G-forces as they relied typically only on the force of gravity to accelerate riders. Newer coasters may catapult, sling or use hydraulic or jet forms of propulsion to accelerate riders along faster and faster. These newer coasters have created exciting ways to create ***action,*** which you in turn the rider experience as a ***reaction*** on your body.

Friction is a force that opposes (goes against or opposite to) the motion of an object. If the roller coaster cars are moving to the east, the force of friction is to the west. The force of friction acts on the moving cars, decreasing the total amount of mechanical energy in the roller coaster. The mechanical energy is not lost, however. It is transformed into thermal energy, which can be detected as an increase in the temperature of the roller coaster track and car wheels. Because of friction between the coaster cars and the track, and let's not forget air resistance (fluid friction) as the cars move forward the amount of mechanical energy available decreases throughout the ride, and that is why the first hill of a roller coaster must always be the tallest. The force of forward momentum slowly depreciates throughout the ride. At the end of the ride friction between the wheels and the track or wheels and their brakes slowly wins out and the cars come to a halt. The harder the brakes are applied the more rapidly the coaster come to a stop also known as deceleration.

Writing Assignment Details –part of your Authentic Final Assessment in this course is as follows.

Your challenge - How to build, construct and engineer a faster roller coaster?

- In the boxes below, form a first draft for your argument.
- Your essay must contain these four paragraphs (minimum).

Paragraph structure

- First sentence: reiterate Newton's Law in your own words. Second sentence: relate the concept to a roller coaster. Then explain how you might take advantage of these laws of physics to design your own dream roller coaster.
- Then expand on your ideas and include details about your roller coaster and how you might make it faster, more exciting, exhilarating, perhaps include a theme, etc.

Once you have completed hashing out your ideas in the boxes you can then continue by composing more complete thorough well thought out essay paragraphs on lined paper.

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Main idea: Newton's First Law

Main idea: Newton's Second Law

Main idea: Newton's Third Law

Main idea: How friction is related to a roller coaster