Roller Coaster Physics

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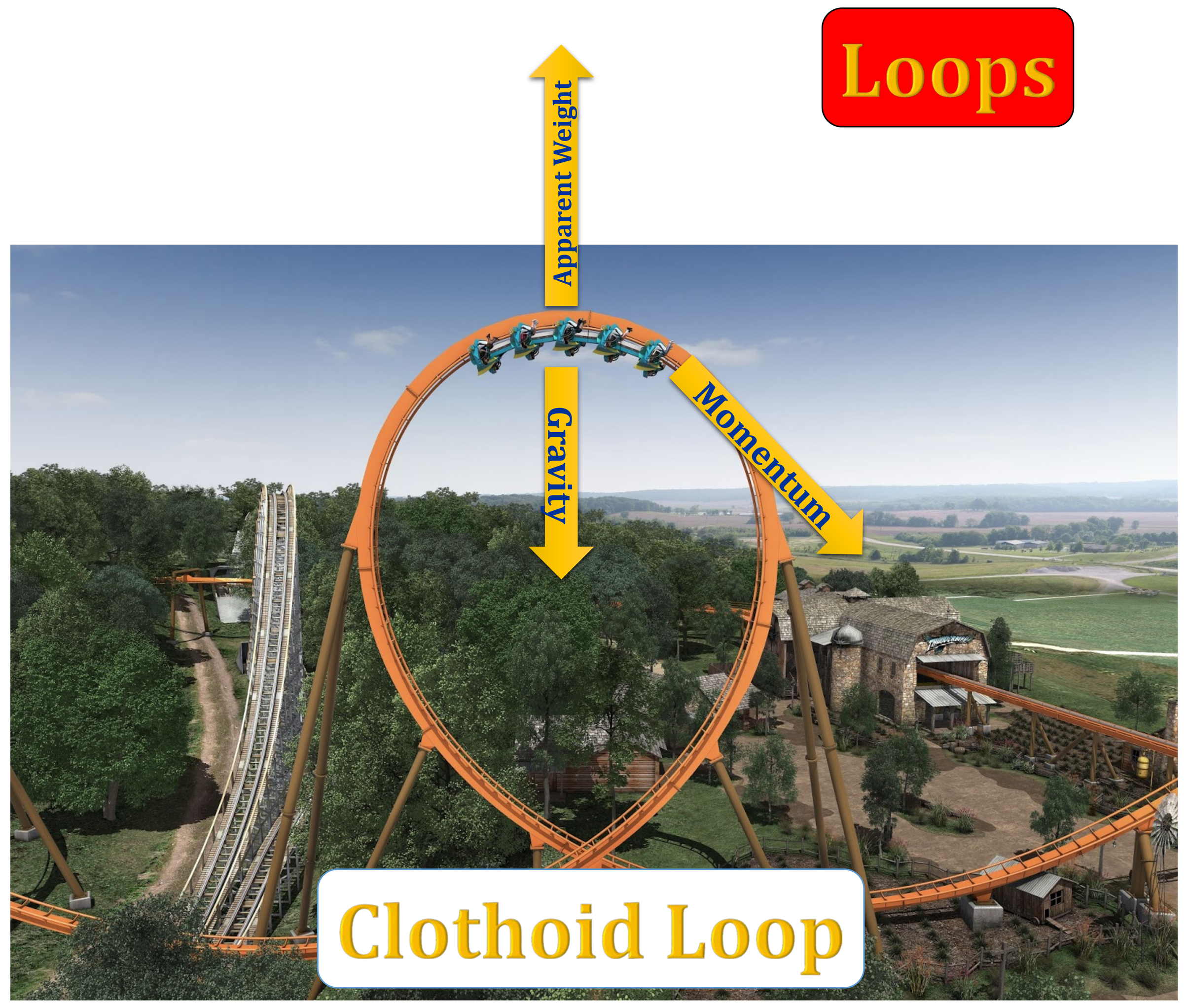
Overall

Roller Coaster engineers do more than just make rides for the public's enjoyment. They keep Theme Park-enthusiasts safe. The amount of Physics and Calculus that goes into designing a Roller Coaster track and its carts and harnesses is extensive. One miscalculation can send many people to the hospital or even their deaths.

Keep arms and legs inside the vehicle at all times.

Loops



Roller Coaster Engineers find that the Clothoid loop is much more efficient and realistic to build. If roller coaster loops were perfectly circular, the cars would have to reach a much higher speed to complete the loop due to the larger radius.

In addition, the Clothoid makes the ride much more enjoyable for the riders. In some cases, the G-force load the riders would experience from the perfectly circular loop would cause not only great discomfort but even death.

G-forces must be considered. Astronauts have to be trained to withstand high G-forces, but the average human can only withstand up to approximately 4 to 5 G's or -2 to -3 G's before passing out.

$$KE = \frac{1}{2}(mv^2)$$

$$GPE = (m)(g)(h)$$

$$ME = KE + PE$$

$$F_c = \left(\frac{mv^2}{r}\right)$$

$$F_D = C_D A\rho v^2$$

$$F_f = \mu N$$

Centripetal force is the force that keeps the passengers in the cars and the cars on the tracks. Centripetal Force isn't a force like gravity. It is the sum of several forces acting on an object in circular motion. When dealing with circular motion, the acceleration points toward the center of the circle. The sum of the forces at the top of the loop in the y direction (vertical) is zero, therefore the car does not fall, but continues along its path in the x direction.

Banked Turns

Banked turns are not only fun, but they also serve a purpose.

When an object is moving at a high velocity in a certain direction, it is going to want to keep on moving in that same direction (rule of inertia). With normal turns, the car feels inclined to come off the track (or at least jerk the passengers around during turns). At a high enough speed, the passengers feel the force of the acceleration (extra G's) and the change in their apparent weight.

With banked turns, the shift in direction is eased since the change is direction is more gradual. The force of acceleration felt by the passenger is alleviated and the ride is made safer as well as more enjoyable.

Note that when calculating the velocity around a banked turn the engineers must use a titled coordinate system to solve for the vectors.

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Energy: The Ride

Although brakes are required by official roller coaster standards, through the calculation of mechanical energy, the roller coaster should come to somewhat of a stop by the end of the ride.

The Law Conservation of Energy states that the roller coaster should have the same energy at the end of the ride as it does at the top of the first hill.

$$PE_i + KE_i = PE_f + KE_f$$

However, energy is not conserved throughout the course of the ride. Friction (F_f), air resistance (F_D), and several other factors contribute to a loss of energy.

Because kinetic energy is the energy of the coaster in motion, the engineers must calculate a situation in which the kinetic energy is equal to zero (or close to zero and interact with the breaking system) at the end of the ride. A miscalculation could result in the car smashing through the station or the car failing to finish the entire course of the track.

Kinetic Energy (KE) involves mass. This can lead to another safety issue. If the mass of the car and passengers combined is greater than the allowed mass, the roller coaster can malfunction and pick up too much speed. If the brakes are not properly prepared for the car to have attained a certain speed then a crash is inevitable.

References

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