Designing the Perfect Rollercoaster

July 22, 2015
By Leanne Gunn

Whether you love the feeling of flying through the air on a roller coaster or can't think of anything worse, the simple fact that rollercoasters have ever been designed and built is a testimony to engineering.

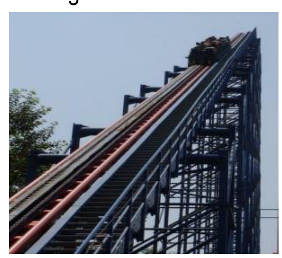
Takabisha at Fuji-Q Highland theme park in Japan opened in July 2011 and still holds the title of the worlds steepest rollercoaster.

P1 Engineering is a rapidly advancing field. As new ways are discovered to exploit and manipulate physics we see new roller coasters being designed, built and opened, each one boasting to be somehow different from any rollercoaster that has been build before. Despite building more and more extreme rides for the enjoyment of thrill seekers, rollercoaster designers still need to maintain a careful balance between speed, height and safety. Too fast and the ride becomes too intense, too many turns and loops and it is simply nauseating, and if the ride is too slow the rollercoaster train will never reach the end of the track.

So how do they do it? What things need to be considered when building the perfect rollercoaster?

Power and Speed

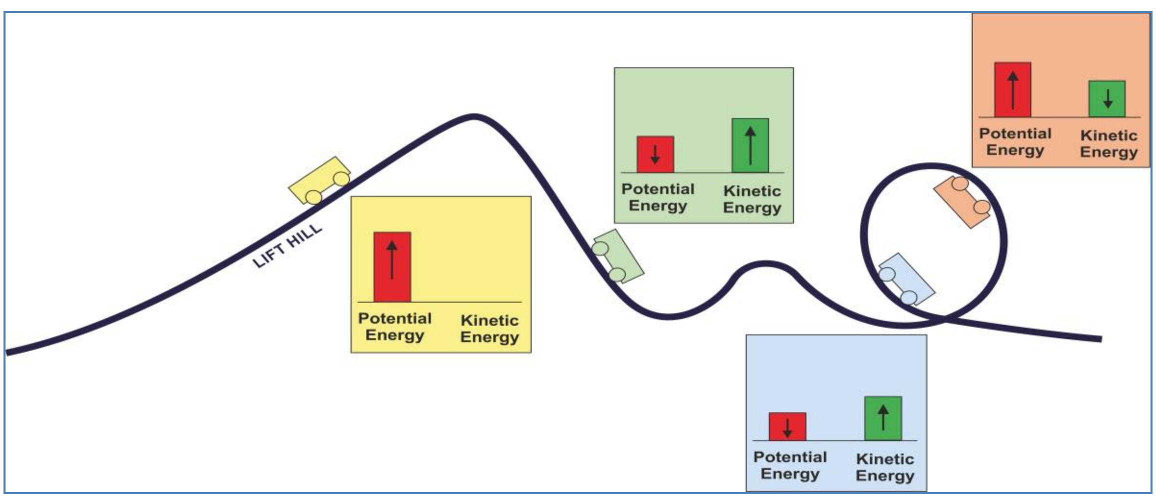
P2 Rollercoaster trains are not powered. They do not have their own engine to regulate their speed and keep them moving around the track. Instead the majority of the ride is powered by gravity alone.



P3 This is why traditional rollercoasters begin with a long high hill followed by a big drop. This 'lift hill' consists of a long length of chain running up the hill beneath the track and fastened in a loop. The loop is wound around two gears; one at the top and one at the bottom. The bottom gear is turned using a simple motor causing the chain to move in an uphill direction, much like a conveyor belt.

P4 Rollercoaster cars and trains are built with special hinged hooks beneath them called **Chain Dogs**. When the train rolls onto the hill these hooks latch onto the chain and it is gradually pulled up the hill by the conveyor belt motion.

P5 The purpose of this first hill is to store up **potential energy**. The higher the hill the greater its potential energy will be. As the train reaches the top of the first hill the Chain Dog releases and gravity takes over, pulling the train down the first hill. This converts the potential energy to **kinetic energy** (motion).



Rollercoaster trains store potential energy during the rides lift hill.
This is converted to Kinetic energy during drops and back to potential energy during hills. CC-BY-science made simple

P6 The kinetic energy is used to propel the train up future hills or into any loops. Each time the train climbs a hill it looses speed as some of its kinetic energy is converted back into potential energy. However, once the train reaches other drop or leaves the other side of a loop the potential energy is once again converted into kinetic energy and the train will speed up.

P7 The potential energy stored during the first lift hill determines how much energy the rollercoaster has for the entire ride. During the ride this energy **reservoir** is gradually reduced due to **friction** between the train wheels and the track and also the train and the air. To allow for this traditional rollercoasters are designed with hills decreasing in height as you move along the track, and by the time the train reaches the end of the track this energy reserve is almost completely empty.

Forces and funny feelings

P8 All of these hills, drops, twists, turns and loops change the train's elevation above the ground and its speed. This alters the **gravitational force** and **acceleration force** acting on the riders throughout the ride. A well-designed rollercoaster takes advantage of the interplay between gravity and acceleration to make sure the rider really feels these forces acting on their bodies.

P9 Inertia is the resistance of an object to a change in its state of motion. On a roller-coaster the rider's inertia is separate from that of the roller coaster train. This means the force you feel is the opposite of the force actually acting on you. For example, when the roller coaster train speeds up the force acting on you is that of the seat accelerating you forwards, however, you will feel like you are being pushed backwards into the seat. When the roller coaster slows down the opposite happens.

P10 Have you ever let go of the restraints when you reach the top of a hill and felt yourself being lifted upwards, out of your seat? This is also due to inertia. It lifts you up while the coaster train has already started its decent.

P11 We feel these forces most intensely during loops. Your inertia pushes you into the roller coaster car floor even when the train is fully upside down. The restraints are obviously there for your own safety and security but in most cases these forces would keep you firmly in your seat even if they were not there.

Keeping on track

P12 With all those forces it would be quite easy for a rollercoaster train to leave the track completely at corners or over hills. It is therefore important that rollercoaster trains are designed with **safety mechanisms** keeping them on the tracks.

P13 Early rollercoasters were made from **wood** and their trains ran of wheels much like those of traditional passenger trains. These wheels have wide lips either side of the track restricting sideways movement. Additional wheels or a bar beneath the track stop the train from lifting up over the crest of hills.

P14 Nowadays rollercoasters are far more varied and often build from **stee**l allowing more elaborate rollercoaster train design to take place. These often have wheels above, below and on the side of the tracks ensuring that the trains keep on the track through all their intricate twists, turns and

<u>Questions:</u>

1. ***Describe*** how natural forces are used to power a rollercoaster ride. ***Cite text*** in your response.

2. ***Using evidence from the diagram*** in the text, ***explain*** the relationship between potential and kinetic energy.

3. ***Using evidence from the text***, ***explain*** the meaning of the term reservoir used in paragraph 7.

4. ***Explain*** how energy transformations determine roller coaster design. Support your response with ***evidence from the text.***

5. ***Using evidence from the text, describe*** the science of keeping you in your seat!!