

Some Common Questions

(And their Answers)

How does a roller coaster work?

A **roller coaster** is essentially a gravity-powered train. When the chain pulls the train up the first hill, it transfers an enormous amount of energy to that train. This energy initially takes the form of gravitational potential energy – energy stored in the gravitational force between the train and the earth. But once the train begins to descend the first hill, that gravitational potential energy becomes kinetic energy – the energy of motion. The **roller coaster** reaches maximum speed at the bottom of the first hill, when all of its gravitational potential energy has been converted to kinetic energy. It then rushes up the second hill, slowing down and converting some of its kinetic energy back into gravitational potential energy. This conversion of energy back and forth between the two forms continues, but energy is gradually lost to friction and air resistance so that the ride becomes less and less intense until finally it comes to a stop.

What role do gravity and inertia play in making a roller coaster work?

Gravity provides the energy source for a **roller coaster** and inertia is what keeps the **roller coaster** moving when the track is level or uphill. Once the **roller coaster** is at the top of the first hill and detaches from the lifting chain, the only energy it has is gravitational potential energy (and a little kinetic energy – the energy of motion). But once it begins to roll down the hill, its gravitational potential energy diminishes and its kinetic energy increases. Since kinetic energy is related to speed, they both increase together.

At the bottom of the first hill, the **roller coaster** has very little gravitational potential energy left, but it does have lots of kinetic energy. The **roller coaster** also keeps moving, despite the absence of gravitational potential energy. You can view its continued forward motion as either the result of having lots of kinetic energy or a consequence of having inertia. Inertia is a feature of everything in our universe – a tendency of all objects to keep doing what they're doing. If an object is stationary, it tends to remain station. If an object was moving forward at a certain speed, it tends to keep moving forward at a certain speed. Inertia tends to keep the **roller coaster** moving forward along the track at a certain speed, even when nothing is pushing on the **roller coaster**. While the **roller coaster** will slow down as it rises up the next hill, its inertia keeps it moving forward.

What are g-forces?

Whenever you accelerate, you experience a gravity-like sensation in the direction opposite that acceleration. Thus when you accelerate to the left, you feel as though gravity were pulling you not only downward, but also to the right. The rightward "pull" isn't a true force; it's just the result of your own inertia trying to prevent you from accelerating. The amount of that rightward "pull" depends on how quickly you accelerate to the left. If you accelerate to the left at $9.8 \text{ meters/second}^2$, an acceleration equal in

amount to what you would experience if you were falling freely in the earth's gravity, the rightward gravity-like sensation you feel is just as strong as the downward gravity sensation you would feel when you are standing still. You are experiencing a rightward "fictitious force" of 1 g. The g-force you experience whenever you accelerate is equal in amount to your acceleration divided by the acceleration due to gravity (9.8 meters/second²) and points in the direction opposite your acceleration. Often the true downward force of gravity is added to this figure, so that you start with 1 g in the downward direction when you're not accelerating and continue from there. If you are on a **roller coaster** that is accelerating you upward at 19.6 meters/second², then your total experience is 3 g's in the downward direction (1 g from gravity itself and 2 g's from the upward acceleration). And if you are accelerating downward at 9.8 meters/second², then your total experience is 0 g's (1 g downward for gravity and 1 g upward from the downward acceleration). In this last case, you feel weightless-the weightlessness of a freely falling object such as an astronaut, skydiver, or high jumper.

What are positive and negative g's?

Let me start with the concept of inertia. Like all objects in this universe, we naturally tend to keep doing what we're doing – if we are stationary, we tend to remain stationary, and if we are moving, we tend to keep moving in a straight line at a steady pace. In fact, the only way that your speed and/or direction of travel (in short, your velocity) can change is if something pushes on you. When that happens, you accelerate (which is to say your velocity changes).

Whenever you accelerate, the various parts of your body can no longer follow their inertia; they must accelerate, too. This acceleration requires forces within your body and you can feel these forces. In fact, they make it feel as though a new type of gravity were acting on the parts of your body. You can't distinguish true gravity from the experience of acceleration because they feel exactly the same. The strength of this gravity-like experience depends on how fast you accelerate and it points in the direction opposite your acceleration. If you accelerate upward, as you do when an elevator first starts moving upward, this gravity-like sensation points downward and you feel extra heavy (the experience of "positive g's") If you accelerate downward, as you do when a rising elevator comes to a stop, this gravity-like sensation points upward and you feel unusually light (the experience of "negative g's") Since there is no fundamental limit to how rapidly one can accelerate, these positive and negative g's can become extremely strong and can easily feel stronger than the true force of gravity. However, when these gravity-like sensations become a few times stronger than gravity itself, they become difficult to tolerate. That's why elevators start and stop gradually and why the turns on **roller coasters** aren't too sharp.

What is the difference between apparent weight and true weight?

Your true weight is caused by gravity--it is the force exerted on you by gravity; usually the earth's gravity. Your apparent weight is the sum of your true weight and a fictitious

force associated with your acceleration. Whenever you accelerate, you experience what feels like a gravitational force in the direction opposite your acceleration. Thus when you accelerate to the left, you feel a gravity-like experience toward your right. It is this effect that seems to throw you to the right whenever the car you are riding in turns toward the left. In fact, this effect is caused by your own inertia--your own tendency to travel in a straight line at a constant speed. Your apparent weight can be quite different from your true weight. Perhaps the most striking example occurs on the loop-the-loop of a **roller coaster**. While your true weight remain downward throughout the ride, as it always is, your apparent weight actually becomes upward as you pass around the top of the loop-the-loop. You are accelerating downward so rapidly at the top of the loop that the experience you have is one of a gravity-like force that is pulling you skyward. Since the car you are riding in is invert and above you, you feel pressed into your seat even though the ground is in the other direction.

If the fictitious force you experience on a loop-the-loop isn't greater than your weight, will you fall?

Yes. If you go over a loop-the-loop too slowly, so that you don't accelerate downward quickly enough, you will leave the track and fall. That's why some **roller coasters** strap you in carefully before taking you upside-down slowly. Without the supports, you would fall out of the car.