KLOTHOID LOOP

Maybe you've noticed that coaster loops are not circular in shape. They're actually taller and skinnier than perfect circles and are called Klothoid loops. In Figure 1, the Hot Wheels track loop on the left is circular, and the one on the right is a Klothoid. On a coaster, the purpose of the Klothoid is to keep the coaster from falling off the track at the top of the loop, where it is going the slowest.

To demonstrate this with the Hot Wheels loops, launch a Hot Wheels car into the circular loop with a speed slow enough so that it comes as close as possible to making it all the way around the loop, but actually does fall off at the top. Then launch it at the same speed into the Klothoid loop of the same height, and note that it makes it all the way through the loop without falling off! Figure 1 shows the loops, track and launchers. Figure 2 is a close-up of the launcher.

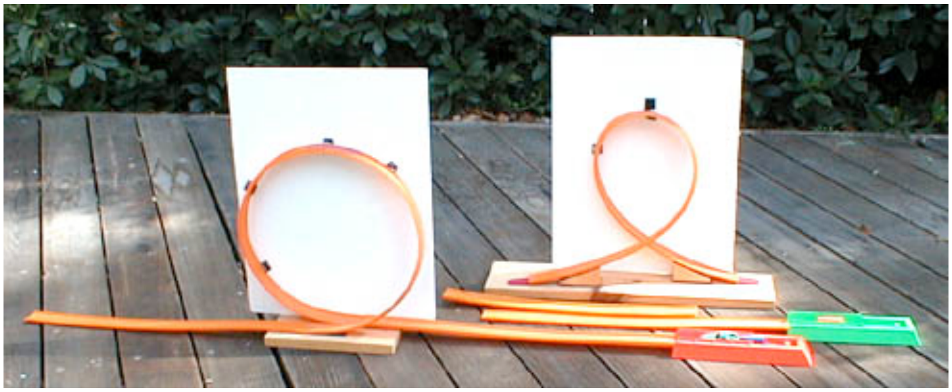

Figure 1

Figure 2

To understand how this works, imagine that the two Hot Wheels track loops in Figure 1 are coaster loops. The higher a coaster climbs on either loop, the slower it travels. (The higher it goes, the more potential energy it gains, and hence the more kinetic energy it loses.) Note that the two loops in Figure 1 have the same height. Thus if the speed of the coaster is the same when it enters either loop at the bottom, the loss of speed will be the same for both loops, and the coaster will be travelling at the same speed at the top of either loop.

The equation for centripetal force is $F = \frac{mv^2}{r}$, where m = mass, v = velocity, r = radius

For a circular coaster track, m and r remain constant, while v decreases as the coaster climbs to the top, and then increases again as it descends. Therefore the centripetal force required at the top is considerably less than at the bottom. If the speed at the top of the circle is slow enough, then the weight of the coaster might exceed the required centripetal force, in which case the coaster would fall off the track! To prevent this, the coaster could be sent into the loop at a higher speed, but this could subject riders and the coaster structure to excessive forces at the entrance to, and exit from, the loop.

To overcome these problems, the Klothoid loop uses a varying radius. The radius is larger than the circle at the entrance and exit, and smaller than the circle at the top. Since m and v are the same for the Klothoid as for the circle at corresponding points, the changing value of r makes the required centripetal force for the Klothoid smaller than for the circle at the entrance and exit, and greater than for the circle at the top. Consequently, as the coaster enters the loop on a Klothoid, it demands less centripetal force from the tracks than it would from the circle, and you feel less squished into your seat than you would at the same speed on the circle. At the top of the loop, the coaster on the Klothoid demands more centripetal force than on the circle. The centripetal force required is more than gravity alone can provide, and the remainder is provided to the coaster by the tracks, and to you by the seat of the coaster. So the coaster doesn't fall off the tracks, and you don't fall out of your seat!

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