Student 4: High Achieved

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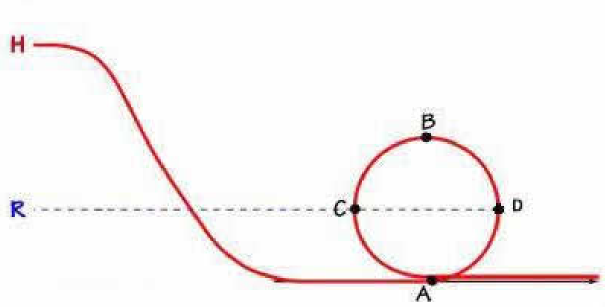
One of biggest attraction at a theme park takes passengers at high speed through a track of loops and twists and hills. The popular theme park attraction is a staple for mainstream theme because of the iconic "weightless" feeling and thrilling speeds. While many have experienced a roller coaster many do not have a full understanding of the physical interaction that happens that they experience such as weightlessness at the top a loop or feeling heavier at the bottom of the loop. A series of physic formulas and concepts can be used to explain these events, Such as Gravitational potential and kinetic energy, Centripetal force, Gravity and friction forces. In this assignment, I will explain the basic forces and energy passenger s and the roller coaster experience in a basic track, from the start of the ride when the coaster is pulled up to a height down then around a loop and then slowed down to the end of a track.

When the passenger first enters a roller coaster the coaster is hooked on the track where is pulled slowly along and up the track where the track reaches a high height, H, where all the energy required to get the rollercoaster though the track. This is important the amount of energy the rollercoaster gained in this height must higher than the energy required to make it through the loop.



This energy at the top of the track is called gravitational potential energy calculated by multiplying the total mass of the coaster and the passenger(s) and the acceleration by gravity (9.81ms^{-1}) (Ep=mgh). When roller coaster falls down to the bottom of the track and converts its potential into kinetic energy E(lin)=½ mv^2 along this whole time some of the energy is lost due to friction and air resistance though this is negligible when designing the track this has to be taken into account. If we ignore or assume there is no friction or air resistance, we know that the coaster will follow the conservation of energy where its states the total energy of an isolated system (roller coaster) cannot be created or destroyed only transferred/converted to other sources such as chemical potential energy or kinetic energy. This is also described by newton's first law of motion (An object in motion remains in motion unless acted on by an outside force). Minimum starting height to keep the cart from falling off at the top of the loop:

$$a_c = \frac{v^2}{r} \rightarrow v^2 = gr$$

$$2rmg + \frac{1}{2}mv^2 = mgh \rightarrow 2rmg + \frac{1}{2}mgr = mgh \rightarrow 2r + \frac{1}{2}r = h \rightarrow 4r + r = 2h \rightarrow 5r = 2h \rightarrow \frac{5}{2}r = h$$ (1)

The minimum height the for the cart has to be at least 2.5 time higher than the radius or 1.25 times the height of the diameter of the loop assuming there is no loss of energy due to fraction or external forces.

When the cart is traveling on the loop/circle it experience centripetal force accelerating the cart to the tangentially. Although normally the direction of acceleration due to centripetal force of an object is tangential to its velocity(path) and is constant, We know that as the cart gains height traveling up the loop it's speed decreases so the acceleration experienced is changing proportionally to the velocity (F_c=mv^2/r) F_c proportional to v^2.

Once the cart has made it all the way to the top of the loop(B) it's has converted its energy into gravitational potential energy by displacing itself about the track below (2*r) plus by the energy required to move the cart past the top of the loop. It is important that the design of the roller coaster has the roller coaster moving faster enough once it reaches this point.

This is because if the velocity too low the only force acting it will be gravity causing it to fall off the track (Minimum speed). At this point of the ride the passenger will feel weightlessness because seat no longer applying a force on the passenger. This brief windows of weightlessness will no longer be felt when the passenger when reached at (c) but then will feel heavier because acceleration of gravity and centripetal force will apply a greater force to the passenger until the loop ends at D where the cart is no longer changing direction.

The gravitational potential energy converted into kinetic energy then some gravitational potential energy can be shown here.

$$Ep = mgh = mg2r + ½ mv^2$$

The force and acceleration experienced at each point:

(A) At the point A the kinetic energy(velocity) is reduced and converted into some gravitational potential $\sqrt{\frac{2((mgh)-(mgr))}{m}} = V$ Both gravity and centripetal force are accelerating the cart

(B) At this point the only force accelerating the cart is gravity unless the cart is traveling faster than minimum speed $v^2/r > g \rightarrow v^2 > gr \rightarrow v > \sqrt{gr}$. At this point notice that the mass of the cart does not matter and does not affect the minimum speed

(C) The cart gains some kinetic energy from gravitational potential energy gained from the top of the loop plus by the previous kinetic energy. The velocity at C is equal to A

The roller coaster is famous for its thrilling "weightlessness" feeling felt at the top of a loop or hill. To explain a passenger who feels the perceived "weightlessness" is due to the net forces are 0N there for the reaction force (weight force) which the passenger experience/preserves is 0. So as the passenger approaches the top the one of the two forces the passenger perceives changes (due to change in speed ($F_c = \frac{mv^2}{r}$)). 2

At stage A the cart still has a high velocity so the centripetal force is great and the main force felt by the passenger. When the force of gravity and centripetal force are added, the net force are unbalanced and a reaction force is still felt by the passenger.

When the cart gets to stage B the 2 forces cancel out to bring the net force to 0. Gravity Acceleration (acceleration object down to the ground) +Centripetal Acceleration=0. At this point the Centripetal Acceleration must be equal or greater than the acceleration of gravity or else the cart will start to acceleration down to the ground and fall off the track. Centripetal force must be equal or greater than the force by gravity $Fc \geq 9.81ms^{-2}$ and $9.81ms^{-2} \geq \frac{mv^2}{r} \rightarrow \sqrt{\frac{9.81m}{r}} = v$:
Because $F_R = F_c + F_g = 0$ (reaction force equal to Centripetal plus gravity force is equal to 0) $F_c + F_C$ Cancel out because they are both vector quantities pointing in opposite directions (Gravity down and Centripetal up).

A rollercoaster designer would have to consider all of the physics concepts I have mentioned in order to create a loop in a roller coaster track. This and consideration for friction and energy lost while the cart is moving along the track due to friction between the track and the cart and air resistance. The equations I supplied take the track out of reality into a world with no friction affecting the cart. So, a good design would bring the top of the track higher in order to compensate for energy lost on the way down and through the track in order to reach at least the minimum speed to at the top of the loop. In order for the user to feel true "weightlessness" the cart would reach the minimal speed at the top perfectly but due to changing winds and different factor I the designer of the track should never build the track to only this speed at a gust of wind could slow the cart down on the its way onto the loop or while it's only the loop. Also, the designer would need to design the rest of the track so that the cart would not fall off, such as another loop if there were another loop it would need to be at an equal or smaller diameter with consideration of friction at the same height.