Physics of Roller Coasters

Lesson Notes

Learning Outcomes

- How does Physics explain the thrills of a roller coaster ride?
- How can Newton's Laws be used to analyze the roller coaster experience?

The Physics Behind the Phun

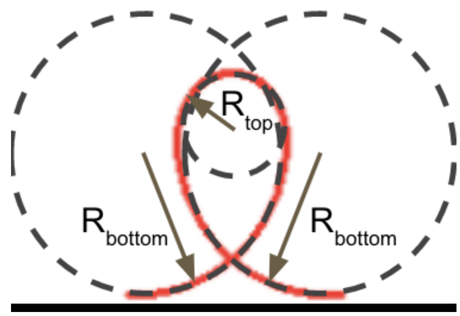
- It's not about the speed!
- It's about the acceleration and the sensations of weightlessness and weightiness associated with the accelerations.

Clothoid Loops

There are two safety issues with looping coasters:

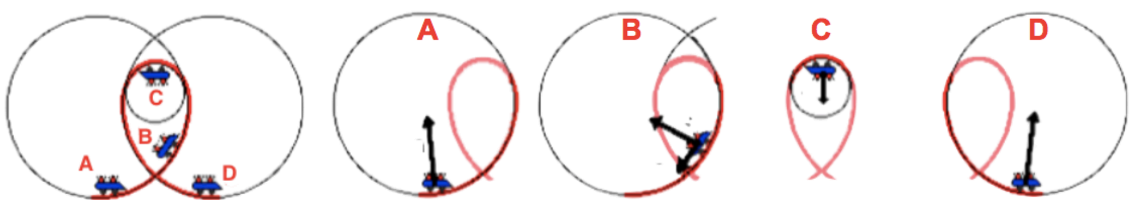
- At loop bottom: **a** cannot be too large or riders will black out.
- At the loop top: **a** ≥ 9.8 m/s/s.

The tear-dropped shape loops are known as **clothoid loops**. They have a continuously changing radius. The radius at the bottom is significantly larger than that at the top. Accelerations decrease when the turning radius is larger. ($a = v^2/R$)



Accelerations in the Loops

The magnitude and direction of a rider's velocity (in blue) is constantly changing. This is the cause of acceleration. The accelerations in the loop have a centripetal (inward) component due to the direction change and a tangential component due to the speed change.



Normal Force

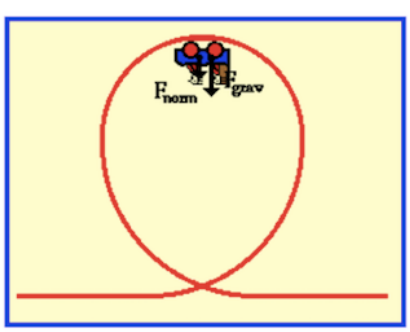
The normal force varies in size and direction.

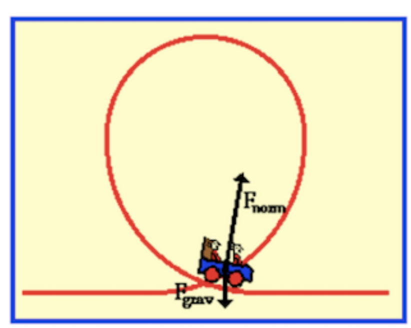
Loop Top:

F_{grav} and F_{norm} are both inward.

Loop Bottom:

F_{grav} is outward and F_{norm} is inward.





Show your solutions to Example Problems 1, 2, and 3. (Example 3 is on Slide 11.)

Example 1 - Analysis of a Loop Top

Anna Litical experiences a downward acceleration of 15.6 m/s^2 at the top of a loop. Determine the normal force acting upon Anna's 48.5-kg body.

Example 2 - Analysis of a Loop Bottom

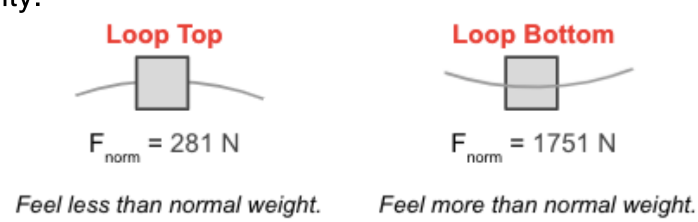
Anna Litical experiences a downward acceleration of 15.6 m/s^2 at the top of a loop. Determine the normal force acting upon Anna's 48.5-kg body.

Example 3 - Analysis of a Hill Top

Anna Litical is moving at 18.9 m/s over the crest of a hill that has a radius of curvature of 24.8 m. The safety bar applies a downward force on her body. Determine this applied force that acts on Anna's 48.5-kg body.

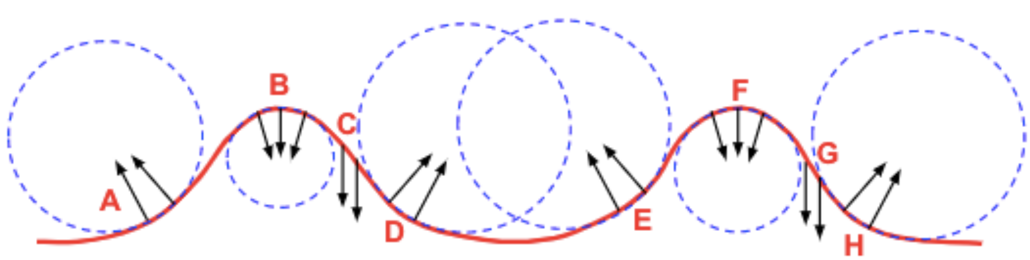
The Normal Force as a Thrill Factor

- The force of gravity on our bodies - our *weight* - cannot be felt. We only feel the contact forces that counteract the force of gravity.
- Our sense of how much we weigh is based on our feel for these contact forces - usually F_{norm}.
- Usually 48.5 kg Anna feels 475 N of normal force.



Hills and Dips

The dips and hills of a coaster ride blend circular motion and free fall experiences. The thrill results from the accelerations and the sensations of weightlessness and weightiness.



Locations **B** and **F**: Partial weightlessness or negative Gs.
Locations **C** and **G**: Weightlessness; free fall.
Locations **D** and **H** (also **A** and **E**): feelings of weightiness; large # of Gs.