Name(s)

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Project Number

J0224

Project Title

Loop the Loop: Physics of Vertical Loop Roller Coasters

Abstract

Objectives/Goals

My general objective was to investigate how the shape of a roller coaster's vertical loop affects the ability of the roller-coaster car to complete the loop. At the top of the loop, the car's velocity must exceed a critical value at which centripetal force balances the force of gravity. Based on this, my project tested the hypothesis that the minimum velocity to complete vertical loops with equal height varies directly with the radius of curvature (R) at the top of the loop.

Methods/Materials

I modeled the roller coaster using clear plastic aquarium tubing as tracks and ball bearings as cars. Tubing was bent into 1 of 3 vertical-loop shapes with equal height: Tear Drop (R = 6.1 cm), Circle (R = 13.1 cm), and Watermelon (R = 16.5 cm). Ball bearings were released from 3 different heights, 5 times for each loop shape (total 45 trials). Results were classified as (1) incomplete loop, does not reach top; (2) incomplete loop, reaches top but falls off outer rim; or (3) complete loop. Each trial was recorded on high-speed, digital video at 210 frames per second (fps), imported into Logger Pro software, and digitized to measure the position of the ball bearing in each video frame using the time-motion analysis module. From this, I determined the velocity at the bottom and top of the loop.

Results

For the Tear Drop, Circle, and Watermelon, ball bearings reached the top on 13, 8, and 5 trials, respectively. They completed the loop on 10, 1, and 0 trials. The minimum velocity at the bottom required to reach the top (with or without a complete loop) was least for the Tear Drop, intermediate for the Circle, and greatest for the Watermelon: 2.1, 2.7, and 2.8 m/s. For completed loops, the minimum measured velocity at the top was 0.80 m/s for the Tear Drop and 1.40 m/s for the Circle.

Conclusions/Discussion

The minimum velocity required to complete vertical loops of equal height was lowest for the Tear Drop, intermediate for the Circle, and highest for the Watermelon. This finding is consistent with my hypothesis that the minimum velocity varies directly with the radius of curvature at the top of the loop. It explains why amusement park roller coasters use the Tear Drop shape for their vertical loops.

Summary Statement

This project investigated how the shape of a roller coaster's vertical loop affects the ability of the roller-coaster car to complete the loop.

Help Received

At school, my science teacher Mr. Norman Brennen showed me how to use Logger Pro software, and my math teacher Mr. Larry Weiner helped me measure the radius of curvature of the loops. My father helped me attach the tubing to the back board. My mother helped me paste up my presentation.