MOVIE GUIDE

MOVIE NUMBER 1008

Roller Coasters

The Movie:

Designing safe roller coasters requires an understanding of forces, so that engineers know exactly how the trains will move before anything is built. Featured: Ron Toomer, president, Arrow Dynamics, Inc.; Dal Freeman, engineer, Arrow Dynamics, Inc.; Ed Dangler, engineer, Six Flags. *(Movie length: 2:00)*

Background:

Just as most other aspects of life have speeded up in the past 50 years, so have roller coasters. Fueled by our ever-increasing thirst for thrills and intense competition amongst amusement parks in areas of large population, roller coaster design is one engineering discipline where bigger is always better—as long as bigger also means faster, higher, steeper, and scarier.

Fortunately, the laws of physics that govern the motion of a roller coaster train have been well understood for hundreds of years, and were clearly stated by Isaac Newton in the 17th century. And even before that, Galileo discovered the fact that all objects fall to earth with the same acceleration (if air resistance is ignored).

Still, the roller coaster of today would be impossible without the strong, light and durable alloys and plastics that have been the product of very modern chemical and metallurgical knowledge.

Put it all together and you have something unique: a product of old physics, new engineering and consumer demand, built solely for the purpose of fun.

Curriculum Connections:

Decimals, Percents — 1

An amusement park decides to build a roller coaster at a cost of $3.5 million. They expect to sell 800 tickets a week at a cost of $5.00 each, and plan to use 12% of the ticket sales to repay the loan. How long will it take to repay the loan? (Assume there is no interest on the loan, so that exactly $3.5 million must be repaid.)

Measurement (energy, power) — 2

In physics, work is the use of force to move something through a distance. For example, if you lifted 4 pounds straight up 10 feet, you would be doing 40 foot-pounds of work. If you did that in two seconds, you would be doing work at a rate of 40 foot-pounds in 2 seconds, or 20 foot-pounds per second. The rate of doing work is called power.

Suppose a roller coaster train weighing 4,000 pounds is pulled to a height of 200 feet in 15 seconds. How much power would that require, in foot-pounds per second? If 1 foot-pound per second is equal to 1.3 watts, what is the power required in kilowatts?

Measurement (force), Decimals 3

When a roller coaster moves quickly around a curve, passengers experience a force called a "G-force", as their seats push back against them to keep them from flying off the train. This G-force is measured as a multiple of the pull of gravity—thus a G-force of "2 G's" means a force which is 2 times the force of gravity.

Since the force of gravity on a person is equal to the person's weight, a G-force of 2 G's means that a person who weighs 150 lbs will experience a total force of 300 pounds.

If the G-force around a sharp turn is 2.34 G's, how much force would be felt by someone who weighs 142 pounds?

Percents 4

The safety bar that holds passengers in is designed with a safety margin, so that it is much stronger than any force that might be applied to it. Suppose a designer calculates that the safety bar on a car might have a maximum of 1,000 pounds of force applied to it (for example, if the car stopped abruptly and the passenger were thrown against the bar). If the safety margin is 275%, how much force should the safety bar be designed to withstand?

Statistics 5

Roller coaster engineers must be able to accurately estimate the total weight of a train, including passengers. Suppose a train can carry 24 passengers, and an engineer has collected the following data about passengers who had ridden other roller coasters at the same amusement park. How would he estimate the most likely total weight of 24 passengers on a train that had not yet been built?

Weights of 50 passengers, in pounds:

134	172	193	432	172
167	276	141	167	276
95	224	138	75	222
240	105	134	223	135
210	165	113	243	165
165	234	141	165	232
170	194	149	173	172
138	93	114	135	73
154	141	113	152	124
113	211	193	143	244

How would you estimate the absolute maximum weight of 24 passengers?

Geometry (circles), Measurement (conversion) 6

If a roller coaster car is traveling at 80 miles an hour on wheels with a 6" diameter, how many times do the wheels rotate per second? (Hint: Determine how far the car travels in one rotation of the wheel.)

Probability 7

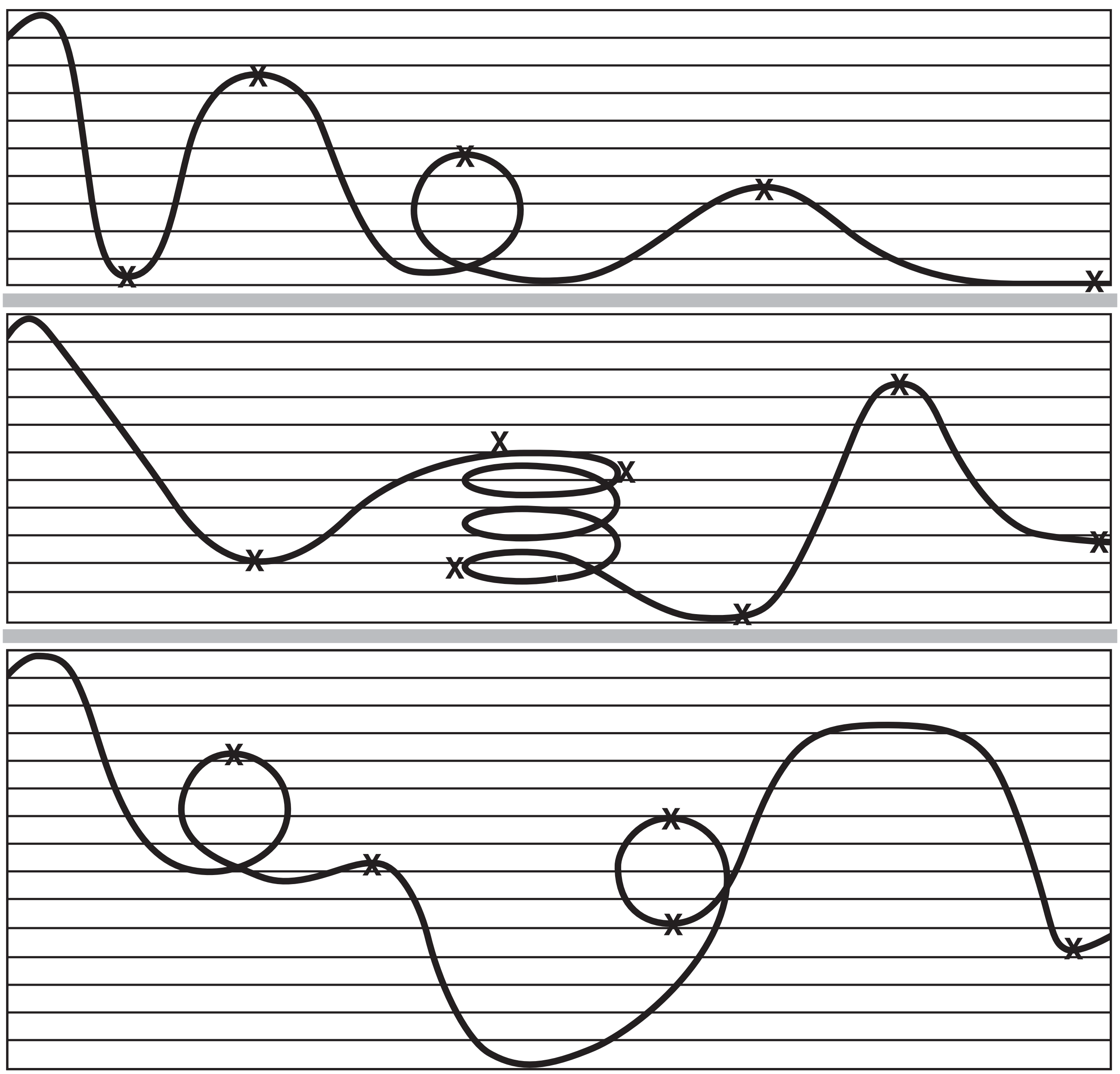
Suppose there are 2 backup safety systems to slow down a roller coaster which is starting to go too fast. One of the systems has a probability of failure of 1 in 100,000 (it is likely to fail once in 100,000 instances of being used). The other safety system has a probability of failure of 1 in 20,000. What is the probability that both would fail at the same time?

AIR COASTERS

Luis,

Here are a few ideas for our new frictionless coaster design. Could you have your team figure the car speeds at the points marked and write them in there? (As usual, figure that velocity is zero at the top of the first hill. The grid is marked at five-meter increments.)

Tina



Teaching Guidelines: Air Coasters
Math Topic: Algebra (equations)

This project should be done by students individually or in teams of two.

Distribute the handout and discuss it. Ensure that students understand the assignment.

The solution of this problem involves these two equations:

$$\text{Potential Energy} = mgh$$
$$\text{Kinetic Energy} = \tfrac{1}{2}mv^2$$

As the car moves on the roller coaster, its potential energy is converted to kinetic energy when the car moves downhill, and then back into potential energy as the car moves uphill. Since this is a frictionless roller coaster, there is no energy lost to heat. The total energy is therefore always constant, and its value is equal to the potential energy at the top of the first hill (since kinetic energy at that point is zero). Thus at any point "p":

> $\text{Energy} = mgh_p + \tfrac{1}{2}mv^2 = mgh_1$, where h_1 is the height at the top of the first hill and h_p is the height at point "p".

This equation can be solved for the velocity at any point:

$$v = \sqrt{2g\,(h_1 - h_p)}$$

If you enjoyed this Futures Channel Movie, you will probably also like these:

Maglev Trains, #1004	Gliding on a wave of electromagnetic force, a maglev (magnetic levitation) train could travel at 300 miles per hour or faster.
Electricity from the Wind, #1010	The natural force of the wind is harnessed by mathematics and physics to generate clean electricity.
Solar Powered Cars, #1001	Using the energy it takes to run a hair dryer, this solar-powered car travels 200 miles at speeds of 50 to 65 mph.