About the Author

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Momentum and the Third Law

INVESTIGATION 3A

Question for this Investigation:

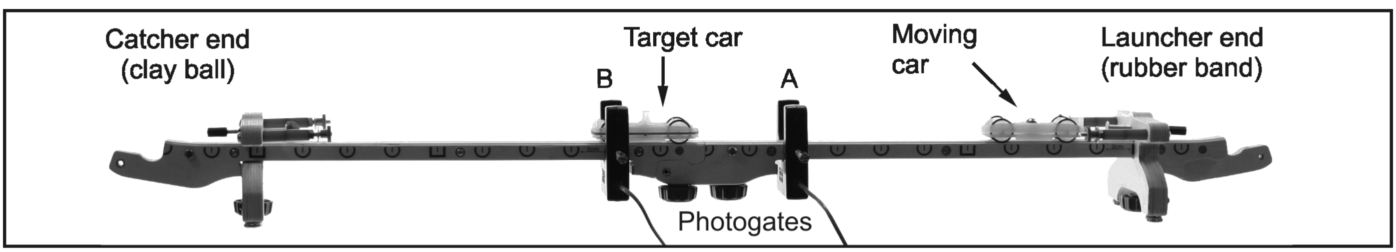
What makes moving objects keep going at the same speed in the same direction?

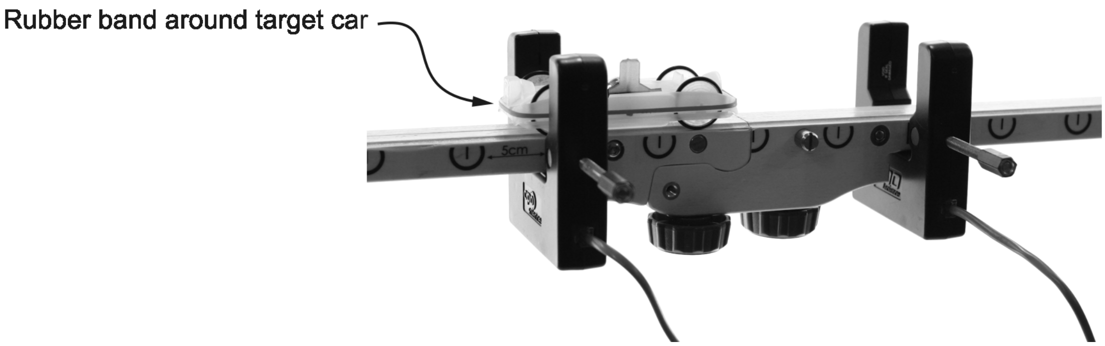
When you throw a ball it goes in the direction you threw it and does not suddenly turn one way or another unless a big force is applied. If you did try to deflect the ball you would find that for every force you apply to the ball, the ball exerts an equal and opposite force against your hand. This Investigation is about momentum and Newton's third law: the law of action and reaction.

Materials

- Car and track (need 2 cars)
- two magnets
- Timer
- Rubber bands
- Mass balance
- Clay

1 Making a collision





1. Set up the long straight track with a rubber band launcher on one stop and a clay ball on the other. Use the photogates to adjust the track so it is level (same time through A and B).
2. Put a photogate on either side of the center. Photogate A should be closest to the rubber band.
3. Wrap one car with a rubber band and put it between the photogates. This is the target car. The car should have 1 steel ball and the "V" should be facing the launching end of the track.
4. Launch the other car from the rubber band launcher with your finger. This is the moving car. This car should also have 1 steel ball and should have its pointed nose facing the target car. The cars will collide with each other at the center of the track.
5. After each collision, record the times through photogates A and B. You may have to use the memory button to see the time if the moving car goes through twice (bounces back). Observe the direction and motion of both cars after the collision.

2 Thinking about what you observed.

Table 1: Collision data

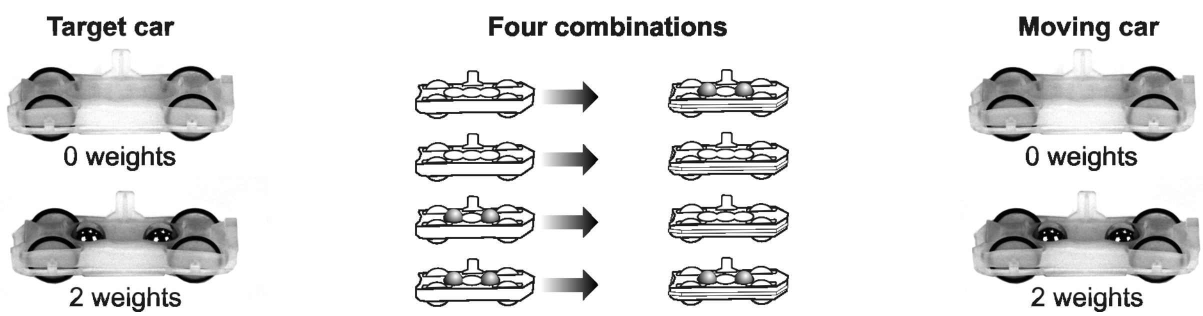
Mass of target car (kg)	Mass of rolling car (kg)	Rolling car before collision		Rolling car after collision		Target car after collision	
		Photogate (sec)	Speed (m/sec)	Photogate (sec)	Speed (m/sec)	Photogate (sec)	Speed (m/sec)

a. Consider two colliding cars of equal mass. Describe in words the motion of the two cars before and after the collision.

b. The target car must exert a force on the rolling car to stop it. How strong is this force relative to the force the rolling car exerts on the target car to get it moving? What experimental evidence supports your answer?

c. Look up Newton's third law and state how it applies to the collision of the two cars.

3 Momentum



1. Try the experiment with the four combinations of mass shown above. Add the data to Table 1.
2. Try the experiment for several different speeds of the moving car.

4 Thinking about what you observed

a. Describe the motion of the two cars when the target car has more mass than the rolling car.

b. Describe the motion of the two cars when the target car has less mass than the rolling car.

c. Research and write down a formula for the momentum of a moving object. State what each of the variables are and what units they have.

d. Calculate the total momentum of the two cars before and after each collision. Be sure to remember that momentum can be positive or negative depending on the direction of motion.

e. Research and write down the law of conservation of momentum. Describe how your data either support or do not support this law.

Conservation of Energy

INVESTIGATION 3B

Question for this Investigation:

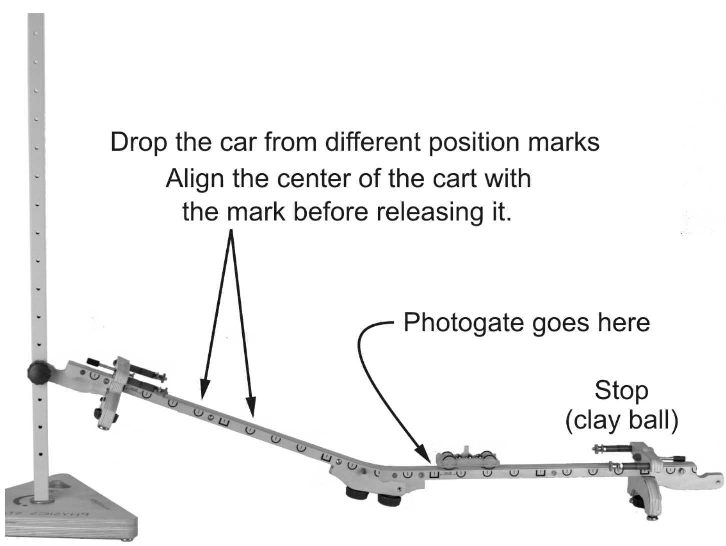
What limits how much a system may change?

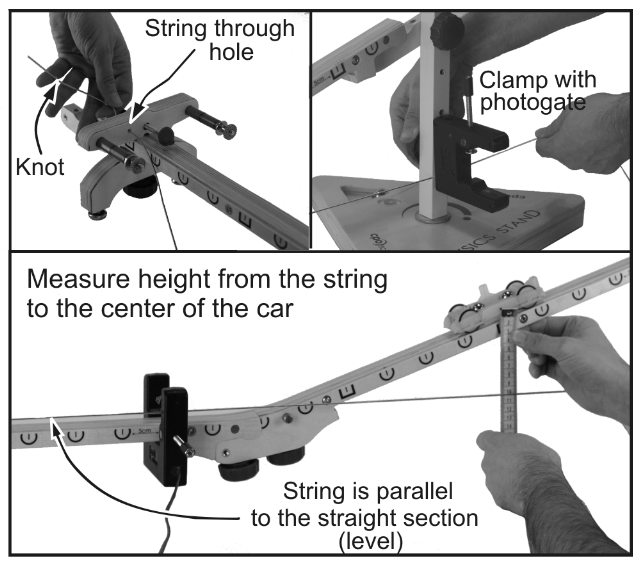
A car launched up the hill at a given speed will never go higher than a certain point. A car rolling downhill will only reach a certain speed. Why? The answer is that nature keeps an exact balance of energy. Speed uses one form of energy and height uses another. This Investigation explores the exchange of energy.

Materials

- Car and track
- Physics stand
- Mass balance
- Clay
- Meter stick

1 Energy exchange from potential to kinetic





1. Set up the track with the steeper hill and a level section. Make the level section as level as you can.
2. Thread a string though the hole in the lower stop and use a photogate to clamp the other end of the string to the stand. Adjust the string so it is parallel to the level section of the track.
3. Put a photogate at the bottom of the hill on the level section.
4. Drop the car from each 5-cm mark on the hill and measure the speed with the photogate. Measure the height of the car from the string to the center of the car.
5. Measure the mass of the car. Do the experiment for at least two different masses.

Table 1: Downhill data

Drop Height (m)	Mass of car (kg)	Photogate time (sec)	Speed (m/sec)

2 Thinking about what you observed

a. Graph the speed of the car vs. the height. Use different symbols for different masses.

b. What does the graph tell you about the relationship between speed and height?

3 Analyzing the data

a. Use the formula for potential energy to fill in the first column of Table 2.

b. Use energy conservation to derive a formula for the speed of the car in terms of the energy it has at the start. (Hint: your formula should include only two variables, energy and height.)

c. Use the formula you just derived to fill in the column for the predicted speed of the car.

d. Plot the curve for the predicted speed on the same graph as you made in part 2a above.

Table 2: Energy data and predicted speeds

Drop Height (m)	Potential energy (J)	Predicted speed (m/sec)	Measured speed from Table 1 (m/sec)

4 Thinking about what you observed

a. Explain the relationship between speed and height using the idea of energy conservation.

b. Explain any difference between the predicted and measured speeds. If there is a difference, what does it tell you about the energy of the car as it rolls along the track?

c. Did changing the mass have a significant effect on the relationship between height and speed? How does your data support your answer?

d. Let the car roll downhill, bounce off the rubber band and go back up hill again. Does it reach the same height as it was dropped from? Explain why or why not using the idea of energy conservation.

e. Challenge experiment. Use a rubber band to launch the car uphill so it goes through the photogate with the same speed as it had going down. You won't be able to get it precisely the same, but come as close as you can. If the speeds are the same, the car's kinetic energy is also the same. Does the car reach the same height on the hill that it was dropped from to get the same speed in part 1? Explain any difference using the idea of energy lost to friction.