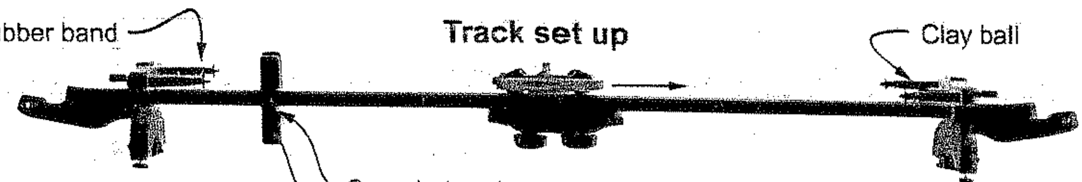
B4 Newton's Second Law

How do force and mass affect motion?

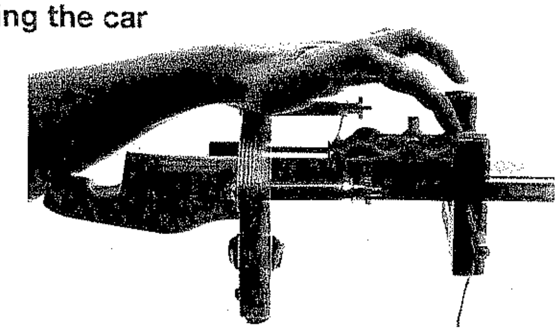
It takes a force to get an object moving. As early as Aristotle's time, in the third century BC, philosophers were seeking the relationship between force and motion. It was not until 2000 years later (1686) when Newton published the *Principia* that this riddle was solved by his second law of motion. In this investigation, you follow in Newton's footsteps and figure out the relationship between force, mass, and acceleration.

1 Changing the force on a launched car



1. Connect the two pieces of the track so it is level by locking together the two straight ends.
2. To make one end of the track into a launcher, loosen the two thumbscrews a few turns. Stretch a rubber band between the screws. It should fit between the washer and the nut. Give the rubber band one twist so makes an "X" between the posts, and gently tighten the screws.
3. Adjust the stopping post so its flat end is 1 cm from the rubber band. Place a ball of clay on the screw on the other end of the track to make a bumper.
4. Attach one photogate about 20 cm away from the rubber band and connect it to the timer set to interval mode.
5. Place three steel balls in the car. Practice launching the car by pulling it back until it touches the screw. Position the car and your hand as shown in the picture for consistent launches.The launch times should be within 0.002 seconds of each other if you have good technique.

Launching the car



6. Once you can launch the car consistently, record the photogate time in Table 1 on the next page.
7. Adjust the position of the screw so it is 2 cm from the rubber band and record the time. Repeat with 3 cm and 4 cm stretch distances.
8. Calculate the speed of the car for each row in the table by dividing the distance by the time. The distance the car moves while blocking the photogate is 1 cm, the width of the "flag" on the top of the car that breaks the light beam.

Table 1: Constant mass data

Rubber band stretch distance (cm)	Time through photogate (s)	Speed (cm/s)
1		
2		
3		
4		

2 Changing the car's mass

1. Adjust the stopping post so the rubber band will stretch 2 cm when launching the car.
2. Measure and record the mass of the car when it is holding 0, 1, 2, and 3 steel balls.
3. Launch the empty car. Make sure you use the same launching technique you used in the first part of the investigation. Record the time through the photogate.
4. Repeat the launch with 1, 2, and 3 balls. Load the balls as shown in the picture to keep the mass evenly distributed.

Add mass to the car so the steel balls are evenly spaced around the center.

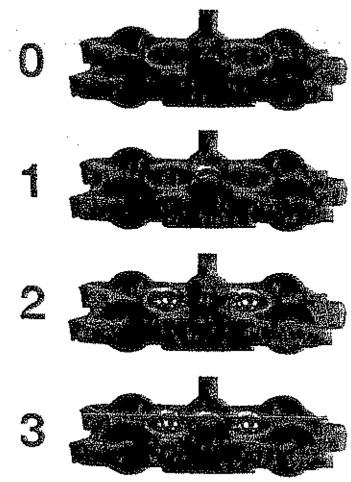


Table 2: Constant force data

Number of steel balls in car	Mass of car (g)	Time (s)	Speed (cm/s)
0			
1			
2			
3			

3 Thinking about what you observed

a. Factors that affect the results of an experiment are called *variables*. The *experimental variable* is the variable you purposely change in an experiment. What was the experimental variable in part 1 of the investigation? In part 2?

b. Variables that are kept the same are called *control variables*. List three control variables for part 1 of the experiment and three control variables for part 2.

c. Use Table 1 to graph the speed of the car (y) against the rubber band stretch distance (x).

d. What effect did increasing the stretch distance have on the launch speed? Why? Use the word *force* in your explanation.

e. Use Table 2 to graph the speed of the car (y) against the mass of the car (x).

f. What effect did increasing the mass have on the launch speed? Why?

g. *Newton's second law* explains the relationship between force, mass, and acceleration. *Acceleration* is the rate at which an object changes speed. The car's speed changed from zero to the launch speed as the rubber band exerted a force on it. Use your data to explain how force and mass are related to acceleration.

Assessment

1. Give an example of Newton's second law acting in everyday life.

2. You are using a constant force to accelerate a person on a sled. Suddenly another person jumps on, doubling the mass you are pulling. What happens to the acceleration?

3. You are using a force of 2 N to push a hockey puck across the ice. You double your force to 4 N. What happens to the puck's acceleration?

4. Use Newton's second law to fill in the missing quantities in the table. The first two examples are already done for you.

Force (N)	Mass (kg)	Acceleration (m/s^2)
10	2	5
18	3	6
	4	5
50	25	
6		2
	0.5	10
100	2	
30		3

5. A car has a mass of 1000 kg. A force of 500 N is applied when the car pulls out from a stoplight. What is the car's acceleration?

6. You kick a 2 kg ball and it accelerates at 10 m/s^2. What force did you apply?