Force and Motion

Reference Guide

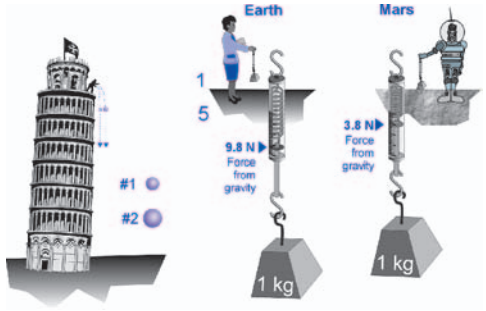
Equipment Setup

Investigation Guides

Investigation Guides (continued)

B-7 Weight, Gravity, and Friction

Key Question: How does increasing the mass of the car affect its acceleration?



According to physics, heavier objects should fall at the same speed as lighter ones. In the real world, friction often creates proportionally more resistance on light objects than on heavier objects. In this Investigation, students carefully analyze how changing a car's mass affects the speed of the car rolling downhill. They use the experience to discuss friction, the difference between mass and weight, and how to use percent change as a tool for assessing the relevance of changes in variables.

Preparation

Students should understand the concepts of speed, force, and acceleration before beginning this Investigation. You should also introduce gravity and friction before the Investigation.

Gravity is a force that pulls every mass toward every other mass. Since the Earth is the biggest mass around, we experience gravity as a force that pulls everything toward the center of the Earth. We call the force of gravity *weight*. Using Newton's second law, we calculate an object's weight and acceleration in free fall.

Friction is a catchall word for all forces that act against motion. Friction can come from rubbing, sliding, fluid motion, air motion, and other situations. The force of friction always opposes the motion that produces the friction.

Setup and Materials

Students work in groups of four at tables.

Each group should have:

- Car and ramp, physics stand, CPO timer with two photogates, set of weights.
- Spring scale for measuring force, tape measure, balance for measuring mass, graph paper, pencils, ruler

Each student should have:

- Copy of the Investigation and answer sheets

The Investigation

Time One class period

Leading Questions

- How is motion affected by friction?
- Do heavier objects fall faster than lighter objects?
- What is friction?

Learning Goals

In this Investigation, students will:

- Describe the effects of friction.
- Explain why in real life, heavier objects often fall faster than lighter objects, even though this appears to contradict the laws of physics.
- Evaluate the percent change in a variable and correlate this to an observed effect.

Key Vocabulary force, weight, mass, gravity, friction, percent change

1

1b. It is hard to tell just by looking if adding weights changes the speed. The time does seem to get a little shorter but not by much.

B

Sample data (table shown on page 2):

Mass (g)	Distance from A to B (cm)	Time from A to B (sec)	Speed (cm/sec)
330	20	0.1475	135.6
520	20	0.1425	140.4
710	20	0.1402	142.7
900	20	0.1391	143.8

B-7 Weight, Gravity, and Friction B-7

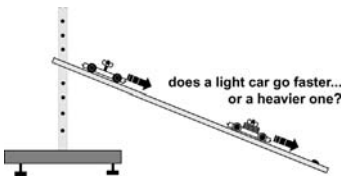
Question: How does increasing the mass of the car affect its acceleration?

In this Investigation, you will:

1. Explore how added weight affects a car's acceleration.
2. Discuss and learn whether or not heavier objects fall faster than lighter objects.
3. Investigate friction and how friction affects motion.

So far, you have learned that the car accelerates as it moves down the ramp. That is, its speed increases over time. In the last Investigation, you explored what happened to the acceleration of a car when more force was applied to it.

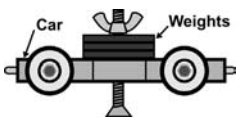
The force that you used in the last Investigation was gravity. Gravity pulls all objects toward the center of Earth with a force we call weight. The more mass an object has, the greater its weight. If you increase the weight of the car, how will acceleration be affected? Do heavier objects fall faster than lighter ones?



1 Do you think adding weights to the car will change its speed?

a. You can add up to three weights to the car for this experiment. Weights are attached to the top of the car using the wing nut.

b. Roll a car down the ramp with different amounts of weight and watch it, without using photogates. Does the change in mass seem to make a difference in the speed?

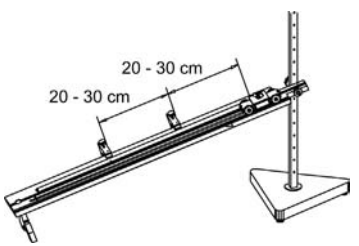


Safety tip: Keep your fingers away from the ramp when the car is rolling. Especially, keep your hands away from the bottom of the ramp until the car stops.

2 Testing your hypothesis

It is difficult to know for sure that the car is going faster (or not) without making measurements. Set up the car and ramp with two photogates. The photogates should be about 20 centimeters apart. Set the angle at the seventh hole from the bottom of the stand.

You will want to measure the mass of the car with no weights, and with one, two, and three weights. On the data table, record the masses and the speeds at which the car rolled between the two photogates.



B-7

Mass and Speed Data

Mass (g)	Distance from A to B (cm)	Time from A to B (sec)	Speed (cm/sec)

3 Graphing and analyzing the data

a. Make a graph of speed vs. mass using your data.

b. Which is the dependent variable? On which axis does it go?

c. Which is the independent variable? On which axis does it go?

d. From your graph, what can you say about the effect of increasing mass on the speed of the car? Did the speed change by a lot or by a little? Did the mass change by a lot or a little?

4 Friction

Try the following experiment. Take a steel weight and a flat sheet of paper. Drop them both and the steel weight will hit the ground before the paper every time. Next, crumple the sheet of paper and do the experiment over. They should hit the ground about the same time.

a. The crumpled paper has the same weight as the flat sheet of paper. What is the explanation for why the crumpled sheet fell fast and the flat sheet fell slowly?

b. The car has friction, even though the wheels have ball bearings. Can you think of a way to increase the friction in the car? See if you can create enough friction so the car does not accelerate, but keeps the same speed from one photogate to the next.

5 Thinking about the results

Suppose you have a jar of 1,000 marbles. If you lose one marble, it is hard to notice because 1 out of 1,000 is a small change. If you only had 5 marbles in the jar, you would immediately notice if one were missing because 1 out of 5 is a much larger change.

	Mass (g)		Change in mass (g)	100 % x	% Change
a					
b		b-a		(b-a)/a	
c		c-b		(c-b)/b	
d		d-c		(d-c)/c	

a. We often express change in percent. One out of 5 is a change of 20 percent (1/5 × 100%). The percent change is the change divided by what you started with, times 100 percent. Calculate the percent change for the weight experiment.

b. Does the percent change have anything to do with how much the speed changed as you added the second and third weights?

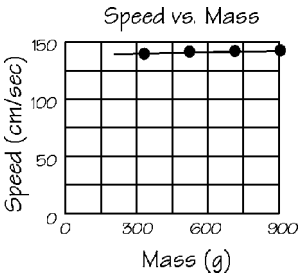
3

3a. Graph right:

3b. The dependent variable is speed. It goes on the y-axis.

3c. The independent variable is mass, and it goes on the x-axis.

3d. The speed changed only a small amount, but the mass changed a lot.



4

4a. The flat paper floats on the air, but the crumpled piece of paper doesn't float as much.

4b. We increased friction on the car by using string to prevent the wheels from turning. The speed was still not constant because the car jerked a bit as it went down the ramp. However, the car did not speed up.

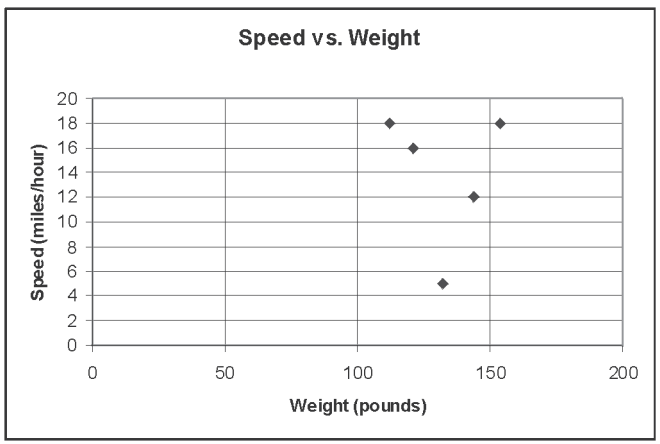
5

	Mass (g)		Change in mass (g)	100 % x	% Change
a	330				
b	520	b-a	190	(b-a)/a	57%
c	710	c-b	190	(c-b)/b	37%
d	900	d-c	190	(d-c)/c	27%

5a. We also calculated percent change in speed. The results are 3.5%, 1.6%, and 0.8%.

5b. Although the effect of weight on speed was small, as the percent change in mass went down, so did the percent change in speed.

1. Mass is the amount of matter an object has. Mass is constant and is measured in kilograms. Weight is the force created by gravity on objects. The weight of an object depends on its mass and is measured in newtons.
2. 3.0 feet/sec - 2.5 feet/sec = 0.5 feet/sec
   (0.5 feet/sec ÷ 2.5 feet/sec) × 100 = 20% increase in speed.
3. Graph of data:



The data are inconclusive. There seems to be no relationship between weight and speed. The problem does not state the procedures that the students followed when pushing off from the top of the hill. Maybe some of them had a running start and others did not.

Curriculum Resource Guide: Car and Ramp

Credits

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