Free Fall in a Vacuum

Introduction

Use this economy-choice "Guinea and Feather Tube" to show students that all objects fall at the same rate due to gravity, just as Galileo predicted!

Science Concepts

- Vacuum
- Acceleration due to gravity

Materials (for each demonstration)

Magnet, neodymium
Paper, 3 cm × 3 cm, or a small feather
Steel ball bearing, 5/8″ diameter
Three-way valve (optional, depending on operation of vacuum plate)
Vacuum chamber, transparent
Vacuum plate
Vacuum pump, two-stage
Vacuum tubing

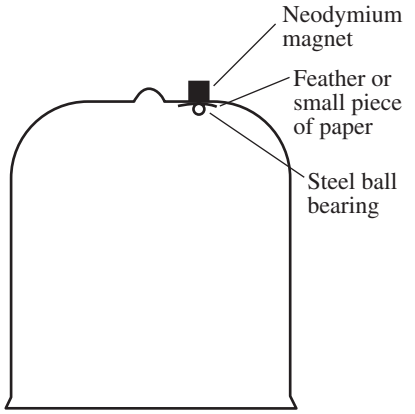

Figure 1.

Safety Precautions

Wear safety glasses when working with an evacuated bell jar. All students and teachers near an evacuated bell jar must wear safety glasses.

Preparation

1. Using a neodymium magnet on the outside of a bell jar, secure a small piece of paper or a feather between a steel ball bearing and the inside wall of the vacuum chamber. See Figure 1.
2. Place the vacuum chamber on the vacuum plate, and connect the plate to a vacuum pump. See Figure 2.
3. Turn on the vacuum pump to evacuate the inside of the chamber. (Follow the procedures that are appropriate for your vacuum pump and vacuum plate.)
4. Once the chamber is under vacuum, close the valve on the vacuum plate (or the three-way valve) and turn off the vacuum pump. The vacuum should be maintained inside the chamber.

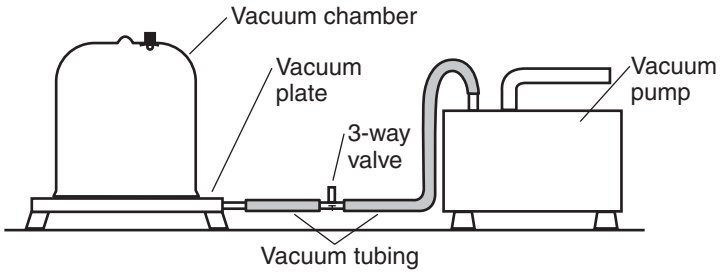

Figure 2.

Procedure

1. Show students the ball and paper setup. Explain that the magnet is holding the ball bearing and paper to the top of the vacuum chamber. When the magnet is removed, both the ball and paper will fall.
2. Ask students to predict which object, the steel ball bearing or the paper, will fall at a faster rate when the magnet is removed.
3. Once students have recorded their predictions on the worksheet, quickly pull the magnet straight up from the top of the chamber. (The steel ball bearing and paper should fall at the same rate.)
4. Instruct students to record their observations on the worksheet.
5. Open the valve on the vacuum plate (or the three-way valve) and allow the chamber to fill with air.
6. Repeat the demonstration using the air-filled chamber. (The steel ball should fall faster than the sheet of paper.)

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Teaching Tips

- Any magnet may be used as long as it is strong enough to hold up the steel ball bearing.
- A two-stage vacuum pump is recommended for this demonstration.
- Some bell jars may have sloped tops and the magnet may slip. A vacuum chamber with a flat top, such as Flinn Catalog No. AP4506, is a good alternative to a glass bell jar.

Discussion

Galileo Galilei (1564–1642) was the first person to claim that all objects fall at the same rate, regardless of their size, shape or mass. He had difficultly convincing the people of his generation because universal observations showed otherwise. Everyone at the time knew that heavy objects, like cannon balls, fell faster than light objects, such as feathers. Legend has it that Galileo attempted to convince his skeptics by dropping two cannon balls, one ten times heavier than the other, from the "Leaning Tower" of Pisa. By the end of the seventeenth century (after Galileo's death), the ability to obtain a vacuum had greatly improved. A device consisting of an enclosed glass tube attached to a vacuum pump, a feather, and an English guinea (a coin) was built and used in 1660 by Robert Boyle (1627-1691) to prove that Galileo had been correct. When there was no vacuum inside the tube, the guinea and feather fell as they normally would, with the coin striking the bottom of the glass tube first. However, once a vacuum was established, the guinea and the feather fell through the tube at the same rate and reached the bottom at the same time. This confirmed Galileo's theory that *all* objects fall at the same rate due to gravity. The reason why the feather falls slower than a coin in air is because of air resistance. Air creates friction and drag for all objects that travel through it. This drag has a tendency to slow down lighter objects (or objects with greater surface area) more than heavier objects (or objects with less surface area), which is why a feather "floats" to the ground while a coin "falls" quickly.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Process: Grades K–12
Evidence, models, and exploration

Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter, understanding of motions and forces.

Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, motions and forces.

Answers to Worksheet *(Student answers will vary.)*

Part I.

Prediction: Which object will fall faster in a vacuum—the steel ball or the piece of paper? Give a reason for your prediction.

The ball will fall faster because it is heavier and round.

Observations

The ball and paper fall at the same rate and hit the bottom at the same time.

Part II.

Prediction: Which object will fall faster in air—the steel ball or the piece of paper? Give a reason for your prediction.

The steel ball will fall faster because it is heavier.

Observations

The steel ball fell faster. The paper "floated" down slowly.

Questions

1. What conditions are needed for objects to fall at the same rate?

   The objects must fall in the absence of air.

2. What conditions cause objects to fall at different rates when they are dropped from the same height?

   Air resistance may cause some objects to fall at a slower rate than others. This air resistance tends to have a greater drag effect on objects with a larger surface area.

Materials for *Free Fall in a Vacuum* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP5819	Ball, Steel, 5/8"
AP4506	Vacuum Chamber with Plate
AP5666	Neodymium Magnet
AP4670	Guinea and Feather Tube
AP1597	Vacuum Pump, Two-Stage
AP8789	Vacuum Tubing, 10 feet
AP5353	Valve, Three-Way

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Student Worksheet

Free Fall in a Vacuum

Part I.

Prediction: Which object will fall faster in a vacuum—the steel ball or the piece of paper? Give a reason for your prediction.

Observations

Part II.

Prediction: Which object will fall faster in air—the steel ball or the piece of paper? Give a reason for your prediction.

Observations

Questions

1. What conditions are needed for objects to fall at the same rate?

2. What conditions cause objects to fall at different rates when they are dropped from the same height?