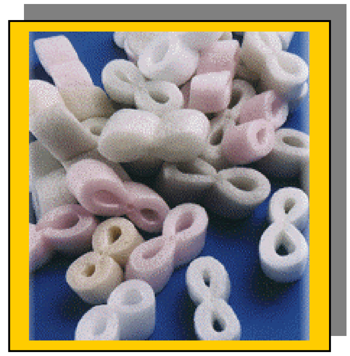
GENESIS SEARCH FOR ORIGINS Education

Cosmic Chemistry: Cosmogony

Density and Gravity: The Push and Pull of the Universe

TEACHER GUIDE

BACKGROUND INFORMATION



Gravity is a topic that has stimulated thought since the very beginnings of scientific investigations. We remember Newton, of course, for his development of a theory of gravitation, and Einstein's famed theory of general relativity is actually a gravitational theory. Today, astronomers recognize the force of gravity as a major component of the universe that has enormous influence on its structure and evolution. Unfortunately, gravity is difficult to demonstrate with small objects of the type that might be used in the classroom since the gravitational force is so small. Even the original Cavendish experiment in which the universal gravitational constant was measured is difficult to reproduce outside of well-equipped physics labs. Various experimental procedures for investigating micro-gravity have been described, but these generally require a rather complex experimental set-up [See Sawyer. "Unveiling the Universe" National Geographic Society, 196, 8 (1999) and http://zeta.lerc.nasa.gov/mini/minit.htm]. Because of these difficulties, the section of this activity dealing with gravity is of the "pencil and paper" type, although you will find a Teaching Tip in the section on gravity that you might want to pursue.

The density of the universe is a major consideration in deciding whether the universe is open, closed, or flat [see Appendix A, "Cosmology"]. Measuring the density of the universe offers major problems for obvious reasons. However, in contrast to the case of gravity, the concept of density and its determination are amenable to investigation in the classroom. In this activity the students will explore the concept of density and contemplate the difficulties faced by astronomers as they attempt to obtain accurate and meaningful measures of the universe's density.

NATIONAL SCIENCE STANDARDS ADDRESSED

Grades 5-8

Science As Inquiry
    Understandings about scientific inquiry
Earth and Space Science
    Earth in the solar system
Physical Science
    Properties and changes of properties in matter
    Motions and forces
Science and Technology
    Understandings about science and technoogy
History and Nature of Science
    Nature of science and scientific knowledge
    History of science and historical perspectives

Grades 9-12

Science As Inquiry
    Understandings about scientific inquiry
Earth and Space Science
    The origin and evolution of the universe
Physical Science
    Structure and properties of matter
    Motions and forces
History and Nature of Science
    Nature of scientific knowledge

(View a full text of the National Science Education Standards.)

MATERIALS

PART 1

For each student:
- Copy of Student Activity, "The Push and Pull of the Universe"
- Copy of Student Text, "The Push and Pull of the Universe"
- Copy of Appendix A, "Cosmology"
- Copy of Student Text Strategies, "The Push and Pull of the Universe Anticipation Guide"

For each team:
- Copy of "Student Reporting/Data Sheet"
- A box with a lid (shoebox is suggested) that will be completely filled by the items listed below.
- Several metal nuts, preferably large, black, and threaded.
- Several marbles.
- Some cotton balls.
- Several small wooden blocks.
- Two partially filled balloons. Ideally, the balloons should be filled with different gases. One possibility is to fill one with carbon dioxide by letting a small piece of dry ice sublime inside of the balloon and to fill the other balloon with helium. If helium is unavailable, air will suffice.
- Enough "packing peanuts" to fill the box after the other objects have been placed inside of it. With all of the objects in the box, make sure it is possible to fit the lid on the box.
- A collection of supplies that may be requested by the students for determining densities. These probably will include the following: a metric ruler and/or meter stick; a graduated cylinder or other calibrated vessel for measuring volume by water displacement; a calculator.
- A balance accurate to at least 0.01 gram.

Teaching Tip

The effects of gravity in determining what direction is "up" can be observed with a mass suspended from the ceiling of a car (plumb bob). Take students out for a ride and have them observe the plumb bob when the car accelerates, goes around a corner, and when it stops. Ask them to interpret the motion of the car relative to the plumb bob and explain the role of gravity in determining the behavior of the plumb bob. It will be interesting as well for you to have them observe a helium-filled balloon tethered to a string under the same conditions.

PART 2
- Scale that could measure a person's mass in Kg.

PROCEDURE

PART 1

1. Before class make copies of the following handouts:
   Student Text, "The Push and Pull of the Universe"
   Student Activity, "The Push and Pull of the Universe"
   Appendix A, "Cosmology"

2. Also, before class, gather the materials needed for the activity. The amount of material will depend on how you decide to divide the class up into teams. For each team you will need a box and items to fill it, as described in the list of materials. Give each team the same materials, but widely different quantities of each item (with the exception of the balloons).

3. Divide the class up into teams of at least two members. Have each team select a reporter who will write the team's plans and report the team's results.

4. Distribute a copy of the Student Activity, "The Push and Pull of the Universe" to each student.

5. Gather the students together and review the concept of density. Emphasize that density is a derived quantity, (i.e. it cannot be measured directly). Review the two measurements (mass and volume) that one must make in order to determine the density of an object and emphasize that the density units most often used in science are g/cm^3. With the class discuss the various ideas they might have for measuring the volume of an object, emphasizing the ease with which the volume of objects having a regular shape can be determined. Contrast this to the case for irregularly shaped objects and discuss methods for determining the volume of such materials. Introduce to the discussion the idea of making reasonable approximations and the advisability of making several measurements if there is any possibility of variation in density of objects that appear to be the same. [Note: this is why it is useful to fill the balloons with two different gases. The balloons will appear to be the same, but they will have different densities if inflated with different gases.] Measuring the density of cotton balls will challenge their ingenuity.

Alternate Strategy Tip

Using Student Text Strategies, complete an Anticipation Guide with your students as a pre-reading strategy for the student texts Appendix A, “Cosmology” and “The Push and Pull of the Universe.” Ask students to react to each statement, write a response to it, and be prepared to defend their opinions.

6. Instruct the students to carry out Part 1 of the activity, “The Push and Pull of the Universe.”

7. Post the teams’ Reporting/Data Sheets around the room so that team results can be compared.

8. After the students have completed the activity, distribute copies of Appendix A, “Cosmology” and the Student Text, “The Push and Pull of the Universe.” The alternate strategy tip provides a pre-reading strategy that can be used before and during the reading of the texts. After they have read Appendix A and the student text, call students together for a discussion of the team observations. Stimulate the discussion with questions of the following type:
   a) Why might the calculated density of the full box differ from the measured density?
   b) Why might the results of one team differ from another team’s results? What were the variables?
   c) What approximations did the teams make in determining the densities? Were the approximations reasonable?
   d) Would the density of the box completely filled with marbles be the same as the density of an individual marble?
   e) Which of the objects would come closest to providing a “full-box” density that is the same as that of an individual object?
   f) Would a box twice as big, but filled with objects in the same ratio as the original box, have a different density?
   g) How does the filled box resemble the universe?
   h) What features of the universe are modeled by the various objects in the box?
   i) Is the idea that the universe is homogeneous consistent or inconsistent with determining an average density of the universe?
   j) What assumptions and approximations might astronomers have to make in order to determine the density of the universe?
   k) How would the presence or absence of “dark matter” (see activity, Dark Matter-”More Than Meets The Eye”) affect the value of the density of the universe?
   l) How does the density of the universe compare to the density of the objects in the box?

Teaching Tip

For questions 7 and 8 have available a scale that can measure a person’s mass.

Teaching Tip

You may want to have an interested student post information on the board for student activity question 10.

PART 2

In this part of the activity, students will work on an individual basis. Before they begin the activity, make sure they have read the Student Text, “The Push and Pull of the Universe.”

After students have completed the problems and questions in Part 2, bring the class together for a general discussion of the role of gravity in determining the structure of the universe and in influencing the fate of the universe. Pursue with them the question of whether or not gravitational effects are of any importance in determining the structure of atoms. Contrast the forces at work in a solar-system picture of an atom and in the solar system itself. You might also pursue the question of whether light is affected by gravity, although this relates to Einstein’s theory, which probably is beyond the reach of your students. Add to the discussion the recent discovery of planets outside of the solar system and how gravity has played a role in these discoveries.

It would be appropriate for you to reinforce the idea that mass and weight are not the same thing, although we often use the terms more or less interchangeably. Pursue questions like the following:

a) What is meant by “weightlessness?”
b) Why does an astronaut’s mass stay the same, but his/her weight changes while in orbit around the Earth?
c) Why does an astronaut weigh less on the surface of the moon than on the surface of Earth?

There are many extensions of the types of questions posed in this part of the activity. For example, you might ask interested students to determine the magnitude of two masses, separated by 10 meters, that would provide a force of sufficient size such that it could be measured with everyday laboratory equipment. Some students might also be interested in comparing the force of gravity to the electrostatic force that exists between two charged particles.