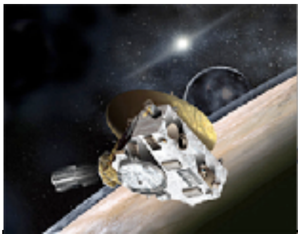


Speaking Volumes About Dust

Lesson Summary

Students will investigate density as an introduction to the Student Dust Counter on the New Horizons mission. They will explore the SDC website and use mission data to answer questions concerning the distribution of dust in the solar system.

Prior Knowledge and Skills

- Knowledge of Astronomical Units (AU)
- Unit conversion
- Scientific notation

AAAS Science Benchmarks

The Nature of Science
Scientific Inquiry
The Physical Setting
The Universe
Habits of Mind
Computation and Estimation

NSES Science Standards

Science as Inquiry
Abilities Necessary to do Scientific Inquiry
Science and Technology
Understandings about science and technology
Earth and Space Science
Origin and evolution of the Earth system

Teaching Time: 1-2 50-minute period(s)

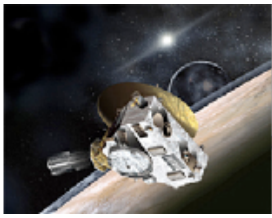
Materials (per group)

- 1 clear plastic rectangular container with lid
- 1 rectangular block of wood
- 1 nonporous rock (that will fit in graduated cylinder)
- 1 bag of black-eyed peas (or similar beans)
- 1 digital scale
- 1 500 mL graduated cylinder
- 1 calculator
- Access to the Internet

Advanced Planning

Preparation Time: ~20 minutes

Gather materials and familiarize yourself with the SDC New Horizons website http://lasp.colorado.edu/sdc



Speaking Volumes About Dust

Educator Guide and Lesson Key

In this activity, students explore the concept of density before using the Student Dust Counter (SDC) interface to determine the density of dust grains in a volume of space in the Solar System. In this version, we suggest different segments of New Horizon's path. As New Horizons continues on its journey, this activity will be supplemented with additional path segments. The degree of autonomy given to students may depend on the level of the class' independence in day-to-day activity. Questions are deliberately open-ended to encourage exploration of the data.

Time: 1-2 50 minute period(s)
Grade level: 8-10
Group size: 4 or more

Materials

Per group
1 clear plastic rectangular container with lid (32-64 oz)
1 rectangular block of wood, any size
1 nonporous rock (that will fit in graduated cylinder)
1-32 oz bag of black-eyed peas (or similar beans)
1 scale accurate to at least 500g (can share 1-3 scales between groups)
1 500mL-graduated cylinder
1 Calculator
Access to Internet

Prior Knowledge and Experience

- Good understanding of scientific notation and powers of 10
- A general understanding of the layout of the solar system
- Definition of Astronomical Unit (AU)
- Knowledge of how an AU is used to establish distance
- Ability to use a graduated cylinder and scale
- Familiarity with units and unit conversion

Skills Used

Communicating directions for a procedure
Accessing and interpreting data
Presenting results to peers

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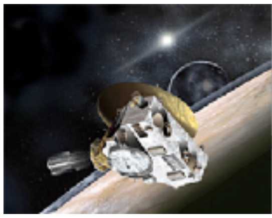
Procedure

1. Break the class into groups
2. Distribute the materials
3. Distribute the "Speaking Volumes About Dust" student worksheets and ask groups to complete parts I and II.
4. Part I: Students find the density of a block of wood and a rock after being given the density equation. They create procedures for determining the density of solid objects.
5. Part II: Students are asked to consider the density of a space that is not solidly filled with matter. They are given a plastic container, which they fill partially with black-eyed peas. They determine the density of the peas within the container.
6. Point students to the SDC website, http://lasp.colorado.edu/sdc/ to begin completing Part III.
7. Part III: After examining specific parts of the SDC webpage, students turn their attention to the data interface. They examine a region of space to determine the density of dust and compare values with peers. They should encounter some differences in the density from region to region. Students compare the density value from this section with results from Part II to discover that space is much more sparsely populated with dust than they may have thought. Students discuss their findings with the class.



Speaking Volumes About Dust

Answer Key

Part I

Record your answers on a separate sheet or lab book.

Density = Mass ÷ Volume
1 liter = 1000 cm^3
1 m^3 = 1 x 10^6 cm^3
1 kg = 1000 g

Complete the following. Include your units in all answers.

I.I. Find the density of the block of wood:
Write the procedure below:
Find the volume of the block of wood by measuring all sides and multiplying to get volume:
Volume = Length x width x height

Weigh the block of wood on the scale to determine the mass.
Use the density equation given above to compute the density. Answers will vary depending on the dimensions and mass of the block of wood.

I.II. Find the density of the rock:
Write the procedure below:

Weigh the rock to determine the mass. Let's say the mass of the rock is 20 grams. Next, fill the graduated cylinder to a specific volume such as 50mL. Carefully, so water does not splash, drop in the rock. The water level will rise. The difference between the volume reading from the graduated cylinder and the initial value is the volume of the rock:
V_final – V_initial = V_rock

The graduated cylinder measures in milliliters.

1 liter = 1000 cm^3   *There are 1000 mL in one liter. This gives:*

$$\frac{1000cm^3}{1L} \times \frac{1L}{1000mL} = \frac{1cm^3}{1mL}$$

or

$$1cm^3 = 1mL$$

Let's say the volume of the rock is 10 mL. This is the same as saying the rock is 10 cm^3. Use the density equation to determine the density:
D= 20 grams/ 10 cm^3
D=2 g/ cm^3

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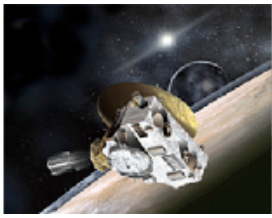

Speaking Volumes About Dust

Part II

Density is a measurement of the amount of mass that is contained in a specific volume. Consider a solid to be a collection of atoms that are fit into a certain shape and size. The density of an object depends on how many atoms fit into that shape (and the mass of those atoms). This is why a cube of lead is denser than a cube of wood of the exact same size. Even though the two cubes are the same size, lead has a greater mass in the same amount of volume. In this section, instead of a solid, you will be finding the density of peas in a space. The interior of the plastic container with the sealed lid is the space. Assume that the sides are negligible thickness. Record your answers on a separate sheet or lab book.

II.I.

a. After zeroing the mass of the lidded container, add half the bag of peas to the container. Reseal the container and place on the scale. Record your answer.

b. Calculate the volume of the space assuming the walls of the container are negligible thickness. Record your answer.

Volume of container:
Again, use equation: Volume = Length x width x height

c. Compute the density of the space using the density equation. Record your answer.
Density:
Use the mass of the peas and the volume of the container to determine this density.

d. Convert the density into kg/m^3. Record your answer.

The students will have their values in g/cm^3. Remember:
1 m^3 = 1 x 10^6 cm^3
1 kg = 1000 g
In this example, we use 'X' to denote the value the students obtained in part c (since the values will vary depending on the size of the container and mass of the peas.

$$\frac{X\ g}{cm^3} \times \frac{1kg}{1000g} \times \frac{1\times10^6 cm^3}{1m^3} = X \times 10^3\ {}^{kg}\!/_{m^3}$$

e. Imagine that all sides of the container were doubled. Would the density of the container with peas increase or decrease, and by how much? Show your work.
Again, use equation: Volume = Length x width x height, and represent the new volume as shown here:
Call the old value of volume, 'V', and the new value 'V_{new}'
V_{new} = 2L x 2W x 2H
V_{new}= 8 x L x W x H
V_{new} = 8 x V

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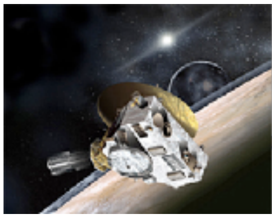


The total mass of the system has not changed, just the volume. Since density equals mass divided by volume:
Call the old value for density, 'D', and the new value 'D_{new}'

$$D_{new} = \frac{M}{V_{new}} = \frac{M}{8V}$$

$$D_{new} = \frac{1}{8}\frac{M}{V} = \frac{1}{8}D$$

The answer is that the density would decrease by a factor of 8 (in other words, it would be 1/8th the original value).

f. Imagine that all sides of the container were halved. Would the density of the container with peas increase or decrease, and by how much? Show your work.
Again, use equation: Volume = Length x width x height, and represent the new volume as shown here:
Call the old value of volume, 'V', and the new value 'V_{new}'
V_{new} = (1/2) L x (1/2)W x(1/2)H
V_{new}= (1/8) x L x W x H
V_{new} = (1/8) x V

The total mass of the system has not changed, just the volume. Since density equals mass divided by volume:
Call the old value for density, 'D', and the new value 'D_{new}'

$$D_{new} = \frac{M}{V_{new}} = \frac{M}{\frac{1}{8}V}$$

$$D_{new} = 8\frac{M}{V} = 8D$$

The answer is that the density would increase by a factor of 8 (in other words, it would be 8 times the original value).

g. If we decreased the total mass of the system, would the density increase or decrease? Explain.

The density would decrease because the container would remain the same size (and volume), but have less mass filling it, therefore making it less dense.

II.II. Extra Credit
a. How could you estimate the number of peas in the container without counting them? Write the procedure.

Since the mass of a group of peas is known, students can measure the mass of one pea to determine how many peas are approximately in the container. Finding the mass of peas in container and dividing by the mass of one pea gives approximate number of peas in the container.

b. About how many peas are in the container?

c. Are you feeling brave? Using the skills of all of your teammates, count the peas to get the actual number in the container. How good was your estimate?

Student answers should vary from the estimated number of peas because they found the mass of one pea, and the mass of each individual pea will vary. This is why it is an estimate. This may bring up concepts of error analysis in science, so it is good to probe students about why their estimate is not identical to the actual value. It would also be good to ask students how to improve their estimate i.e. taking an average mass of 10 peas before making an estimate.

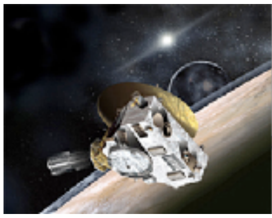
Part III

Density for SDC is computed by assuming that the volume of dusty space the instrument travels through is similar to the box with peas. The instrument has a specific rectangular area that sweeps through space collecting dust as it travels. If we put an imaginary box around the space the SDC instrument has traveled through, we can determine the volume of space. If we collect all of the dust in that volume of space, we get a density. Record your answers on a separate sheet or lab book.

III. I. Before your group begins, hypothesize about how the density of the dust recorded by SDC will compare to the density of peas recorded in Part II.
Write out your hypothesis:
Values of density vary through space, and the regions where SDC recorded data limit us. Sometimes SDC is turned off, as it was during the Jupiter fly-by. Some regions have little to no dust, and some have lots of dust. Despite this, the density of the dust recorded by SDC will be more than a billion times smaller than the density of the peas! Accept a variety of reasonable answers.

III.II. At a computer, open the Student Dust Counter New Horizons page.
http://lasp.colorado.edu/sdc/

- Conduct research on studying dust and also on the instrument. Pay particular attention to where dust comes from, why it is studied, and the goals and design of the instrument.
- Under “Education” along the top, select “Data Viewer” from the drop-down menu
- In the top box of the SDC Data Viewer, click on “Geography”



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- In the bottom box, click on "Density"
- Your group will be assigned a region of space
- Use the arrows to scroll to your region of space and the plus/minus buttons to zoom in and out
- At the bottom of the Data Viewer, enter the Solar System distance range in the "Low AU" and "High AU" boxes
- Click "Calculate"

Section	Region of the Solar System From AU To AU	Density Note: these values may adjust when data is updated. Check the SDC viewer for exact numbers.	Average Mass	# of hits (unitless)	Total Mass Multiply the average mass by the number of hits (Units need to be given in kg). The answer should be rounded based upon the number of significant figures given for the average mass.
1	1.15 to 1.55	1.703×10^{-18} kg/m^3	5.05×10^{-13} kg/hit	181	9.086×10^{-11} kg
2	1.625 to 1.95	4.754×10^{-18} kg/m^3	1.74×10^{-12} kg/hit	216	4.099×10^{-10} kg
3	2.65 to 3.25	1.463×10^{-17} kg/m^3	1.194×10^{-12} kg/hit	859	1.019×10^{-09} kg
4	3.99 to 4.7	8.24×10^{-18} kg/m^3	6.883×10^{-13} kg/hit	1149	7.86×10^{-10} kg
5	5.1 to 6.98	4.776×10^{-18} kg/m^3	6.206×10^{-13} kg/hit	1561	9.688×10^{-10} kg
6	7 to 7.96	6.412×10^{-18} kg/m^3	7.208×10^{-13} kg/hit	708	5.103×10^{-10} kg
7	8.8 to 9.9	6.827×10^{-18} kg/m^3	6.74×10^{-13} kg/hit	1810	1.22×10^{-09} kg
8	9.9 to 10.96	7.815×10^{-18} kg/m^3	7.756×10^{-13} kg/hit	1670	1.295×10^{-09} kg
9	TBD				

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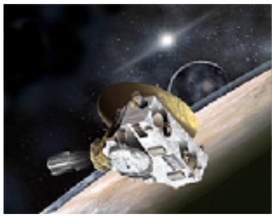


III.III. Share your values with the class, and fill in the chart above.

III.IV. In your group, describe the region of space you were examining. Be specific. *For example: The spacecraft was approximately 1.3 AU away from the Kuiper Belt at the end of our data collection period.*

III.V. Imagine you meet someone who has never heard of dust in space. You want to tell the person exactly what you know without making any assumptions. What true statements can you make about dust in space?

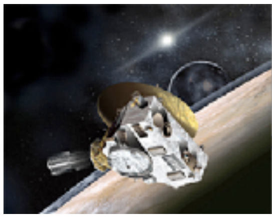
Students should note that the density of dust in space is extremely low. Some regions of space have fewer, more massive dust particles than other regions, and some regions of space have more dust particles but the particles are less massive. Students may note that even if the mass of all of the particles are combined, that total value is still much smaller than the mass of one pea. Accept a variety of reasonable answers.

III.VI. As a class, discuss the things that might affect dust in space.

Students should note that comets create dust as they approach the Sun and asteroid collisions account for the creation of some dust. If they have carefully read the Introduction page, they might also understand that gravity from the Sun and Jupiter play a distinct role in the dust distribution.

(Extrapolated from the SDC website introduction page) Comets, asteroids, and Kuiper Belt objects can all turn into a source of small dust particles. As they approach the Sun, comets heat up and release volatile material (like water) and dust, forming cometary trails. All other solid surfaces can turn into sources of dust due to mutual collisions or bombardment by interstellar and interplanetary dust. Gravity from the Sun and planets also can affect dust particles. Small dust particles in the Solar System lose energy due to drag, and follow a slow spiral towards the Sun. Many of them never make it closer than Jupiter's orbit. Jupiter is very effective at scattering the inward moving grains, acting as a 'gate-keeper' of the inner Solar System. The small fraction of the particles that sneak by Jupiter continue spiraling towards the Sun. As they heat up they lose mass like a mini-comet. Eventually radiation pressure (outward pressure created by light from the Sun) gets larger than the gravitational attraction of the Sun, and these tiny travelers end up zooming out of our Solar System.

III.VII. Write your concluding remarks and comment on the hypothesis you made.



Speaking Volumes About Dust

Student Handout

NAME:

Part I

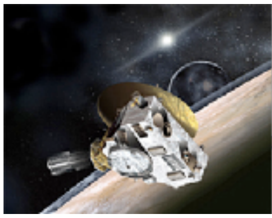
Record your answers on a separate sheet or lab book.

Density = Mass ÷ Volume
1 liter = 1000 cm^3
1 m^3 = 1 x 10^6 cm^3
1 kg = 1000 g

Complete the following. Include your units in all answers.

I.I. Find the density of the block of wood:
Write the procedure below:

I.II. Find the density of the rock:
Write the procedure below:



Speaking Volumes About Dust

Part II

Density is a measurement of the amount of mass that is contained in a specific volume. Consider a solid to be a collection of atoms that are fit into a certain shape and size. The density of an object depends on how many atoms fit into that shape (and the mass of those atoms). This is why a cube of lead is denser than a cube of wood of the exact same size. Even though the two cubes are the same size, lead has a greater mass in the same amount of volume. In this section, instead of a solid, you will be finding the density of peas in a space. The interior of the plastic container with the sealed lid is the space. Assume that the sides are negligible thickness. Record your answers on a separate sheet or lab book.

II.I.

a. After zeroing the mass of the lidded container, add half the bag of peas to the container. Reseal the container and place on the scale. Record your answer.

b. Calculate the volume of the space assuming the walls of the container are negligible thickness. Record your answer.

c. Compute the density of the space using the density equation. Record your answer.

d. Convert the density into kg/m^3. Record your answer.

e. Imagine that all sides of the container were doubled. Would the density of the container with peas increase or decrease, and by how much? Show your work.

f. Imagine that all sides of the container were halved. Would the density of the container with peas increase or decrease, and by how much? Show your work.

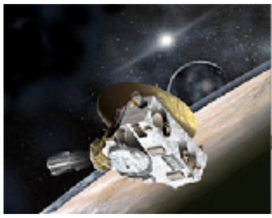
g. If we decreased the total mass of the system, would the density increase or decrease? Explain.

II.II. Extra Credit

a. How could you estimate the number of peas in the container without counting them? Write the procedure.

b. About how many peas are in the container?

c. Are you feeling brave? Using the skills of all of your teammates, count the peas to get the actual number in the container. How good was your estimate?



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Part III

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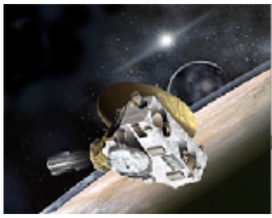
Write out your hypothesis:

III.II. At a computer, open the Student Dust Counter New Horizons page.
http://lasp.colorado.edu/sdc/

- Conduct research on studying dust and also on the instrument. Pay particular attention to where dust comes from, why it is studied, and the goals and design of the instrument.
- Under “Education” along the top, select “Data Viewer” from the drop-down menu
- In the top box of the SDC Data Viewer, click on “Geography”
- In the bottom box, click on “Density”
- Your group will be assigned a region of space
- Use the arrows to scroll to your region of space and the plus/minus buttons to zoom in and out
- At the bottom of the Data Viewer, enter the Solar System distance range in the “Low AU” and “High AU” boxes
- Click “Calculate”
- Fill in the table that appears on the following page.



Speaking Volumes About Dust

Section	Region of the Solar System From AU To AU	Density	Average Mass	# of hits	Total Mass
1	1.15 to 1.55				
2	1.625 to 1.95				
3	2.65 to 3.25				
4	3.99 to 4.7				
5	5.1 to 6.98				
6	7 to 7.96				
7	8.8 to 9.9				
8	9.9 to 10.96				
9	TBD				

III.III. Share your values with the class, and fill in the chart above.

III.IV. In your group, describe the region of space you were examining. Be specific.
For example: The spacecraft was approximately 1.3 AU away from the Kuiper Belt at the end of our data collection period.

III.V. Imagine you meet someone who has never heard of dust in space. You want to tell the person exactly what you know without making any assumptions. What true statements can you make about dust in space?

III.VI. As a class, discuss the things that might affect dust in space.

III.VII. Write your concluding remarks and comment on the hypothesis you made.

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