Lesson 2:
Scale of Objects

Teacher Materials

Contents

Scale of Objects: Teacher Lesson Plan

Orientation

This lesson helps students think about the enormous scale differences in our universe. There are three classroom activities that you can choose between and combine.

- The Student Reading on Visualizing the Nanoscale reviews common size units and provides several examples to help students imagine the nanoscale.
- The Number Line/Card Sort Activity has students place objects along a scale and reflect on the size of common objects in relation to each other.
- The Scale of Small Objects Activity/Worksheet has students identify the size scale of objects with less focus on their relation to each other.
- The Cutting It Down Activity has students cut a strip of paper in half as many times as possible and focuses on tools and their precision at different scales.
- The Scale of Small Objects Quiz tests the absolute and relative size of objects.

Essential Questions (EQ)

What essential questions will guide this unit and focus teaching and learning?

(Numbers correspond to learning goals overview document)

1. How small is a nanometer, compared with a hair, a blood cell, a virus, or an atom?

Enduring Understandings (EU)

Students will understand:

(Numbers correspond to learning goals overview document)

2. There are enormous scale differences in our universe, and at different scales, different forces dominate and different models better explain phenomena.

Key Knowledge and Skills (KKS)

Students will be able to:

(Numbers correspond to learning goals overview document)

1. Describe, using the conventional language of science, the size of a nanometer. Make size comparisons of nanosized objects with other small sized objects.

Prerequisite Knowledge and Skills

- Familiarity with atoms, molecules and cells.
- Knowledge of basic units of the metric system and prefixes.
- Ability to manipulate exponential and scientific notation.

Related Standards

- NSES Science as Inquiry: 12ASI2.3
- AAAS Benchmarks: 11D Scale #1

Day	Activity	Time	Materials
Prior to this lesson	*Homework*: Reading & Worksheet: Visualizing the Nanoscale	*30 min*	Photocopies of Visualizing the Nanoscale: Student Reading
Day 1 (40 min)	Use Visualizing the Nanoscale: Student Reading as a basis for class discussion and student questions. Use the Scale Diagram: Dominant Objects, Tools, Models, and Forces at Various Different Scales as a reference.	10 min	Students will refer to the Scale Diagram handout; photocopy it if not previously handed out.
	Number Line/Card Sort Activity	20 min	Photocopies of Number Line/Card Sort Activity: Student Instructions & Worksheet A set of cards (objects and units) for each small group of students (consider printing cards on card stock for reuse)
	or		
	Cutting it Down Activity		Photocopies of Cutting It Down Activity: Student Instructions & Worksheet Strips of Paper Scissors
	or		
	Scale of Objects Activity		Photocopies of Scale of Objects Activity: Student Instructions & Worksheet
	Return to whole class discussion for questions and comments	5 min	
	Scale of Small Objects: Student Quiz	5 min	Photocopy Scale of Small Objects: Student Quiz Teacher Key for correcting Student Quiz

Number Line/Card Sort Activity: Teacher Instructions & Key

Overview

In this activity, your students will explore their perception of the size of different objects. Have your students form into pairs or small groups, and give each group the Number Line/Card Sort Activity: Student Instructions & Worksheet handout and two sets of cards: one with objects on them and one with units on them. Their task is to create a number line and place the cards at the appropriate places on the number line.

You may also want to discuss with your students why we are using powers of 10 for the units in this exercise instead of using a "regular" linear scale (e.g., a meter stick). Here are some questions and issues you may want to bring up:

The number line units are powers of 10; that is, they are a base 10 logarithmic scale. Why don't we just use a linear scale, like a meter stick? Using a linear scale, we could easily mark off 1 meter, 1 cm, and 1 mm. But it's hard to mark (or see) smaller than that. Plus, most of the cards (for small objects) would pile up on top of each other!

Instead, we'd like to spread our cards out to clearly see which objects are bigger or smaller than others. We can do this if we use a logarithmic scale. The word logarithm is a synonym for the words "exponent" or "power." Powers of 10 use a base 10 logarithm scale. In base 10, $Log_{10}(10^{-10}) = -10$. So, each card unit represents an exponent (-10, -9, -8 … -1, 0) of 10. These are integers that are equidistant from each other.

Materials

- Cards for the objects
- Cards for the units, in powers of 10 meters

Instructions

On a surface like a lab table, order the cards for powers of 10 in a vertical column, with the largest at the top and the smallest at the bottom. Space the cards equidistant from each other, leaving a gap between the cards for 10^{-10} and 10^{-15}. This is your number line.

Next, place each object next to the closest power of 10 in the number line that represents the size of that object in meters. Some objects may lie between two powers of 10.

When you are done placing all of the cards, record your results in the table on the next page and answer the questions that follow.

Card choices adapted from Tretter, T. R., Jones, M. G., Andre, T., Negishi, A., & Minogue, J. (2005). Conceptual Boundaries and Distances: Students' and Experts' Concepts of the Scale of Scientific Phenomena. *Journal of Research in Science Teaching.*

Size (meters)	Objects
10^{0}	21. height of a typical NBA basketball player 4. height of a typical 5-year-old child
10^{-1}	20. length of a phone book 16. length of a business envelope 9. width of an electrical outlet cover
10^{-2}	17. diameter of a quarter 7. width of a typical wedding ring 14. length of an apple seed
10^{-3}	1. thickness of a penny 23. thickness of a staple 11. thickness of sewing thread
10^{-4}	6. length of a dust mite 8. length of an amoeba 18. length of a human muscle cell
10^{-5}	3. diameter of a red blood cell
10^{-6}	13. width of a bacterium
10^{-7}	24. wavelength of visible light (between 10^{-7} and 10^{-6}) 15. diameter of a virus
10^{-8}	10. diameter of a ribosome 5. width of a proteinase enzyme 19. diameter of a carbon nanotube
10^{-9}	12. width of a water molecule
10^{-10}	22. diameter of a nitrogen atom
10^{-15}	2. nucleus of an oxygen atom

Questions

1. Which items were the hardest for you to estimate size for? Why?

> Students will probably list small objects they know the least about. For example, if they haven't taken biology, they may list virus, ribosome, etc.

2. Why are we using powers of 10 for the number line instead of a regular linear scale (like a meter stick)?

> With a powers of 10 scale, we can spread the unit markers out evenly so that we can clearly place and see all of the cards. If we used a linear scale, most of the cards would pile up on top of each other. And we can't easily make marks much smaller than a millimeter anyway, so we couldn't make or see our scale if it were linear!

Cutting it Down Activity: Teacher Instructions & Key

Purpose

The purpose of this activity is to help students understand the smallness of the nanoscale, appreciate the impossibility of creating nanoscale materials with macro scale objects, and to understand the invisibility of the nanoscale to the unaided eye. [1]

Materials

For each group of students, provide

- Scissors
- A strip of paper (cut a narrow strip from an 8.5 x 11 inch sheet of paper, approximately 8.5 inches long by 1/4 inch wide, or 216 mm x 5 mm)
- Pen or pencil
- Ruler
- Calculator

Classroom Activity

Show the students the strip of paper and tell them what its dimensions are. Explain to them that the challenge is to cut the piece of paper in half repeatedly in order to make it 10 nm long.

Have the students get in pairs and give each pair the ruler, calculator, scissors, pen/pencil (if necessary), strip of paper, and the Cutting It Down Activity: Student Worksheet. Remind them to answer the first two questions on the worksheet before they begin cutting. Tell them they have 10 minutes to complete the activity.

As a variation, you could have students do the exercise more than once with different kinds of scissors or other cutting tools to demonstrate the power and limitations of tools.

Discussion

When the students have finished the activity, discuss the questions on their worksheets. Focus on the following questions first:

- Were their predictions to the first two questions accurate?
- How many times were they able to cut the paper?

After discussing these questions, focus on the remaining questions on their worksheets. As a closing point, emphasize that the demonstration shows how small nano really is and how inadequate macro scale tools (like the scissors), are in dealing with the nanoscale.

- If you have had students use different kinds of scissors or other cutting tools, you can also discuss the relationship between form and size of the tool and its precisions and usefulness at a certain size scale. For example, an x-acto blade can be used to make much finer cuts than a pair of scissors, although both are too big to be useful at the nanoscale.

[1] Adapted from http://mrsec.wisc.edu/Edetc/IPSE04/educators/activities/cuttingNano.html

Student Instructions

How many times do you think you would need to cut a strip of paper in half in order to make it between zero and 10 nanometers long? In this activity, you'll cut a strip of paper in half as many times as you can, and think about the process.

BEFORE you begin cutting the strip of paper, answer the following questions (take a guess):

1. How many times do you need to cut the paper in half to obtain a 10 nanometer long piece?

Answers will vary, since this is a prediction. Should be a fairly large integer value.

2. How many times do you think you can cut the paper before it becomes impossible to cut?

Answers will vary, since this is a prediction. Should be an integer value that is smaller than the answer to question 1.

Now cut the strip of paper in half as many times as you can. Remember to keep track of how many cuts you make.

AFTER completing the activity, answer the following questions.

3. Were your predictions to the above two questions accurate?

Answers will vary, but should indicate if their predictions matched their results.

4. How many times were you able to cut the paper?

Answers will vary, but should be an integer number, likely in the range of 6-8 cuts.

5. How close was your smallest piece to the nanoscale?

Very far. By cutting with a typical pair of scissors, you probably can get down to about the 1 mm range, which is 10^{-3} meters. The nanoscale range is 10^{-7} to 10^{-9} meters, or 4 to 6 powers of ten smaller.

6. Why did you have to stop cutting?

Couldn't position the paper on the scissors; the scissors were too big relative to the paper to cut any more, etc.

7. Can macroscale objects, like scissors, be used at the nanoscale?

No.

8. Can you think of a way to cut the paper any smaller?

Answers might include using a microscope, smaller scissors, or finer cutting tools.

Scale of Objects Activity: Teacher Key

In this activity, you will explore your perceptions different sizes. For each of the following items, indicate its size by placing an “X” the box that is closest to your guess.

Key:

A. Less than 1 nanometer (1 nm) [Less than 10^{-9} meter]
B. Between 1 nanometer (nm) and 100 nanometers (100 nm) [Between 10^{-9} and 10^{-7} meters]
C. Between 100 nanometers (100 nm) and 1 micrometer (1 µm) [Between 10^{-7} and 10^{-6} meters]
D. Between 1 micrometer (1 µm) and 1 millimeter (1 mm) [Between 10^{-6} and 10^{-3} meters]
E. Between 1 millimeter (1mm) and 1 centimeter (1 cm) [Between 10^{-3} and 10^{-2} meters]
F. Between 1 centimeter (1 cm) and 1 meter (m) [Between 10^{-2} and 10^{0} meters]
G. Between 1 meter and 10 meters [Between 10^{0} and 10^{1} meters]
H. More than 10 meters [More than 10^{1} meters]

	Less than 1 nm	**1 nm to 100 nm**	**100 nm to 1 µm**	**1 µm to 1 mm**	**1 mm to 1 cm**	**1 cm to 1 m**	**1 m to 10 m**	**More than 10 m**
Object	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
1. Width of a human hair				x				
2. Length of a football field								x
3. Diameter of a virus		x						
4. Diameter of a hollow ball made of 60 carbon atoms (a “buckyball”)		x						
5. Diameter of a molecule of hemoglobin		x						
6. Diameter of a hydrogen atom	x							
7. Length of a molecule of sucrose		x						
8. Diameter of a human blood cell				x				
9. Length of an ant					x			
10. Height of an elephant							x	
11. Diameter of a ribosome		x						
12. Wavelength of visible light			x					
13. Height of a typical adult person							x	
14. Length of a new pencil						x		
15. Length of a school bus								x
16. Diameter of the nucleus of a carbon atom	x							
17. Length of a grain of white rice					x			
18. Length of a postage stamp						x		
19. Length of a typical science textbook						x		
20. Length of an adult’s little finger						x		

Adapted from Tretter, T. R., Jones, M. G., Andre, T., Negishi, A., & Minogue, J. (2005). Conceptual Boundaries and Distances: Students’ and Experts’ Concepts of the Scale of Scientific Phenomena. *Journal of Research in Science Teaching*.

Scale of Small Objects: Teacher Key

1. Indicate the size of each object below by placing an "X" the appropriate box.

Key:

A. Less than 1 nanometer (1nm) [Less than 10^{-9} meter]
B. Between 1 nanometer (nm) and 100 nanometers (100 nm) [Between 10^{-9} and 10^{-7} meters]
C. Between 100 nanometers (100 nm) and 1 micrometer (1 μm) [Between 10^{-7} and 10^{-6} meters]
D. Between 1 micrometer (1 μm) and 1 millimeter (1 mm) [Between 10^{-6} and 10^{-3} meters]
E. Between 1 millimeter (1 mm) and 1 centimeter (1 cm) [Between 10^{-3} and 10^{-2} meters]

	Less than 1 nm	**1 nm to 100 nm**	**100 nm to 1 μm**	**1 μm to 1 mm**	**1 mm to 1 cm**
Object	**A**	**B**	**C**	**D**	**E**
1. Width of a human hair				**x**	
2. Diameter of a hollow ball made of 60 carbon atoms (a "buckyball")		**x**			
3. Diameter of a hydrogen atom	**x**				
4. Diameter of a human blood cell				**x**	
5. Wavelength of visible light			**x**		

2. Order the following items in order of their size, from smallest to largest.

a. Width of a water molecule
d. Diameter of a gold atom
c. Thickness of a staple
d. Diameter of a virus
e. Length of an amoeba
f. Diameter of a carbon nanotube

Smallest:	___d_____
	___a_____
	___f_____
	___d_____
	___e_____
Largest:	___c_____