Teacher's Guide

Exploring the Powers of Ten

Grade Level: 5-8

Subject area(s): General & Physical science; Math

Time required: (1-2) 50 minute classes

Learning objectives: Learn scientific notation and its uses in STEM. Understand the size of the nanoscale.

Summary: Through a series of activities, students will understand why the use of exponents is important in science mathematics, and engineering as well as everyday jobs. The lesson serves as an introduction to the Powers of Ten Notation or Scientific Notation. Included is a homework assignment focused on how different careers/jobs use the scientific notation to perform their work. Students will also learn how small object at the nanoscale are.

Lesson Background: Scientist and engineers (who often use very large or very small numbers) typically write numbers using this method. Powers of Ten Notation is often called Scientific Notation. Scientific notation is a way of writing numbers that accommodate values too large or small to be conveniently written in standard decimal notation.

Students may ask why we need the Powers of Ten. The Powers of Ten is a very useful way of writing down large or small numbers that would require lots of zeros. It allows these number to be conveniently written in decimal form. With scientific notation, we use a number called an exponent to indicate how many powers of 10 or how many 1/10 the number will be multiplied by. Exponents are "shorthand" for repeated multiplication of the same thing by itself. The exponent is positive if it is multiplied by 10 and negative if it is multiplied by 1/10. For example:

$$5000 = 5 \text{ X } 10 \text{ x } 10 \text{ x } 10 = 5 \text{ x } 10^{3}$$
$$.0005 = 5 \text{ X } 1/10 \text{ x } 1/10 \text{ x } 1/10 \text{ x } 1/10 = 4 \text{ X } 10^{-4}$$

Using exponents to express objects that are on the nanoscale is very important when discussing objects that are on the scale of a billionth of a meter. The same holds true for exploring the galaxies where the number of stars can be in the billions.

The term "nano" refers to the metric prefix 10^{-9} or a billionth of something. A nanometer is one billionth of a meter. Nanoscale science and engineering is the study of the structures and materials on the scale of 1 to 100 nanometers. We do not see objects at the nanoscale because they occur below the range of visible light (380-700nm) but we have instruments that will form an image of nanoscale materials. Structures in the nanometer size may take on interesting and useful properties. Researchers are using these new and exciting properties to produce new products and materials. To learn more about nanotechnology see Nano101 at the National Nanotechnology Initiative's website: https://www.nano.gov/nanotech-101.

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Vocabulary and Definitions: Provide these to students and have them define in class or as homework.

1. *Powers of Ten Notation*: large numbers are written using ten to a power, called an exponent. The exponent indicates how many times ten the unit is to be multiplied by itself to equal the number you wish to write.
2. *Scientific Notation*: a method used to represent numbers that are too large or too small to be conveniently written in decimal form. It is a base ten notataion with all numbers expressed as M x 10^n.
3. *Exponent*: expressed as a number or letter written above and to the right of a mathematical expression which represents the power to which a given number is to be raised (multiplied). The base is x and n is the exponent or power such as 4^4 = 4x4x4x4.
4. *Macro*: anything that can be seen with the naked eye or anything greater than ~100 micrometer.
5. *Micro*: objects that are between 100 micrometers to 100 nanometers
6. *Nanoscale*: measured in nanometers; typically referring to materials between 1 and 100 nm but others use up to several hundred nanometers.
7. *Nanometer*: $1x10^{-9}$ or one billionth of a meter.
8. *Nanotechnology*: Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.

Materials:

- Computer with Internet access
- Copies of worksheets

Advance Preparation:

- Confirm that website URLs are correct
- Printout worksheets for students

Directions for the Activity: Begin the activity by introducing scientific notation and exponents. Attached is a list of prefixes (SG#1) that you may want to print out for students or perhaps show on the whiteboard. Ask students how many prefixes are familiar to them. You may want to use one of the online videos on this topic – links listed below. Next, have students complete Student Guide #2 and discuss results as a class. This is a good time to address misconceptions. An extension to this activity could be a size and scale number line activity. A list of these lessons and online resources are below.

Next, direct students to access the websites in the "Exploring the Universe with Powers of Ten" (Student Guide #3). Have them answer the accompanying questions. As a class, discuss what

the students found most interesting and most difficult to understand. Finally, you may assign as homework Student Guide #4. Students will search a list of jobs/careers and determine how the people in these professions use the Powers of Ten. You may assign all of the jobs or assign students specific ones.

Resources: (Other resources can be found in Student Guide #2)

- Index Notation and Powers of Ten - https://www.mathsisfun.com/index-notation-powers.html
- Which Is Greater, The Number Of Sand Grains On Earth Or Stars In The Sky? www.npr.org/sections/kralwich/2012/09/17/161096233/which-is-greater-the-number-of-sand-grains-on-earth-or-stars-in-the-sky
- Molecular Expressions™ Secret Worlds: The Universe Within - http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersoften
- Math Planet: Powers and Exponents - https://www.mathplanet.com/education/pre-algebra/discover-fractions-and-factors/powers-and-exponents
- Kahn Academy Intro to Exponents: https://www.khanacademy.org/math/cc-sixth-grade-math/cc-6th-arithmetic-operations/cc-6th-exponents/v/introduction-to-exponents
- Kahn Academy Exponents and Powers of Ten Patterns - https://www.khanacademy.org/math/cc-fifth-grade-math/powers-of-ten/imp-multiplying-and-dividing-with-powers-of-10/v/patterns-in-zeros-exercise
- A Comparison of Scale: Macro, Micro, Nano - https://nanohub.org/resources/26676/download/Int_Scale_PK12_PG.pdf
- Passy's World of Mathematics: Why Exponent Powers are Important - http://passyworldofmathematics.com/exponents-in-the-real-world/
- Jobs that use Exponents - https://careertrend.com/about-5444244-careers-use-math-everyday.html

Size and Scale

Number line activities:

- Size and Scale – Learning about measurement - https://www.nnci.net/node/5305
- *NanoSense Size Matter Lesson 2: Size and Scale – The Number Line activity* - http://nanosense.sri.com/activities/sizematters/sizeandscale/SM_Lesson2Teacher.pdf (answers) and http://nanosense.sri.com/activities/sizematters/sizeandscale/SM_Lesson2Student.pdf

Interactive links:

- http://www2.mcrel.org/NanoLeap/multimedia/
- http://www2.mcrel.org/NanoLeap/multimedia/Nanosize_me.swf
- http://scaleofuniverse.com/
- http://www.eamesoffice.com/the-work/powers-of-ten/ http://www.cneu.psu.edu/edToolsActivities.html
- http://www.cellsalive.com/howbig.htm
- http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

Game:
http://www.nisenet.org/catalog/programs/exploring_size_-_powers_ten_game_nanodays_2011
Scale Ladder and poster
Scale Ladder: http://www.nisenet.org/catalog/media/scale-ladder
Nanotechnology Size and Scale Poster - https://www.nnci.net/node/5288

Common Core Math Standards:
Grade 5: Number and Operations in Base Ten
Grade 6, 7 & 8: The Number System

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