Name: ______________________________ Date: ______________ Per: ________

Orders of Magnitude: The Universe in Powers of Ten

“How wide is the Milky Way galaxy?” “How small is a carbon atom?” These questions may sound simple, but their answers are virtually impossible to comprehend since nothing in our realm of experience approximates either of these measures. To grasp the magnitude of such dimensions is perhaps impossible, but it is relatively easy to express such dimensions by scaling up or down (expressing them in orders of magnitude greater or smaller) from things with whose dimensions we are familiar. An order of magnitude is the number of powers of 10 contained in the number and gives a shorthand way to describe scale. An understanding of scale allows us to organize our thinking and experience in terms of size and gives us a sense of dimension within the Universe.

To simplify the expression of very large and small numbers, scientists often use scientific notation. Scientific notation involves writing a number as the product of two numbers. The first one, the digit value, is always more than 1 and less than 10. The other, the exponential term, is expressed as a power of 10. The table below compares decimal and scientific notation.

The diameter of the Milky Way Galaxy is believed to be about 1,000,000,000,000,000,000,000 meters. By contrast, the diameter of the nucleus of a carbon atom is only approximately 0.000 000 000 000 01 meters. In scientific notation, the diameter of the Milky Way is $1{\times}10^{21}$ m, and the diameter of the carbon nucleus is $1{\times}10^{-14}$ m. The Milky Way is therefore approximately 10^{35} times (35 orders of magnitude) larger than the carbon atom. Calculators and computers may express the dimensions of the Milky Way and the carbon nucleus as 1.0E21 and 1.0E-14, where E stands for the exponential term. The speed of light, approximately 300 million (299,792,458) m per second, is expressed in scientific notation as approximately $3.0{\times}10^{8}$ m/s (3.0E8). Avogadro’s number, the number of molecules in a mole (602,213,670,000,000,000,000,000), is expressed as $6.02{\times}10^{23}$ (6.02E23).

Scientific notation is particularly helpful when trying to express the scale of the universe. In 1957, Dutch educator Kees Boeke published *Cosmic View: The Universe in 40 Jumps*, in which he helped readers visualize the size of things in the known universe with reference to a square meter (10^{0} m^{2} = 1 m^{2}). In this book, Boeke showed successively smaller pictures, each one a tenth the dimension of the previous (10^{-1} m, 10^{-2} m, 10^{-3} m, and so on) as well as successively larger pictures, each ten times larger than the previous (10^{1} m, 10^{2} m, 10^{3} m, and so on).

Decimal Notation	Scientific Notation	Order of Magnitude	Decimal Notation	Scientific Notation	Order of Magnitude
0.001	$1{\times}10^{-3}$	-3	10	$1{\times}10^{1}$	1
0.01	$1{\times}10^{-2}$	-2	100	$1{\times}10^{2}$	2
0.1	$1{\times}10^{-1}$	-1	1,000	$1{\times}10^{3}$	3
1	$1{\times}10^{0}$	0	10,000	$1{\times}10^{4}$	4

Activity 1:

A number of moviemakers and Web developers have followed Boeke's idea in an effort to help people understand the scale of things in the universe. Go to **http://htwins.net/scale2/** to explore the Scale of the Universe 2. Use the app to help fill in the table below with an example illustrating each power of ten.

Distance	Comparison
10^{26} m	
10^{25} m	
10^{24} m	
10^{23} m	
10^{22} m	
10^{21} m	
10^{20} m	
10^{19} m	
10^{18} m	
10^{17} m	
10^{16} m	
10^{15} m	
10^{14} m	
10^{13} m	
10^{12} m	
10^{11} m	
10^{10} m	
10^{9} m	
10^{8} m	
10^{7} m	
10^{6} m	

Distance	Comparison
10^{5} m	
10^{4} m	
10^{3} m	
10^{2} m	
10^{1} m	
10^{0} m	
10^{-1} m	
10^{-2} m	
10^{-3} m	
10^{-4} m	
10^{-5} m	
10^{-6} m	
10^{-7} m	
10^{-8} m	
10^{-9} m	
10^{-10} m	
10^{-11} m	
10^{-12} m	
10^{-13} m	
10^{-14} m	
10^{-15} m	
10^{-16} m	
10^{-17} m	
10^{-18} m	

Activity 2:

The figure below displays millimeter graph paper. The tiny black square in the upper left corner is 1 mm on a side, (10^{-3} meters). The sides of the gray square in the upper left corner are an order of magnitude greater than the black square (10 mm per side, 10^{-2} m). Finally, the sides of the entire sheet, with 100 mm per side (10^{-1} m), are two orders of magnitude greater than the black square and one order of magnitude greater than the gray square.

Working with your classmates, create a square meter (1000 mm on a side) by taping 100 of these squares together in a 10 × 10 square. This is 1 square meter with sides and area three orders of magnitude greater than the square millimeter represented by the tiny black box.

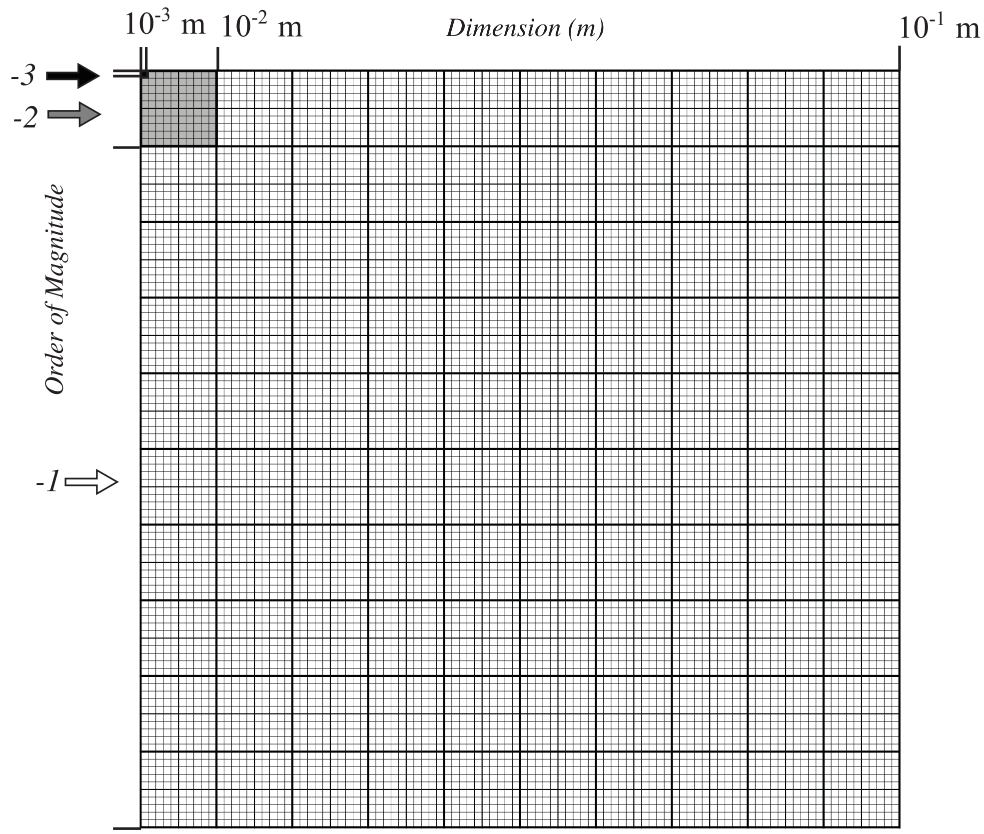

Figure 8.2 Orders of magnitude -3, -2, -1

Activity 3:

Each student will be assigned an order of magnitude. Use the table you filled out in *Activity 1* to create a poster of the item from your table that corresponds to your assigned order of magnitude.

1. In the upper left corner, write on large or bold characters the approximate dimension of your object in scientific notation. For example, if your item is the Earth, you will write "10^8 m".
2. In the upper right corner, identify the object (e.g. "The Earth").
3. In the center of the sheet, draw a picture of the object.
4. Below the image, give a brief description of the object.
5. Once everyone has finished, as a class, arrange the posters around the room from smallest to largest.

Examples below: