A GOOGOL OF ATOMS?
A DIRECTED, INTERRUPTED CASE IN ESTIMATION AND LARGE NUMBERS
PART I

by
Stephen J. Shawl
Department of Physics and Astronomy
University of Kansas

You may remember a time when you were a child and you had a talk with a parent, relative, or teacher that blew your mind. I'd like to tell you of one such talk with my daughter, Jessica, when she was a precocious 7 year old.

Jessica had just become aware of the word *googol*. She was told that a googol was a very large number—a 1 followed by 100 zeros:

10000000000000000000000000000000000000000000000000000
 0000000000000000000000000000000000000000000000000

I asked if a googol is larger than the number of atoms in the visible universe. She said, "There must be more atoms in the visible universe than that! How can you possibly figure it out?" I replied, "We can figure it out together. What do you think we might need to know, Jessica?"

How could you help Jessica? What do you need to know?

Questions

Use scratch paper to write out responses to the following.

1. First let's think about a number of questions:

    a. What do we mean by "the universe"?

    b. What is "matter"? In what way(s) can we say how matter is present in something?

    c. Can we see all matter?

    d. What do we mean by the "visible universe"?

2. List the specific types of information you think might be needed to determine the number of atoms in the visible universe.

3. What assumptions will you be making in obtaining your final result? How valid are those assumptions?
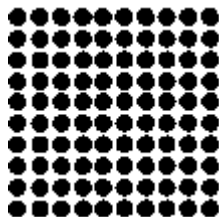
How big is a googol?

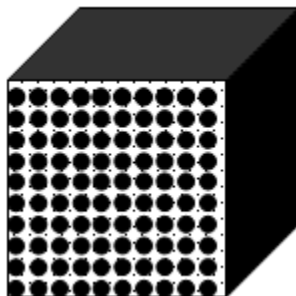To start, here are 10 dots (covering about 1-inch):

●●●●●●●●●●

4. Express this number (10) in scientific notation:

If we make a square 10 dots on a side, we have 100 dots:

If we fill a 10 x 10 x 10 cube with dots, we have 1000 dots, something like this:

5. Express each of these numbers in scientific notation:

100:

1,000:

If we made this cube 10 times larger *on each side* (10 inches), we'd have 1,000,000 dots inside;
10 times larger than that *on each side* (100 inches = 8.3 feet) we'd have 1,000,000,000 dots;
10 times larger than that *on each side* (1000 inches = 83 feet) we'd have 1,000,000,000,000 dots.

6. Express these numbers in scientific notation. What *words* are used for these large numbers?

1,000,000:

1,000,000,000:

1,000,000,000,000:

Words for big numbers, while meaningful, are awkward. For example, you cannot do mathematical manipulations with words; try multiplying the words *billion* and *trillion*! In any case, the numbers soon become large, difficult to imagine, and there's no simple word for them.

7. Express a googol in scientific notation.

We'll now look at some astronomical numbers. Use whatever reference sources you need (including the Internet). Be sure the units of the numbers are consistent.

We can discuss the amount of matter in a variety of ways. One is in terms of mass—the number of kilograms, say. In chemistry, one might discuss the number of *moles*. Or, the amount of matter might be discussed in terms of the number of atoms. In the discussion to come, you will begin with kilograms or moles and then make a calculation to obtain the number of atoms, which you'll then compare to a googol.

8. Approximately how much matter is there in Earth?

9. Approximately how much matter is there in the Sun?

10. How do they compare?

11. What do you think is the importance of that comparison?

12. What is the approximate number of stars in a typical (average) galaxy?

13. What is the approximate number of galaxies in the visible universe?

14. Now, finally, what is the number of atoms in the visible universe?

15. How does this number compare with a googol?