Cutting It Down to Nano

Organization: University of Wisconsin-Madison Materials Research Science and Engineering Center
Contact person: Kim Duncan and Greta Zenner

Contact information: kaduncan@wisc.edu or gmzenner@wisc.edu

General Description

Type of program: Cart demo / classroom activity

"Cutting it Down" is a cart demo that communicates scale through a hands-on activity. Visitors learn that the nanometer size scale is very, very small—and that we can't use macroscale tools to manipulate nanoscale materials. During the program, visitors are challenged to cut a small strip of paper in half as many times as they can—or until they reach the nanoscale, which ever comes first.

Program Objectives

Big Idea: Nanoscale is very very small.

Learning goals:
As a result of participating in this program, visitors will be able to:
understand that the nanoscale is very, very small and that scientists working at the nanoscale require special tools.

NISE Network Main Messages:

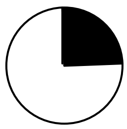
[ ] 1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.
[ ] 2. Many materials exhibit startling properties at the nanoscale.
[x] 3. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.
[ ] 4. Nanoscale research is a people story.
[ ] 5. No one knows what nanoscale research may discover, or how it may be applied.
[ ] 6. How will nano affect you?

Cutting it Down to Nano

Table of Contents

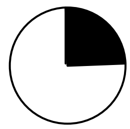
Time Required

Set-up



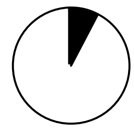
15 minutes

Program



15 minutes

Clean Up



5 minutes

Background Information

Definition of terms

Nano is the scientific term meaning one-billionth (1/1,000,000,000). It comes from a Greek word meaning "dwarf."

A *nanometer* is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eyeblink is to a year what a nanometer is to a meter stick.)
Other analogies:
One billion seconds pass in 31 years, 8 months and 2 weeks.

If a C_{60} molecule (a.k.a. a Buckyball) were the size of a soccer ball, a soccer ball would be the size of planet Neptune.

If all of the people on earth were the size of one nanometer then EVERYONE on the planet could fit into one Hot Wheels sized car.

Nanoscale refers to measurements of 1 – 100 nanometers. Some interesting objects measured in nanometers:

- A single water molecule is about $1/4^{th}$ of a nanometer across.
- 10 hydrogen atoms lined up next to one another spans1 nanometer.
- A cell membrane is about 9 nanometers thick.
- A virus is approximately 70 nanometers wide.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions. For instance, gold nanoparticles appear red (as well as orange, purple or green, depending on the size or shape of the particle) and melt at much lower temperatures than bulk gold, like that used in jewelry. Aluminum nanoparticles spontaneously combust (increased reactivity), but an aluminum can of soda doesn't react with the air around it.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules.

Nanoscience, nanoengineering and other such terms refer to those activities applied to the nanoscale. "Nano," by itself, is often used as short-hand to refer to any or all of these activities.

Program-specific background

Scientists use the metric system to measure things. The metric system uses powers of ten to show how large or small things are with respect to a specific unit of measure (called the base unit). The physical size of an object (length, width or height) is measured using the *meter*. A meter is about the same size as a yard.

Some objects are only a fraction of meter in size, while others are many, many meters long. Scientists use prefixes to the word "meter" to describe how big (or small) something is, relative to one meter.

Some of the prefixes commonly used when measuring things **smaller** than a meter:

> *Deci*-: the meter is divided into 10 (ten) equal parts. Each decimeter is $1/10^{th}$ of a meter long.
>
> *Centi*-: the meter is divided into 100 (one hundred) equal parts. Each centimeter is $1/100^{th}$ of a meter long.
>
> *Milli*-: the meter is divided into 1,000 (one thousand) equal parts. Each millimeter is $1/1000^{th}$ of a meter long.
>
> *Micro*-: the meter is divided into 1,000,000 (one million) equal parts. Each micrometer (or micron) is $1/1{,}000{,}000^{th}$ of a meter long.
>
> *Nano*-: the meter is divided into 1,000,000,000 (one billion) equal parts. Each nanometer is $1/1{,}000{,}000{,}000^{th}$ of a meter long.

Some of the prefixes used when measuring things **larger** than a meter:

> *Deca*-: the meter is multiplied by 10. There are 10 meters in 1 decameter.
>
> *Hecto*-: the meter is multiplied by 100. There are 100 meters in 1 hectometer.

Kilo-: the meter is multiplied by 1,000. There are 1,000 meters in one kilometer.

Sometimes, scientists use a special method of writing these numbers called *scientific notation*. It's a shorthand way to write numbers that are very large or very small by using powers of ten (*exponents*).

If you've got a number 10 or greater, then move the decimal point to the left until there's only one numeral, or *significant figure*, left of the decimal. Then, write the number of places you moved as the exponent. For example, 1,000,000 meters is shortened to 1×10^6 meters. Similarly, 4.5×10^4 equals 45,000.

If your number is less than one, then move the decimal point to the right until there's only one significant figure to the **left** of the decimal. Again, write the number of places you moved as the exponent, only this time make it a negative number. For example, 0.000001 meter would be shortened to 1×10^{-6} meter. You had to move the decimal point 6 places to the right to get the "1" to the left of the decimal. Similarly, 6.7×10^{-3} equals 0.0067.

A *nanometer* is one-**billionth** of a meter, or 1×10^{-9}. The nanometer is very small--too small to see. Most traditional scientific tools are too big, or lack the precision, to be useful at the nanoscale. Scientists and engineers have to develop special tools to look at and manipulate materials that are just a few nanometers in size.

Materials

Scissors

A strip of paper (dimensions 150mm x 5mm, or 5.9" x 0.2")

"Cutting It Down to Nano" work sheet

Ruler

Pen or pencil*

Calculator*

Tape*

*additional supplies needed for the classroom activity

Set Up

Time: (15+ minutes. Most of prep time goes to cutting the strips of paper)

Pre-cut sufficient number of strips of paper.

Arrange materials in a manner convenient for use.

Program Delivery

Time: (10-15 minutes)

Safety:

Scissors should be used with care. Safety scissors are recommended.

Procedure and Discussion:

Explain to the visitor that "nano" means “one billionth” and that a nanometer is one billionth of a meter. If necessary, remind them that a centimeter is one hundredth of a meter and millimeter is one thousandth to help them get it.

Give each visitor the 150mm x 5mm (5.9” x 0.2”) piece of paper and a pair of scissors. Tell the visitor what the paper’s dimensions are. Mention that they also have a calculator, a ruler, and the worksheet to use if they want.

Ask the visitor to guess how many times they would have to cut the paper to make a 10 nanometer long piece. Ask them how many times they think they can cut the paper before it becomes impossible to cut with the scissors.

Tell the visitors to begin cutting the strip of paper crosswise and to continue cutting it in half as many times as they can. Remind them to keep track of the number of cuts they make.

Once the visitor has made as many cuts as possible, have them measure the dimensions of the paper. Discuss the following questions:

- Were their predictions accurate? (It takes 24 cuts to make a 9nm-long piece.)
- How many times did they cut the paper?
- How close was the smallest piece to the nanoscale?
- Why did they have to stop cutting?
- Can macroscale objects, like scissors, be used on the nanoscale?
- Can they think of any way to cut the paper any smaller?

As a closing point, emphasize that the demonstration shows how small nano really is, and how inadequate macro scale tools, like scissors, are for dealing with the nanoscale.

Tips and Troubleshooting:

With younger audiences, or for groups who find scientific notation and/or measuring difficult, concentrate on the "objects on that scale" portion of the “Cutting It Down to Nano” worksheet.

If you do this as a classroom activity, students can create their own measurement table. Ask them to measure and record the length of each successive piece of paper in millimeters. After measuring, the piece of paper can be taped down onto the “Cutting It Down To Nano” worksheet. Use colored strips of paper so they stand out.

In addition, visitors could also rewrite the measurements in scientific notation. If you do this, you might pair students who understand scientific notation with those who don’t. Have the former guide the latter through the activity.

Common Visitor Questions

TBD

Going Further…

Special tools used to manipulate atoms at the nanoscale:

Scanning Probe Microscopes
http://mrsec.wisc.edu/Edetc/background/STM/index.htm
http://mrsec.wisc.edu/Edetc/cineplex/MMSD/scanning2.html

Other types of microscopes that scientists use to work at the nanoscale: Magnetic Force Microscopy (MFM); Chemical Force Microscopy (CFM); Atomic Force Microscopy (SFM); and Electrostatic or Electric Force Microscopy (EFM)

Clean Up

Time: (5 minutes)
Collect scissors, tape, rulers and other non-disposable supplies.

Recycle paper cuttings

Universal Design

This program has been designed to be inclusive of visitors, including visitors of different ages, backgrounds, and different physical and cognitive abilities.

The following features of the program's design make it accessible:

[x] 1. Repeat and reinforce main ideas and concepts

- The overarching main idea is explicitly stated at the beginning of the program, and reinforced by the activity and subsequent discussion.
- The program provides verbal, visual, and tactile entry points into the program's main message and learning objectives.
  - The presenter provides a verbal explanation and description of the challenge and the learning objectives.
  - The size of the nanoscale is also visually conveyed by giving sizes and pictures of a series of objects in decreasing size (that correspond roughly to the size of the paper cuts).
  - The smallness of the cut paper (and the associated difficulty in handling the pieces of paper) provide visitors with both a visual and a tactile experience.

[x] 2. Provide multiple entry points and multiple ways of engagement

- The program engages visitors in a hands-on activity, and provides a guided discussion that helps them to understand its significance.

[x] 3. Provide physical and sensory access to all aspects of the program

- The presenter performs the first two or three cuts of the paper strip alongside the visitors, while verbally explaining and describing the process. This allows for both visual and auditory learners to digest activity directions, and allows visitors who are unable to do the cutting activity to get a sense of the difficulty of the challenge.
- The presenter can vary the pace of the program to suit the audience, providing extra time for working or additional discussion when necessary.

To give an inclusive presentation of this program:

1. Left-handed, right handed and safety scissors should be provided.
2. In addition to the examples given on the worksheet, the demonstrator can provide information regarding the size of other objects that may be more familiar with a given audience.

This project was supported by the
National Science Foundation under Grant No. ESI-0532536.