Nanofibers: Measuring the Visible to Understand the Invisible.

Background: Nanotechnology is the manipulation of matter, atom by atom at the "nanoscale." A nanometer is 1 billionth ($1x10^{-9}$) of a meter – about 3 to 5 atoms (depending on which kind of atoms) wide. In 1998, David Soane founded Nano-Tex, a company created to find ways to improve the strength, durability and usefulness of natural fibers such as cotton and wool, that we use to make clothing. Sloane developed a way to bond nanotubes, tiny structures he called "nanowhiskers" to each individual thread of the cloth. Nanotubes are made of carbon and are only about 10 nanometers long, each. The "nanowhiskers" are so small and so close together, they form a sort of barrier around the cloth that prevents liquids and other substances that stain fabric from even touching the actual fabric. Instead, liquids bead up and can be brushed off like loose dirt. The relative size of the nanowhiskers to the cotton or wool thread can be compared to the relative size of peach fuzz on a lamp post. The nanofibers cannot be seen or felt on the cloth, so it feels as soft as any untreated cloth.

One possible problem with nano-sized particles, is the toxicity of the substance that makes up the particles. The nanotubes that make up the nanowhiskers on fabric do not easily come off, and will stay fused to the fabric through hundreds of launderings (Stenzel, 2007) However, toxicity of nanoparticles, seems to increase as the surface area to volume ratio of the nanoparticles increases.

Purpose: The purpose of this activity is to compare the size and shape of tubes that can be measured, to the size and shape of "nanowhiskers" that are too small to see. Students will gain experience measuring, calculating and graphing the ratio of circumference to diameter of a circle, and ratio of volume to area of a cylinder. They will gain understanding of the significance of the slope of a graph as well as experience in interpreting graphs and using them to make predictions. Through this the student may understand how scientists can extrapolate actual measurements they can make to predict the size, shape and density of objects too small to measure.

Materials:
6" Sections of dowel rods that measure 1 ¼ inches, 1 inch, 3/4 inches and ½ inches and ¼ inches diameter (or something similar), string, scissors, centimeter ruler, samples of treated and untreated nanofiber cloth.

A word on Graphing

A graph is a picture of the data. It is a way to represent data so that trends and changes can be visualized. Line graphs are a way to visualize many data points individually and as a group. Since raw data points are rarely accurate on their own, the line representing the trend shown among all the data points should not be drawn "dot- to-dot" to include each point. Instead, a "best fit" line is drawn in such a way that most of the raw data points are scattered equally around the line, but not necessarily resting on it. **When you graph your data,** find one "best fit" straight or curved line through the data points, and not a jagged point-to-point line that connects each dot.

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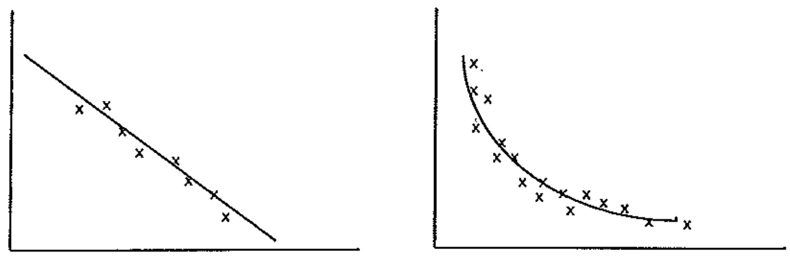
The slope of a best fit line is equal to the derivative of the two values being graphed.

Examples of "best fit" lines through individual data points:



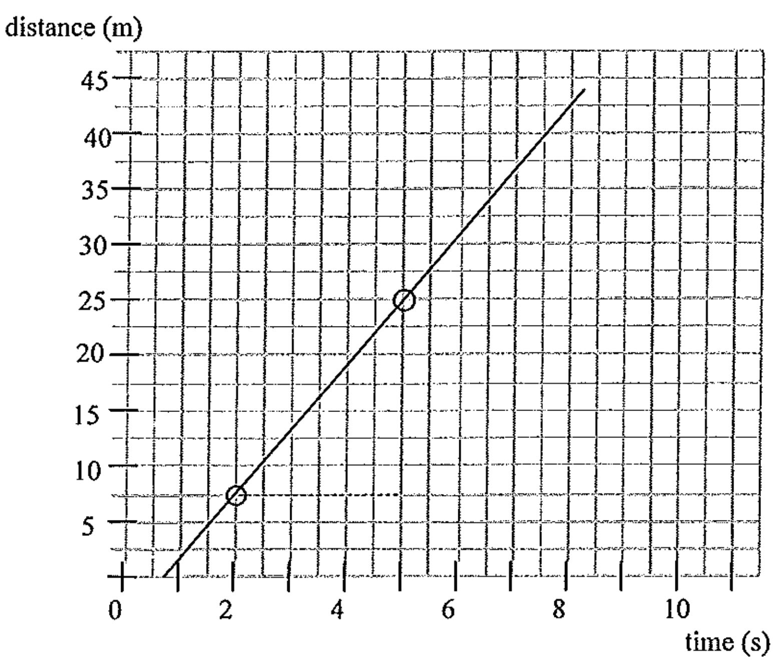
Finding the slope of a Best Fit Line

If the best fit line of data points is a straight line, as in case (A) above, an average value can be determined as follows:

a) Find two places where the line crosses two perfect intersections of the grid.

b) Find the rise and run of the slope by counting the number of vertical (rise) squares and horizontal (run) squares. Multiply the number of vertical and horizontal squares by the unit increment each square represents. For example, if each vertical square represents 2.5 m and there are 7 vertical squares, multiply 7 by 2.5 m. If each horizontal square represents 0.5 seconds and there are 6 horizontal squares, multiply 6 by 0.5 s. The slope of this graph would then be (7 x 2.5 m) \ (6 x 0.5 s) = 5.8 m/s.

Example of finding slope using a best fit line:



Two perfect intersections occur at the points circled. The triangle formed has 7 vertical squares and 6 horizontal squares.

Each vertical square = 2.5 m

Each horizontal square = 0.5 s

The rise over the run $= \dfrac{7 \times 2.5\text{m}}{6 \times 0.5\text{s}}$

$$= \frac{17.5\text{m}}{3.0\text{s}} = 5.8\text{m/s}$$

The slope of a position vs. time graph is equal to the velocity.

Procedure: Part A

1. Measure the diameter and the length of each section of pipe and record your data in Table I of the Data Page.
2. Wrap a piece of string snugly around the outside of each section of pipe and cut it so that the length of string is equal to the circumference of the pipe. Measure the length of string and record your data under "circumference" in table I of the Data Page.
3. Graph circumference vs. diameter putting the circumference on the y-axis and the diameter on the x-axis of your graph. You can do this using graph paper, a computer or a graphing calculator.
4. Find the slope of your graph and compare the slope with the actual value of pi using a % error equation:

$$\left|\frac{\pi - slope}{\pi}\right| x100 = \%error \qquad \text{or} \qquad \left|\frac{3.141592 - slope}{3.141592}\right| \text{x}100 = \%\text{error}$$

Show your work in the space provided under Table I of the Data Page.

Since $slope = \frac{rise}{run}$ and $\pi = \frac{circumference}{diameter}$ the slope of your line should equal pi.

Procedure: Part B

1. Calculate the cross sectional area and volume of each dowel rod section using the equations:
   Cross Sectional Area (X-sect. area) $= \pi$ x radius x radius or π x r^2
   volume = X-Sect. area x height or π x r^2 x height

   Record your values in Table I.
2. Graph volume vs area putting the volume on the y-axis and area on the x-axis. You can do this using graph paper, a computer or graphing calculator.
3. Compare the slope of the graph of volume vs. area with the measured height of your dowels.

A straight line slope is a constant slope and it represents a number that does not change.

Procedure: Part C

1. Calculate the surface area of each dowel. The surface area is calculated by multiplying the circumference times the height, and then adding twice the cross sectional, or:

   Surface area = (Circumference x height) + (2 x π x r^2).

2. Calculate the surface area to volume ratio by dividing the surface area by the volume for each dowel. How doe these ratios compare as the volume of the dowel decreases?

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Data Page and Calculations

Table I

	Diameter (cm)	Circumference (cm)	Radius (cm)	Height (cm)	Cross Sectional Area (cm^2)	Volume (cm^3)	Surface Area (cm)	Surface Area to Volume Ratio
1								
2								
3								
4								
5								
6								
7								
8								

Calculations:

Cross Sectional Area: $A = \pi \times r^2$ Volume: $V = \pi \times r^2 \times h$

Surface Area: (Circumference x height) + ($2 \times \pi \times r^2$)

Surface Area to Volume Ratio: SA/V

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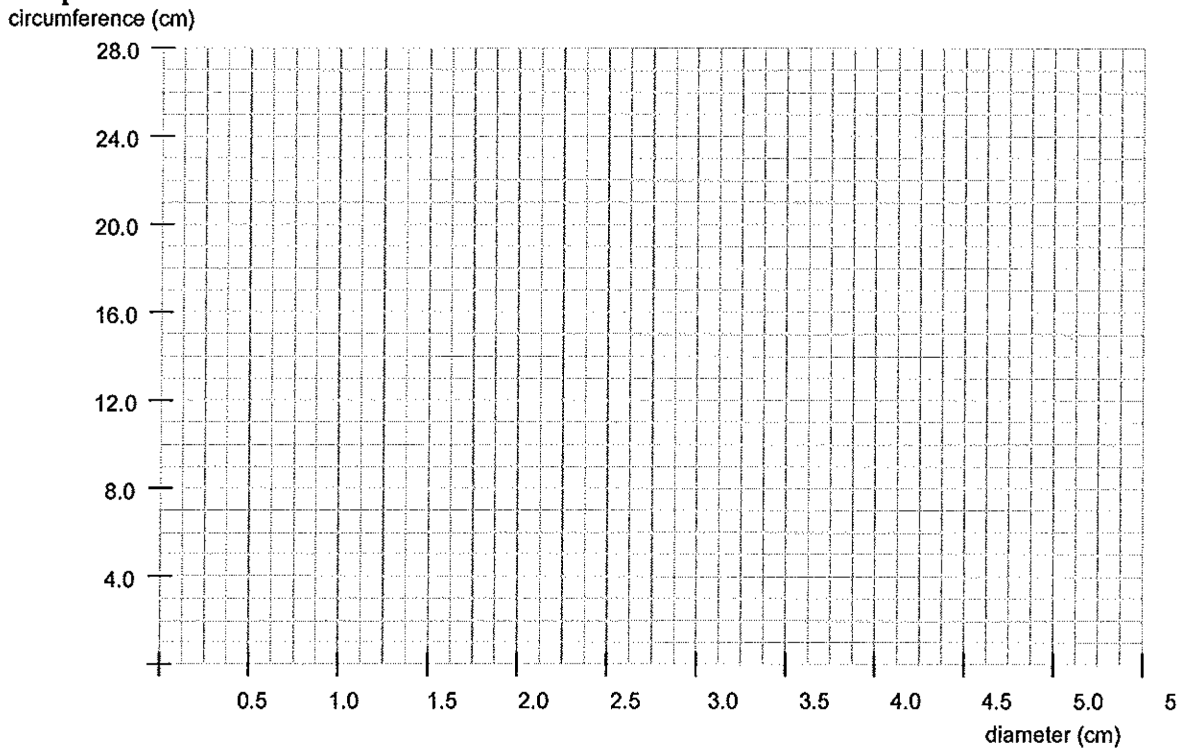
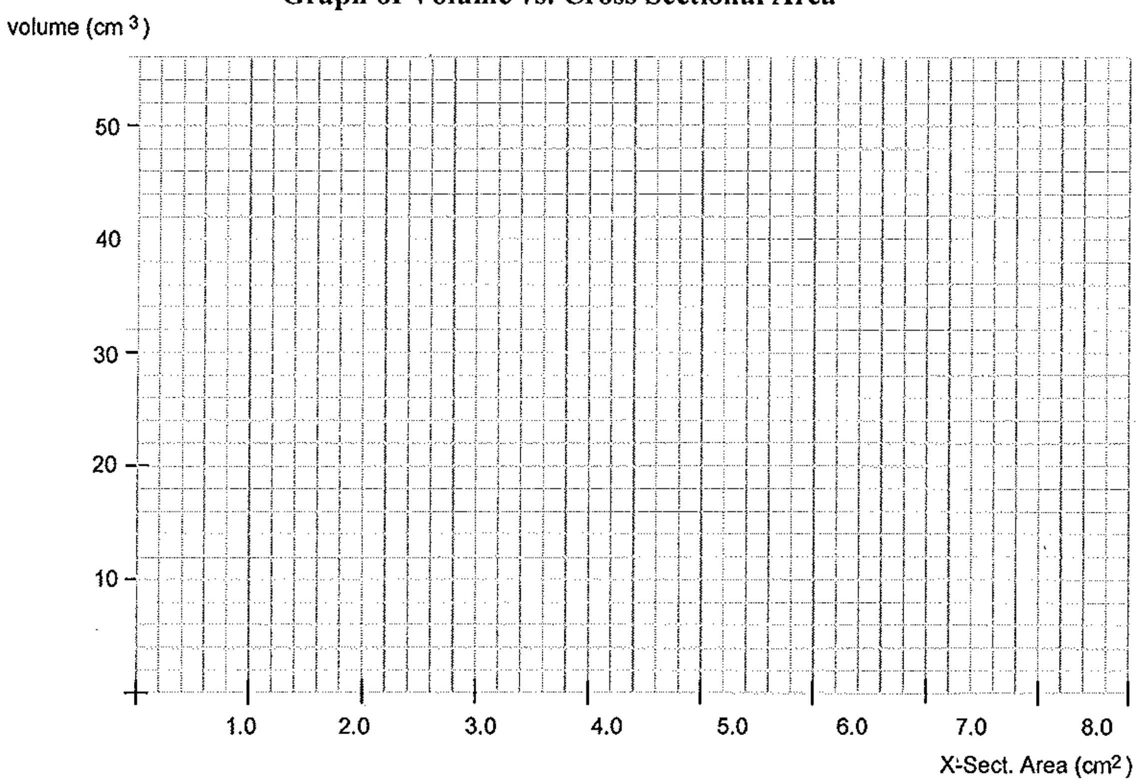
Graph of Circumference vs. Diameter



Graph of Volume vs. Cross Sectional Area



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Questions:

1. Using your graph, predict the circumference of a tube that has a diameter of 5.0 cm

2. Using your graph, predict the circumference of a tube that has a diameter of 0.25 cm

3. How can you use the slope of your volume vs area graph to analyze the accuracy of your measurement for height?

4. What would be the circumference of a nanotube that has a diameter of 1.5 nanometers?

5. What would be the area of a nanotube that has a diameter of 1.5 nanometers?

6. There are 1 billion, or 1×10^9 nanometers in one meter. How many nanometers are there in 1 centimeter?

7. There are $(1 \times 10^9)^2$ square nanometers in $1 m^2$. How many square nanometers are there in $1 cm^2$?

8. How many nanotubes could you place on the end of your smallest dowel rods?

9. How does the ratio of the surface area to volume of a particle change as the volume decreases?

10. How does the surface area of a nanoparticle affect the toxicity?

Insight: ____

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Measuring Magnetic Field Strength Using Ferrofluids

Ferrofluid Preform Display Cell purchased from teachersource.com - $29.95

Five-piece cow magnet from magnetsource.com - $2.91