Teaching Nanotechnology in the High School Curriculum: A Teacher's Guide

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First Edition

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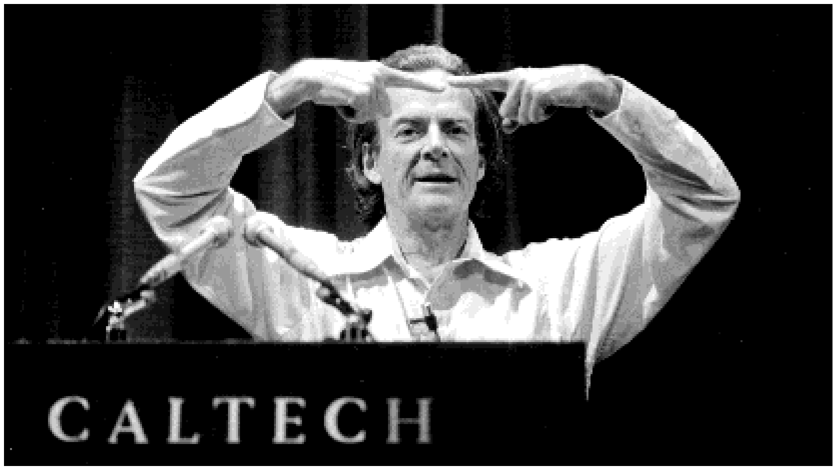
Nanotechnology: A Historical Perspective

The year is 1959. Caltech physics professor and Nobel Laureate (1965), Richard P. Feynman delivers a stunning lecture on the possibility of science research from the bottom up. The lecture, cleverly titled, " There is plenty of room at the bottom", suggests that there are no limits on producing things from the atomic level up. He is quoted as saying,



" The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom."

The questions that arose form this lecture were many. But did Feynman really set the spark towards nanotechnology. In 1808, John Dalton, a British Chemist claimed that every single atom of a certain element, is identical. This idea will become VERY important later in this perspective. In 1868, Gregor Mendel, A Czech Monk, characterized the structures and functions of heredity. Surely, both of these scientists could not have foreseen what we would do with their work.

Probably the most daunting task was to build devices that would allow us to see things that are on the atomic size. The term, "Nano-" itself means a billionth of a meter. This is 100,000 times smaller than a human hair. Feyman suggested in his lecture that we build better microscopes to accomplish the task of seeing things on the atomic level. It wasn't until 26 years later (1981) that we invented the Scanning Tunneling Electron Microscope. This device is widely used in industrial and fundamental research to obtain images of metal surfaces at the atomic scale. It allows us to produce a 3-D profile of the surface, which we can use to characterize roughness, defects, size, and conformation of molecules. The device basically works by placing an atom at the bottom of a very sharp tip of a needle. This needle is brought within close proximity of the surface being tested. Electrical voltage is then applied to the tip. The tip then interacts with the electron clouds on the metal surface. As the tip moves across the surface, the distance between the surface and the tip changes. As the distance changes so does the current flowing between the tip and the surface. These changes can then be converted into an image. And thus the ability to work at the atomic scale exploded.

It is pretty amazing to think that a lump of coal and a diamond are made of EXACTLY the same chemical: carbon. The ONLY difference is how the ATOMS are arranged. What would happen if we could manipulate the carbon atoms and manufacture diamonds as easily as M&M's? This certainly raises some questions about how our economic system might change in the near future. One interesting discovery on maneuvering carbon atoms around was in 1985. Scientist Richard Smalley and fellow researchers were able to construct a cage of 60 carbon atoms. It certainly appears that Dalton's basic theory has opened a door for us to fabricate endless things with basic raw elements.

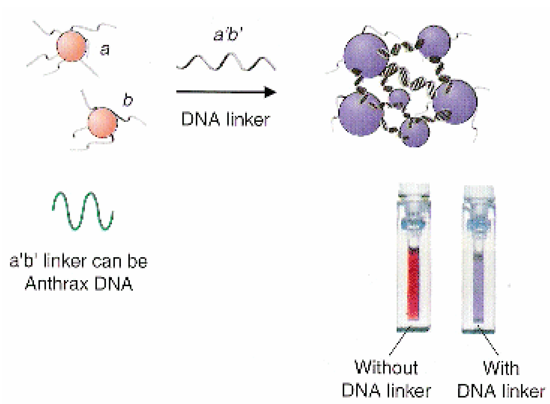
On November 9, 1989 at IBM's Almaden Research Center in San Jose, California, scientists Don Eigler and Erhard Schweizer began a little atomic manipulation project of their own. With company pride they manipulated 35 Xenon atoms to form the logo, "IBM". And thus the era of Nanotechnology began.

Nanotechnology Applications

Nanotechnology, from a business perspective, will create better and entirely new materials, devices, and systems. What does this mean? It means new jobs due to new markets. It is amazing that the science of small will have a HUGE impact in society. In fact, it is projected that by the year 2010, the demand for nanotechnology products and services in the U.S. alone will hit the $1 trillion dollar amount. Funding for nanotechnology research has nearly doubled each year as the U.S. invested $710 million dollars in research in 2003. So what exactly are these research dollars being spent on? Nanotechnology applications can be summarized into several basic areas: Smart Materials, Sensors, Nanoscale Biostructures, Energy Capture and Storage, Magnets, Fabrication, Electronics, and Modeling.

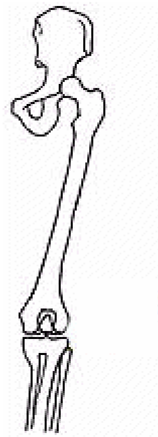
Smart Materials

A “smart material” is any material made at the nanoscale level, which performs a specific task. These are very unusual structures in that they contain MOBILE electronic charges. These charges can be moved to new positions in the structure they inhibit by shining light on them or applying an electric field. The key to understand is that this change is like a code. It is very specific, much like a bar code scanner at the grocery store. An example of a smart material would be self-tinting automotive glass. It is clear most of the time, but when the sunlight reaches a certain intensity the glass darkens to prevent the driver from being blinded.



Sensors

One of the most exciting areas of nanotechnology involves the understanding of molecular recognition. What this entails is being able to capture and recognize a certain molecule. We design a molecular sensor with the ability to capture what is called an “analyte”, which means the molecule we want to analyze. The sensor itself has a gap that only the analyte can fill. This idea is very similar to the idea represented in Cinderella in that ONLY she could wear the shoe. Once the sensor has absorbed the analyte it might change color to indicate the presence. These sensors have been also called “Bioarrays”. Since these sensors operate at the nanoscale you could literally have billions of little detectors available for any type of materials you want to detect. This could be temperature, water, light, sound, and even biological and chemical agents. In the picture above, we see an example of the color change when Anthrax and the nanosensor bind to DNA.

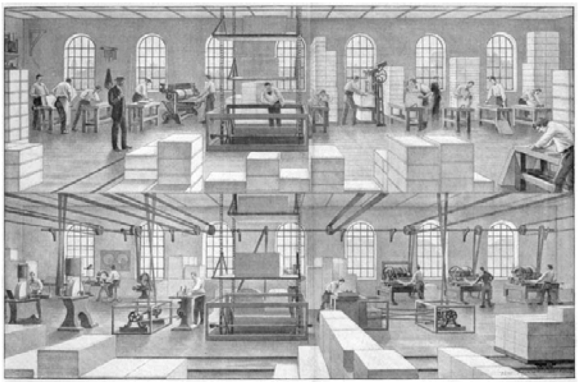


Nanoscale Biostructures
These structures are designed to "mimic" some type of biological process. They can also interact with a biological mechanism. One of the main focuses of this research is in the area of human repair and idea of self-assembly. For example, when we cut ourselves our body is able to heal and repair the cut. But sometimes, in the case of broken bones, our body has a hard time repairing it perfectly. The biostructures will be inserted into the body and form a template to assist the body. Using the bone example again, the biostructure will form an outer shell around the area that needs to be repaired. The natural bone can then grow around the structure like a rose grows over a trellis. So now we don't have to replace the bone we can simply, repair the damage easily.

Energy Capture and Storage
Consider how much sunlight actually strikes the earth. We can safely assume that there is a lot of land available by which we could use to capture the sun's rays. We have determined that on average every square yard of land exposed will receive 5 kW-hours of solar energy per day. So if you had an area covering 100 square yards you would generate 500 kW-hours per day. Upon careful inspection of our energy bill we discover that the average U.S. household generates 500-1000 kW-hours of electrical energy in ONE MONTH. So if we could efficiently harness the sun's energy there could be limitless energy for us to use. Nanotechnology hopes to help that become a reality. One particular nanomaterial that interests us is titanium dioxide. This material, when combined with a special dye, will absorb solar energy and convert it to electrical energy. The hopes are that these photovoltaic cells produced from nanomaterials will be more efficient, cost less to produce, and have significantly less affect on the environment than typical solar cells used today.

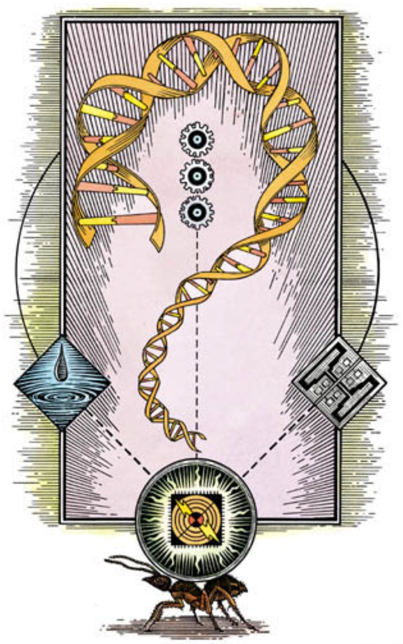
Magnets
The soldier to day is often referred to as a Christmas Tree. He or she has all sorts of gadgets and each one has it own battery. Many times a soldier in the field carries a pack in excess of 80 pounds. One of the goals of nanotechnology is to develop a suit capable of many different functions. One of these functions involves Magneto Rheological Fluids. These fluids are made up of magnetic nanoparticles. These particles are so small it makes the suit very light to wear. When a bullet approaches, the suit senses the approach and the fluid

immediately hardens to not allow bullets or shrapnel to penetrate the suit. Scientists have discovered that when the fluid suddenly undergoes a drastic change in properties it can dissipate or absorb the energy of a projectile. This science will even affect local police officers as well.



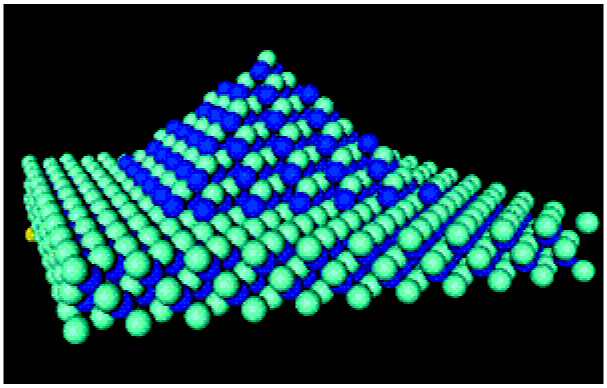
Fabrication

The basics idea of nanofabrication is that devices can be designed or manufactured at the nanometer scale. To have any significance in society a material must be able to be manufactured. This has proved to be difficult as the materials in question are so small. But there are many ideas of how this process could work. One idea is that the device would self-assemble atom by atom using a small nanomachine. This idea is similar to that of a seed, which tends to grow over time. Overall the manufacturing process must be able to produce mass quantities of pure material very efficiently.



Electronics

The field of nanoelectronics is very exciting as it is the combination of biology, chemistry, physics, engineering, and computer science. Imagine creating smaller and faster computer chips. Nanomaterials can absorb heat and conduct electricity as well. This makes them ideal for computer parts. Nanomotors can be fabricated and operate by nanochips. One interesting idea is the combination of organic matter with nanoelectronics. Current research involves attaching nanoelectronics to the body's nervous system. Both can generate an electric current, thus they can be used together in a system. Diseases such as multiple sclerosis and Lou Gehrig's disease could be bodily problems of the past.



Modeling

Modeling is the backbone of nanotechnology research. As scientists begin to discover the properties of nanoparticles, they need to be able to predict the size and shape of the material needed to do the job. Modeling helps the scientist to predict what characteristics a particular experiment might exhibit. Overall, it allows the scientist to work and practice in confidence.

Nanotechnology and the National Science Teaching Standards

So the real question is: If I teach nanotechnology in my classroom, am I teaching to the national standards. The answer to this question is …YES! Below are the National Standards.

Physical Science Content Standards 9-12

- **Structure of Atoms**
- **Structure and properties of matter**
- **Chemical Reactions**
- **Motion and Forces**
- **Conservation of Energy and increase in disorder (entropy)**
- **Interactions of energy and matter**

Science and Technology Standards

- **Abilities of technological design**
- **Understanding about science and technology**

Science in Personal and Social Perspectives

- **Personal and Community Health**
- **Population Growth**
- **Natural Resources**
- **Environmental Quality**
- **Natural and human-induced hazards**
- **Science and technology in local, national, and global challenges**

History and nature of science standards

- **Science as a human endeavor**
- **Nature of scientific knowledge**
- **Historical perspective**

So how does nanotechnology fit in? Below is a chart comparing various nanotechnology ideas and applications with the standards.

Nanotechnology Idea	Standard it can address
The idea of “Nano” – being small	Structure of Atoms
Nanomaterials have a high surface area (nanosensors for toxins)	Structure and properties of matter, Personal and Community Health
Synthesis of nanomaterials and support chemistry (ie. Titanium Dioxide)	Chemical Reactions
Shape Memory Alloys and Smart Materials	Motion and Forces, Abilities of technological design, Understanding about science and technology
Nanocrystalline Solar Cells	Conservation of Energy and increase in disorder (entropy), Interactions of energy and matter, Natural Resources
Nanocoatings resistive to bacteria and pollution	Personal and Community Health, Population Growth, Environmental Quality, Natural and human-induced hazards
Nanomaterials, such as MR (magneto-resistive) fluids in security	Science and technology in local, national, and global challenges
Richard P. Feynman’s talk, “There is plenty of room at the bottom”. Feynman had a vision.	Science as a human endeavor, Nature of scientific knowledge, Historical perspective

Nanocosmetics and nanoclothing	Science as a human endeavor, Science and technology in local, national, and global challenges
Nanotechnology and Science Ethics	Science and technology in local, national, and global challenges, Science as a human endeavor, Historical perspective, Natural and human-induced hazards, Population Growth, Personal and Community Health

We could easily get much more specific and address specific STATE standards as well as SUBJECT area content standards as well.

Nanotechnology makes teaching measurement and math easier because it can give the teacher a direct application to deliver to the students. Because of it's impact on society, nanotechnology should be rather interesting to most students as it can usually be related to almost any individual. Nanotechnology has also been the subject of numerous articles as well as the subject of fictional literature. So not only can you discuss the interesting topics of nanotechnology you can also teach the age old reading, writing, and arithmetic.

Nanotechnology and Science Measurement

Teaching students about the nature of how small or how large things are can be a daunting task. So how are we going to be able to teach students about how small things are at the nanoscale? On way we could do this is to use the idea of EXAMPLE and NON-EXAMPLE. In other words, teach them to compare and contrast.

The following activity was designed for several reasons. It should help students understand graphing and working with slope. It focuses on learning about exponent and how to express how large or how small something is. After the activity, there are two complement activities. One is a reading article, which talks about things at the nanoscale. The other is an assessment using thinking maps. Hopefully, by the time you are done looking over the material as a teacher you will see it address skills across curriculum areas.

NANO-“TUBES”: Measuring the visible and understanding the invisible

Student Activity #1

Objectives: The student should be able to physically measure using a ruler; length, using a gram balance; mass, using a graduated beaker and cylinder; volume. They students should be able to apply these measurements graphically to determine to a constant that can be used to identify the degree of accuracy. In the end, the students should be able to apply measurement techniques to understand units of measure that are larger or smaller (the nanometer) than the one presented in this laboratory exercise.

Standards:

- **The student selects and uses appropriate units and instruments for measurement to achieve the degree of precision and accuracy required in real-world situations.**
- **The student understands and uses the tools of data analysis for managing information.**
- **The student describes, analyzes, and generalizes a wide variety of patterns, relations, and functions.**
- **The student uses the scientific processes and habits of mind to solve problems.**

Materials: Minimum of FOUR Beakers (Nano-“Tubes”) of various sizes (10 ml – 600 ml), string, scissors, ruler, water, triple beam balance, 100 ml graduated cylinder

Part I – Measuring Length

1. Using a ruler, measure and record the diameter of each beaker in centimeters. The diameter is the width of the beaker.
2. Using the string, wrap it around the beaker and cut it so that the string length is equal to the circumference of the beaker. Measure and record the length of the string for each beaker.
3. Make a graph of this data with circumference on the y-axis and diameter on the x-axis. You can use graph paper, a computer, or a graphing calculator.

Data Table

Beaker Capacity	Diameter	Circumference

Calculations: The circumference of a circle is equal to the diameter times the constant “pi” or $C = \pi d$. If we divide the diameter to the left we get: $\frac{C}{d} = \pi, \quad slope = \frac{rise}{run}$. Based on this equation we see that Circumference is the rise, diameter is the run, and “pi” is the slope.

Find the slope of the graph that you made and show your work below.

The ACTUAL value for “pi” is 3.141592. Using the following error equation. Determine your % error. $\left|\frac{3.141592 - Experimental\ value}{3.141592}\right| x100 = \%\ error =$ ☐

Questions:

1) Looking on your % error, describe anything that might have increased your accuracy.

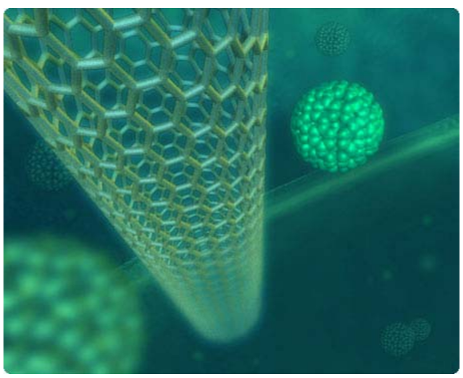
2) Looking at your graph, if you increased your diameter what would happen to your circumference?

3) A direct relationship is when variables do the same thing (both increase or both decrease). An inverse relationship is when one variable does the opposite of the other. Based on your answer to question two, what kind of relationship does the circumference and diameter have?

Graphing extension

4) Using your graph, what would the circumference be of a beaker that has a diameter of 20.0 cm. Explain how you came to this conclusion.

Nano-extension:



One exciting thing that has come out of nanotechnology research is the single-walled carbon nanotube. It is basically a very tiny (1 billion times smaller than a meter) tube that resembles a rope. Heating ordinary carbon until it vaporizes, then allowing it to condense in a vacuum or an inert gas creates them. The carbon condenses in a series of hexagons that curl and connect into hollow tubes. The most interesting thing about the nanotube is that it is the strongest, most conductive, and stiffest material ever made. It is SIXTY times stronger than steel. Many suggest that a nanotube cable the size of a human hair could EASILY suspend a locomotive or reach from the Earth to the Moon. Can you imagine a rope to the moon? Nanotube fibers can be used to make bulletproof vests that are 17 times stronger than normal Kevlar vests. One of the advantages of using nanotubes is that because they are so small they are much lighter as well. All materials, which are made with nanotubes, will be stronger and lighter.

A typical diameter for a carbon nanotube is 1.4 nanometers or $1.4x10^{-9}$ meters. Using what you learned in the lab today, what would the circumference of the nanotube be in meters? In nanometers?

NANO-"TUBES": Measuring the visible and understanding the invisible
Student Activity #2

Part II – Measuring mass

1. Using the same beakers from part I, place then on the mass balance and measure and record the mass of each empty beaker in grams.
2. Using the graduated cylinder add a specific volume of water in milliliters to each beaker and record this value. Make sure you add **DIFFERENT** amounts to each beaker without over filling the beaker.
3. Measure and record the NEW mass of the beaker with the known volume of water added to it.
4. Measure and record the height of the column of water in centimeters inside the beaker.

Data Table

Mass of empty beaker (grams)	Volume of water added to beaker (ml)	Mass of water and beaker (grams)	Height of water column (cm)

Calculations

Subtract the mass of the empty beaker from the mass of water and beaker to get the MASS OF WATER that you added to each beaker. Show your work below and fill in the table appropriately.

Beaker Capacity	Mass of Water added (grams)

Part III- Measuring Volume

Volume is found by multiplying the height by the length by the width ($V = LxWxH$). The area is found by multiplying just the length times the width ($A = LxW$). If this is true, volume can be found by multiplying the area times the height ($V = AxH$). We know the height of our water column, but we still need the area. The tube has a circle on each end. Therefore we must use the area of circle to find the area that the water takes up inside the beaker. The area for a circle is given as $Area = \pi r^2$. The radius can be found by dividing the diameter that you measured in part one by two. Fill in the table below and show your work for at least ONE beaker below.

Beaker Capacity	Diameter From Part I (cm)	Radius of each beaker (cm)	Area of each beaker (cm^2)	Calculated volume of water beaker (cm^3)

Let's now compare the **calculated volume** of water to the **measured volume** of water to see if our calculations are accurate. To compare values in an experiment we find what is called a ***percent difference***.

The formula is $\% \, difference = \left| \frac{Calculated - Measured}{Average} \right| x100$

This formula says you take the difference of the two values then divide by the AVERAGE of the two values. Keep in mind that you ARE NOT finding an error percentage. You are simply comparing the two numbers to see how close they are.

Show the work for at least one trial below. **Average all of the percent differences for each beaker to get an AVERAGE % DIFFERENCE.**

Average % difference

Part IV – Measuring Density

The **DENSITY** of a material is defined as the ratio of the mass to the volume. A ratio is simply a fraction. Therefore we can construct a formula for density that looks like this:

$Density = \frac{Mass}{Volume}$. It just so happens that this formula ALSO resembles, $Slope = \frac{Rise}{Run}$.

What does this mean? This means that we can find the DENSITY of water if we plot its MASS in the y-axis and it VOLUME on the x –axis. Construct a graph with the mass of water on the y-axis and the MEASURED volume of water on the y-axis.

Find the slope of the line and determine the density of water in the units of grams/cubic centimeter.

Slope = (density of water) = ____________

The ACTUAL value for the density of water is 1.0 g/cm^3. Using the following error equation. Determine your % error. $\left| \frac{1.0 - Experimental \; value}{1.0} \right| x100 =$

NANO-"TUBES": Measuring the visible and understanding the invisible
Student Activity #3

Part V – Applying Measurement and Understanding the size of things

Materials: roll of 50 pennies, ruler

Procedure:

1) Stack the pennies vertically on a flat surface.
2) Measure and record the height of the stack in centimeters.

Height of stack in centimeters	

A centimeter is SMALLER than a meter. In fact the prefix "centi" means 100. Common words that represent this prefix are centipede (100 legs) and century (100 years). So that means that there are 100 centimeters in 1 meter. So ONE centimeter would be a small fraction in fact it is $1/100^{th}$ of a meter.

So now let's convert the height of our penny stack to meters. To do this we divide by 100.

Height of stack in meters	

Remember, the stack above had 50 pennies. So how many pennies would it take to make a tower 1 billion meters tall (1,000,000,000 m)? One billion meters is also known as 1 Gigameter. "Giga" means one billion and it is often used to describe how fast a computer can operate. Stores that sell computers advertise computers, which have an operating speed of 2 Gigahertz. This means that the computer can perform 2 billion different tasks every second. We also about see that computer manufacturers express the hard drive of a computer in terms of Gigabytes. This is a measure of storage capacity. The hard drive, therefore, can hold 1 billion bytes of data.

# of pennies for a tower 1 billion meters tall	

How much money is the 1 billion meter tall tower? What could you buy with this amount of money? Show below how you determined your amount.

The "FLIP" side

When you are dealing with units that are LARGER than a meter you multiply by the appropriate factor. When you are dealing with units that are SMALLER than a meter you multiply. Below is a chart that shows what happens every time you multiply and divide by a thousand. So basically if you move up the chart you multiply and if you move down the chart you divide.

Greek Prefix	Magnitude as an exponent	Magnitude as a number	English Expression
Exa-	10^{18}	1,000,000,000,000,000,000	One Quintillion
Peta-	10^{15}	1,000,000,000,000,000	One Quadrillion
Tera-	10^{12}	1,000,000,000,000	One Trillion
Giga-	10^{9}	1,000,000,000	One Billion
Mega-	10^{6}	1,000,000	One Million
Kilo-	10^{3}	1,000	One Thousand
METER	$\mathbf{10^{1}}$	**1**	**One**
Milli-	10^{-3}	0.001	One Thousandth
Micro-	10^{-6}	0.000001	One Millionth
Nano-	10^{-9}	0.000000001	One Billionth
Pico-	10^{-12}	0.000000000001	One Trillionth
Femto-	10^{-15}	0.000000000000001	One Quadrillionth
Atto-	10^{-18}	0.000000000000000001	One Quintillionth

For example, how many meters are in 25 gigameters? Well, remember that there are 1 billion meters in one gigameter; therefore there must be 25 BILLION meters in a gigameter. What would happen if we didn't multiply? What would happen if instead of multiplying by 1 billion we divided by one billion? In other words, 1/1,000,000,000.

Is this a large or small number?

Let's go back to how tall your stack of pennies was in METERS. **Let's DIVIDE this number by 1 billion.**

Height of stack in # meters/1,000,000,000	

How many pennies would this be? Would you even have ONE penny? A half of a penny? Could you buy anything with this amount? Do you think you would be able to physically see this?

When you DIVIDE any amount by a billion you DO NOT have a “GIGA”. You have a new prefix called **“NANO”,** which means 1 divided by a billion or 1/1,000,000,000. This is a very important unit in science. The reason the nanometer is so important is because all matter is made up of atoms and atoms happen to be measured using nanometers. A typical atom is anywhere from 0.1 to 0.5 nanometers in diameter. **That is small!**

Let’s consider this:

A pinhead is 1 millimeter in diameter. Since millimeter is below the meter on the chart we divide by 1000. In other words, a pinhead is 0.001 meters in diameter. Let’s say we have an atom that is 0.25 nanometers in diameter.

Do we move up or down on the chart?

Do we multiple or divide?

How many meters are in 25 nanometers?

Now let’s determine how many atoms are on our pinhead. **Divide the diameter of the pinhead in meters by the diameter of an atom in meters. How many atoms do we have?**

How many zeros does your answer have?

This can be written as 10^x, place the answer you got above where the “x” is and show the exponent below.

Looking at the chart above, what English expression goes with our answer above?

Looking at the chart above, what Greek expression goes with our answer above?

Teacher Notes

Activity 1
Areas covered: measurement, graphing techniques, geometry basics, direct vs. inverse relationships, error analysis, and extrapolation of data

Estimated time for activity: 1 hour

This activity should be guided in such a way that the teacher should be able to monitor the progress of the student as he or she works. The experiment also allows time to discuss error analysis. For example, the lengths of the strings may me a lot shorter than they actually are, as the students tend to stretch them around the beakers. When measured, the strings contract to their normal relaxed state.

Activity 2
Areas covered: measurement, graphing techniques, density, accuracy vs. precision, error analysis

Estimated time for activity: 1 hour

In this activity we see both the percent difference, which is used for comparison and percent error, which is used for accuracy. This activity shows students how to find the volume by measurement as well as geometrically. Graphing is stressed again.

Activity 3
Areas covered: Measurement, application, exponents, converting

Estimated time for activity: 30 minutes

This activity basically has the students apply what they learned earlier but now we are trying to steer them into thinking about something really big, then really small. The overall goal is to think about the applications of nanotechnology.

To wrap up this activity we recommend reading the article "Fancy Pants" and have your students use the Anticipation Reading guide that goes with it. This article should relate nicely to the measurement activity and supply you with the necessary reading requirement under the national standards. A double bubble thinking map can also help kids learn how to compare and contrast the Greek prefix of GIGA vs. NANO. The reason we give all the thinking maps here is that we want to students to eventually be able to choose the appropriate thinking map on their own.

Fancy Pants by Ann Marie Cunningham

It's a commonplace pitfall of the holiday season: You wear your best clothes to a party, and then you spill something and ruin them. But this year, your outfit could be stain proof—because one scientist has used nanotechnology to invent fabric that actually repels spills.

This Science Central News article reports on cutting-edge clothing that simply refuses to get stained, yet doesn't feel like oilcloth.

Peach fuzz for pants

Chemical engineer David Soane's new textiles are exciting examples of nanotechnology, the technology of the future. But you can wear his inventions today. They have been singled out as key advances of 2001.

After almost 20 years at the University of California, Berkeley, Dr. Soane left academe to found a series of small companies. His main interest was biotech—until a friend at Levi-Strauss suggested that he look into textiles. Using his garage as a lab, Soane began devising ways to use nanotechnology to add unusual properties to natural and synthetic textiles, without changing a fabric's look or feel.

What exactly is nanotechnology? It means manipulating matter atom by atom, where measures must be made in nanometers. (A nanometer is one billionth of a meter, only three to five atoms wide.) The goal of nanotechnology is to build tiny machines with extraordinary properties. Over the next twenty to fifty years, these nano-machines' unusual abilities promise to radically change manufacturing, information technologies, and medicine.

Scientists like David Soane have already changed materials with nanotechnology. In 1998, Soane started Nano-Tex, and began inventing a series of ways to improve the strength, durability, and usefulness of natural fibers like wool and cotton. The first is a stain-proofing process that Soane calls Nano-Care.

Other stain-proofing processes coat fabrics, leaving them stiff or fuzzy. Soane's breakthrough was to create tiny structures that he calls "nanowhiskers." Each nanowhisker is only ten nanometers long, made of a few atoms of carbon. These whiskers repel stains by forming a cushion of air around cotton fibers. But they cannot be seen or felt on the fabric's surface, so the fabric stays soft.

To attach these whiskers to cotton molecules, Soane uses an environmentally-friendly method. Cotton is immersed in a tank of water full of billions of nanowhiskers. Next, as the fabric is heated and water evaporates, the nanowhiskers form a chemical bond with cotton fibers, attaching themselves permanently. The whiskers are so tiny that comparatively, a cotton fiber looks like a tree trunk, while the whiskers look like fuzz on its bark.

Soane's nanowhiskers are already on the market in jeans and khakis that repel liquid spills—soda, juice, wine, salad oil and even soy sauce. The nanowhiskers prevent liquid spills from soaking into your clothes. Instead, drops bead up and can be brushed off like liquid lint, leaving no stains.

Next, David Soane promises Nano-Touch, a process that makes more wool and cotton more durable, and Nano-Dry, a means of keeping clothing fresh and free of body odor.

Anticipation/Prediction Guide
“Fancy Pants”

Directions: Read each statement below carefully. Check either “agree” or “disagree” to show what you think. Do this **BEFORE** and **AFTER** reading the selection. Be able to defend your answers with evidence from the text.

Pre-Reading			**Post-Reading**	
Agree	Disagree	**Statement**	Agree	Disagree
		All pants absorb liquids and stains		
		Nanotechnology is the study of things that are really BIG.		
		Example’s of textiles are wool and cotton		
		Nanowhiskers are made of silicon		
		When nanowhiskers are attached to cotton, they attach permanently.		
		In the future, jeans may be able to repel body odor		

Draft at least 2 questions that you have about this reading.

Q1:

Q2:

Predict, and write below, what you think this article is going to focus on. In other words, what do you think the purpose of this article is going to be?
I predict,

Read the article silently to yourself

Summarize and write at least 4 important statements that come from the reading

1)

2)

3)

4)

Confirm your prediction! Prepare a statement below that summarizes your initial prediction and then states whether or not your prediction was verified.

ONE-SENTENCE SUMMARY.

Procedure:

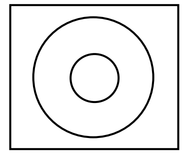
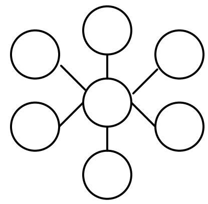
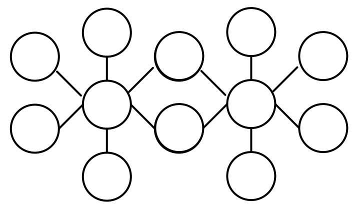
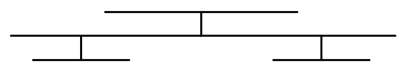
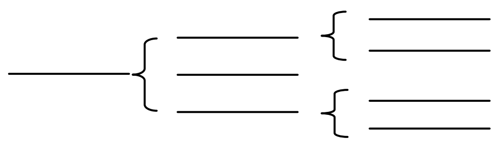
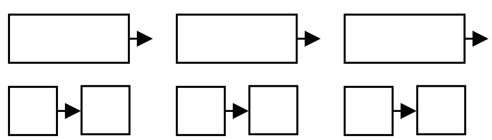
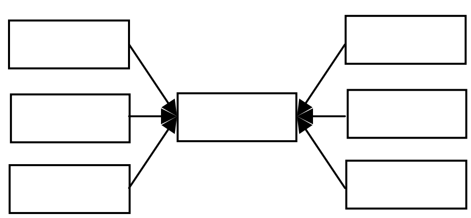
Identify the **THING** being **summarized**	Tell what is **“begins with”**	Tell what’s **in the middle** (what it’s mostly about - “covers”, “discusses”, “presents”.	Tell what it **ends with**

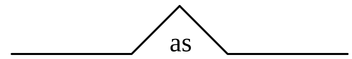
Here is your model:

___________ began with _______________(covering, discussing, presenting, developing the idea that), and (or then) ended with (or when) ____.

Prepare a one-sentence summary of the article below

Thinking Maps / Tools for Learning

Circle Map	Defining in Context	
Bubble Map	Describing Qualities	
Double Bubble Map	Comparing and Contrasting	
Tree Map	Classifying	
Brace Map	Part-Whole	
Flow Map	Sequencing	
Multi Flow Map	Cause and Effect	

Bridge Map	Seeing Analogies	

Pick an appropriate Thinking Map that would adequately organize information based on this topic:

Compare and contrast GIGA and NANO. Provide specific examples.

Show your graphic below:

WRITE a small paragraph based on the question above. Use your chosen thinking map as a guide for your writing.

Below, develop 3 questions that you might ask a reader (you being the author) that would access their understanding of the question. In other words, what questions would you ask to test whether or not they understood what they read?

Nanotechnology in the Chemistry Classroom

Titanium Dioxide is a fantastic example to use to teach chemistry and nanotechnology at the same time. One of the most interesting features of this incredible photocatalyst is that it can break down almost any organic compound (mold, bateria) it touches in the presence of UV light. Hence, it can clean itself. Here are some examples of reactions, which focus on Titanium.

Reaction of titanium with air

Titanium metal is coated with an oxide layer that usually renders it inactive. However once titanium starts to burn in air it burns with a spectacular white flame to form titanium dioxide, TiO_2 and titanium nitride, TiN. Titanium metal even burns in pure nitrogen to form titanium nitride.

$Ti(s) + O_2(g) \longrightarrow TiO_2(s)$
$2Ti(s) + N_2(g) \longrightarrow TiN(s)$

Reaction of titanium with water

Titanium metal is coated with an oxide layer that usually renders it inactive. However, titanium will react with steam form the dioxide, titanium(IV) oxide, TiO_2, and hydrogen, H_2.

$Ti(s) + 2H_2O(g) \longrightarrow TiO_2(s) + 2H_2(g)$

Reaction of titanium with the halogens

Titanium does react with the halogens upon warming to form titanium(IV) halides. The reaction with fluorine requires heating to 200°C. So, titanium reacts with fluorine, F_2, chlorine, Cl_2, bromine, I_2, and iodine, I_2, to form respectively titanium(IV) bromide, TiF, titanium(IV) chloride, TiCl, titanium(IV) bromide, TiBr, and titanium(IV) iodide, TiI.

$Ti(s) + 2F_2(g) \longrightarrow TiF_4(s)$ [white]
$Ti(s) + 2Cl_2(g) \longrightarrow TiCl_4(l)$ [colourless]
$Ti(s) + 2Br_2(g) \longrightarrow TiBr_4(s)$ [orange]
$Ti(s) + 2I_2(g) \longrightarrow TiI_4(s)$ [dark brown]

The actual process and reactions for making nanoparticles of titanium dioxide is a bit complicated, but learning the general process is more important.

The great thing about the nanotitania is its high surface area. It is this high surface area that allows the chemical to react faster. This, of course, is very important if you are creating a nanosensor to detect a chemical agent. In the event of a disaster, you want to be able to detect and identify the toxin quickly.

Understanding Surface Area in Chemical Reactions

Student Activity #4

Objectives: To understand the affect of reaction time based on changing surface area

Standards:
The student understands that all matter has observable, measurable properties.

- Experiments and determines that the rates of reaction among atoms and molecules depend on the concentration, pressure, and temperature of the reactants and the presence of catalysts.

Materials:
Magnesium Ribbon, scissors, 1 M HCL, beaker, stopwatch
(Alternatively Alka-Seltzer and Water can be used as substitutes for the chemicals)

Procedure:
1. Place 100 ml of 1.0 M HCL in 3 separate beakers.
2. Measure out three 5-cm pieces of magnesium ribbon.
3. Leave one piece of ribbon untouched, roll one of the pieces into a tight ball, and cut the other piece into very tiny fragments.
4. Place the tight ball into one of the beakers of acid.
5. Measure and record the time it takes for the reaction to complete.
6. Repeat for the other magnesium pieces. Remember that each piece is placed in a different beaker.

Data Table

Magnesium Ribbon	Time in seconds
Tight Ball	
Untouched Ribbon	
Ribbon Pieces	

Analysis:
Which of the following situations produced the fastest time?

What is the ratio of Tight Ball to Ribbon Pieces?

(optional) Write the balanced equation for HCL and Magnesium ribbon below.

Nanoshells cancer treatment proves effective in first animal test
22 Jun 2004

A revolutionary new form of cancer therapy in development at Rice University and its licensee, Nanospectra Biosciences Inc., has proven effective at eradicating tumors in laboratory animals during the first phase of animal testing.

The noninvasive cancer treatment uses a combination of harmless, near-infrared light and benign, gold nanoshells to destroy tumors with heat. The treatment does not affect healthy tissue.

"We are extremely encouraged by the results of these first animal tests," said Jennifer West, professor of bioengineering and chemical engineering. "These results confirm that nanoshells are effective agents for the photothermal treatment of in vivo tumors."

Results of the study are published in the June 25 issue of the journal Cancer Letters.

Invented in the 1990s by Naomi Halas at Rice, nanoshells are about 20 times smaller than a red blood cell. The multilayered nanoshells consist of a silica core covered by a thin gold shell. The size, shape and composition of nanoshells give them unique optical properties. By varying the size of the core and the thickness of the gold shell, researchers can tailor a nanoshell to respond to a specific wavelength of light.

The photothermal cancer treatment uses nanoshells that are tuned to respond to near-infrared light. Located just outside the visible spectrum, near-infrared light passes harmlessly through soft tissue. In the treatment, nanoshells convert this light into heat that destroys nearby tumor cells. The heating is very localized and does not affect healthy tissue adjacent to the tumor.

The animal trial involved 25 mice with tumors ranging in size from 3-5.5 millimeters. The mice were divided into three groups. The first group was given no treatment. The second received saline injections, followed by three minutes exposure to near-infrared laser light. The final group received nanoshell injections and laser treatments.

The blood vessels inside tumors develop poorly, allowing small particles like nanoshells to leak out and accumulate inside tumors. In the test, researchers injected nanoshells into the mice, waited six hours to give the nanoshells time to accumulate in the tumors and then applied a 5-millimeter wide laser on the skin above each tumor.

Surface temperature measurements taken on the skin above the tumors during the laser treatments showed a marked increase that averaged about 46 degrees Fahrenheit for the nanoshells group. There was no measurable temperature increase at the site of laser treatments in the saline group. Likewise, sections of laser-treated skin located apart from the tumor sites in the nanoshells group also showed no increase in temperature, indicating that the nanoshells had accumulated as expected within the tumors.

All signs of tumors disappeared in the nanoshells group within 10 days. These mice remained cancer-free after treatment.

Tumors in the other two test groups continued to grow rapidly. All mice in these groups were euthanized when the tumors reached 10 millimeters in size. The mean survival time of the mice receiving no treatment was 10.1 days; the mean survival time for the group receiving saline injections and laser treatments was 12.5 days.

"The results of these first animal studies are very promising, and while we don't yet have a target date for our first human trial, our entire team is working hard to make this treatment available to cancer patients as soon as possible," said Halas, the Stanley C. Moore Professor in Electrical and Computer Engineering and professor of chemistry. "We have licensed the technology to the Houston-based firm Nanospectra Biosciences Inc., which will obtain the necessary approvals and funding for human trials."

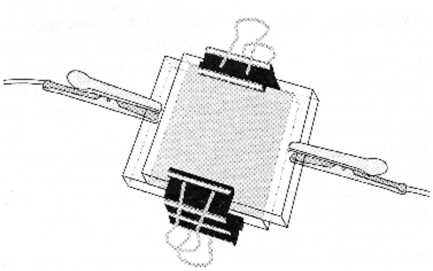
Using information in the article what is so unique about the gold nanoshells?

Using a flow map, document the procedure used by the scientists to treat the cancer cells?

Nanotechnology in the Physics Classroom

Most of the nanotechnology applications that physics teachers can use center around optics or electricity and magnetism.

The photovoltaic capabilities of nanotitania lend itself to a unique study. Physics teachers can easily construct the cell and take various voltage and current measurements. Or you can have a chemistry class construct the cell and a physics class do the calculations. This could also be done in an integrated setting.



Here are the directions for fabrication. The synthesis technique for nanotitania is included, however, to save time it might be easier to simply purchase the powder. But for an advanced chemistry class this may be appropriate.

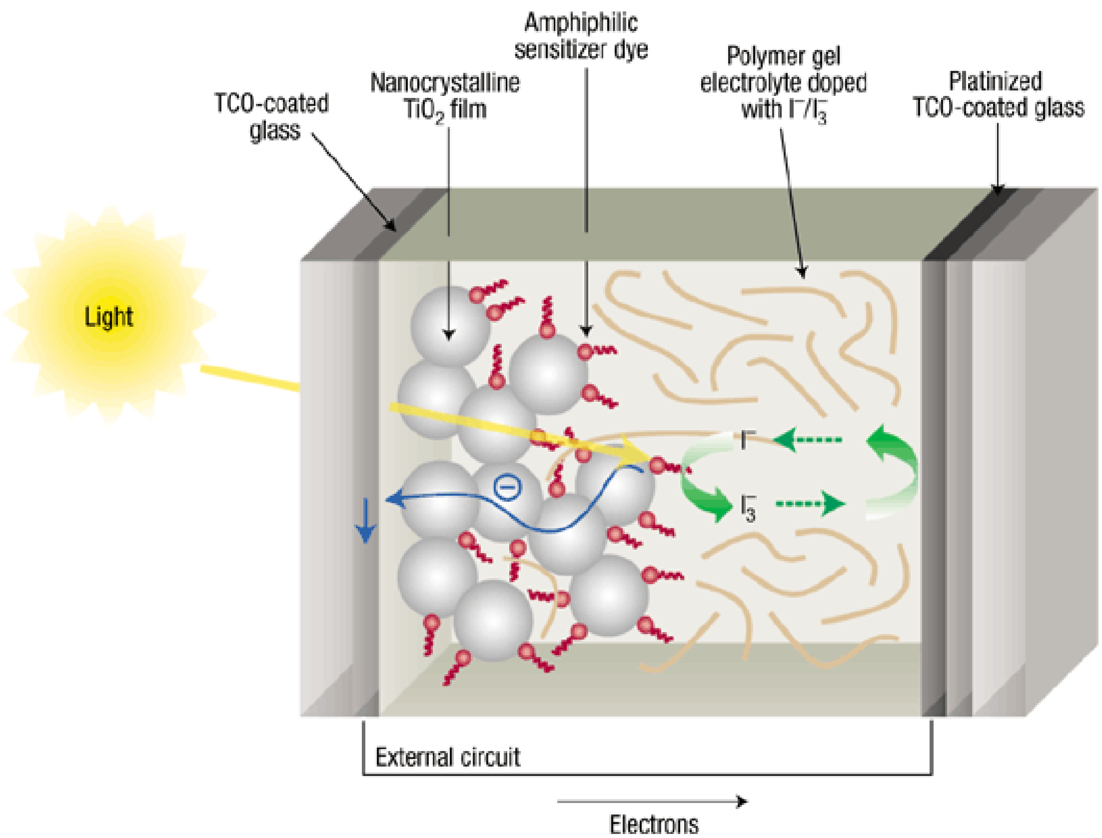
Nanotitania synthesis

1. Add 100-ml of anhydrous isopropanol [$(CH_3)_2CHOH$] to 2-ml of 2,4 – Pentanedione ($C_5H_8O_2$) and stir covered for 20 minutes.
2. Add 6.04-ml of titanium isopropoxide ($Ti[(CH_3)_2CHO]_4$ to the solution and stir for 3 hours.
3. Add 2.88-ml of distilled water and stir for another 2 hours.
4. The solution must then age for 12 hours, as the powder will precipitate out of solution at room temperature.
5. The remaining liquid can be decanted and the precipitate allowed to dry.
6. If you have access to X-Ray diffraction, it might be a good idea to place some crystals on a slide. A Scanning Electron Microscope with and EDX device may also work. This is used simply to determine whether the product is titanium dioxide.

NOTE: The procedure above is used to simply make the powder. A suspension will be needed to actually make the solar cell.

Nanocrystalline Solar Cells: The Materials

1. (2) F-SnO_2 glass slides	2.Iodine and Potassium Iodide
3.Mortar/Pestle	4.Air Gun
5.Surfactant (Triton X 100 or Detergent)	6.Colloidal Titanium Dioxide Powder
7.Nitric Acid	8.Blackberries, raspberries, citrus leaves
9.Masking Tape	10.Tweezers
11.Filter paper	12.Binder Clips
13.Various glassware	14.Multi-meter



The photovoltaic cell has basically four main parts.

1.Nanolayer (nanotitinia suspension)
2.Dye
3.Electrolyte
4.2 electrodes

The nanolayer is the nanotatinia. The dye can be juice extracted from raspberries, blackberries, or citrus leaves. The electrolyte is a solution of Iodine/Iodide. The two electrodes are conductive glass slides, which have been coated with fluorine doped tin oxide.

Preparation of the Electrolyte
1.Measure out 10-ml of ethylene glycol
2.Weigh out 0.127-g of I_2 and add it to the ethylene glycol and stir.
3.Weigh out 0.83 g of KI and add it to the same ethylene glycol.
4.Stir and sore in a container with a tight lid. This container should be dark as well so as to not allow too much light to enter.

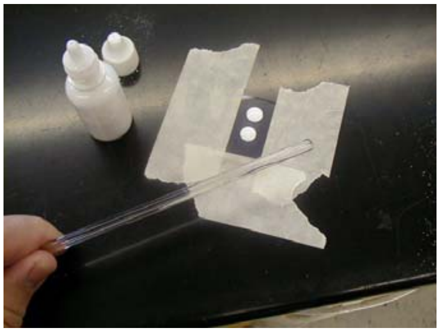
Note: Chem teachers, you may want to simply give out the molarity of each solution and have the students calculate exactly how much they should weigh out. If this is the case, you want 0.5 M of KI and 0.05 M of I_2.

Preparation of the Dye

1. Crush 5-6 berries in a mortar and pestle with 2-ml of deionized water.
2. Filter the solution with a coffee filter or any type of tissue.

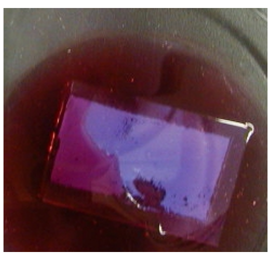
Preparation of the Nanotitania Suspension

1. Add 9 ml (in 1 ml increments) of nitric or acetic acid (ph3-4) to six grams of titanium dioxide in a mortar and pestle.
2. Grinding for 30 minutes will produce a lump free paste.
3. 1 drop of a surfactant is then added (triton X 100 or dish washing detergent).
4. The suspension is then stored and allowed to equilibrate for 15 minutes.

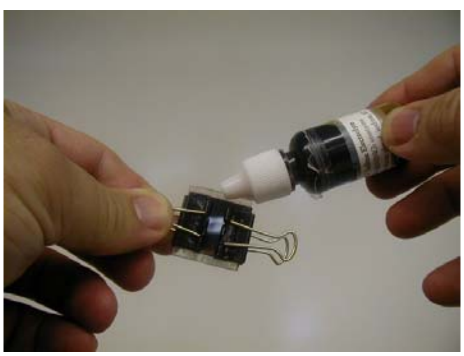


Cell Fabrication Procedure

1. After testing with a multimeter to determine which side is conductive, one of the glass slides is then masked off 1-2 mm on THREE sides with masking tape. This is to form a mold.
2. A couple of drops if the titanium dioxide suspension is then added and distributed across the area of the mold with a glass rod.
3. The slide is then set aside to dry for one minute.
4. After the first slide has dried the tape can be removed.
5. The titanium dioxide layer need to be heat sintered using a hot air gun that can reach a temperature of at least 450 degrees Celsius.
6. This heating process should last 30 minutes.
7. Allow the heat sintered slide to cool to room temperature.



8. Once the slide has cooled, place the slide face down in the filtered dye and allow the dye to be absorbed for 5 or more minutes.
9. After the first slide had absorbed the dye, it is quickly rinsed with ethanol to remove any water. It is then blotted dry with tissue paper.
10. The two slides are then placed quickly in an offset manner together to that the layers are touching. ***A picture showing this is at the beginning of this section on page 27.***



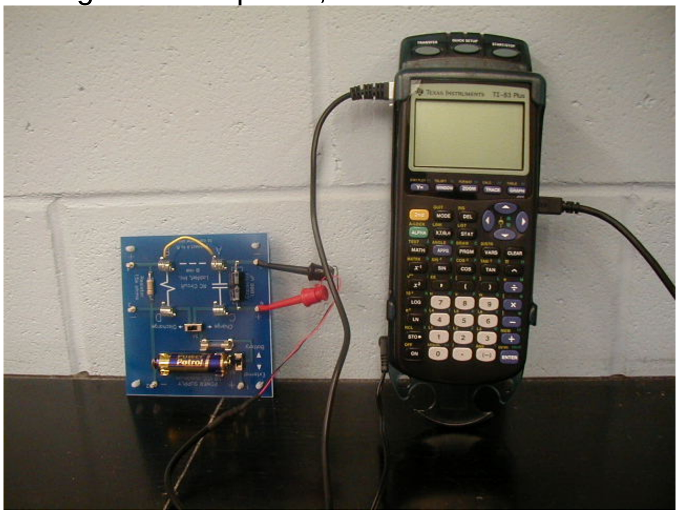
11. Binder clips can be used to keep the two slides together.
12. One drop of a liquid iodide/iodine solution is then added. Capillary action will stain the entire inside of the slides

Activities that can be done:

1. **The cell can be placed in series with a voltmeter and ammeter. Its power can then be calculated.**
2. **The cell can be placed in series with a potentiometer. Voltage vs. Current data can then be obtained.**
3. **The area of the cell can be determined which could then be used to calculate current and power density.**
4. **Multiple Cells could be made and attached in various configurations to measure total voltage output and verify Kirchhoff's Voltage Law.**
5. **The cell can be placed in an RC circuit of which the time constant can be measured.**
6. **"No-Load" motors can be placed in series to show the ability to convert solar energy into useful work.**
7. **Watches and calculators can be disassembled and replaced by the solar cell(s).**
8. **Measuring Cell efficiency by dividing the maximum power output by the incoming solar power, which is approximately 80-100 mW/cm^2.**
9. **Using the cell to predict how much area would be needed to power devices in the home.**
10. **Using the cell to examine SEM pictures at different stages (suspension, sintered, after dye absorption, etc)**

One specific example I would like to include here is using the cell to measure the time constant. This can be used in an advanced placement physics C course or college class.

The materials you will need are:
Solar cell, Logger Pro, Graphical Analysis for Windows, Vernier LabPro, Voltage/Current probe, Pasco RC circuit Board



Charging and Discharging a Capacitor using a Nanocrystalline Solar Cell

Materials: Logger Pro, Vernier LabPro, Voltage/Current Probe, Graphical Analysis for Windows, Pasco RC circuit board (15K-resistor and a 1000μF-capacitor)

Capacitor Basics:

Equation for discharging a capacitor $\rightarrow V_{(t)} = \varepsilon e^{-t/RC}$, V(t) = terminal voltage, ε = EMF (maximum voltage) , t = time, R = resistance, C = capacitance

τ = time constant = RC

$$\frac{V_{(t)}}{\varepsilon} = e^{-t/RC} \quad \rightarrow \quad \ln(\frac{V_{(t)}}{\varepsilon}) = -\frac{t}{RC} \quad \rightarrow \quad \ln(\frac{\varepsilon}{V_{(t)}}) = \frac{t}{RC}$$

$$\ln(\frac{\varepsilon}{V_{(t)}}) = (\frac{1}{RC})t \quad \rightarrow \quad \frac{Rise = \ln(\frac{\varepsilon}{V_{(t)}})}{Run = t} = \frac{1}{RC} = slope$$

What this basically says is that if you plot the natural log of the ratio of potentials versus the time the slope will equal the inverse of the time constant for this particular RC circuit.

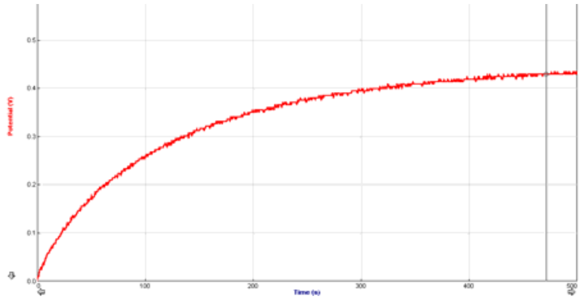
τ = time constant = RC

Purpose: To test whether you can measure the time constant using the solar cell and compare this a standard 1.5 V battery.

Procedure

1. Make sure the RC circuit board is set to battery and discharge.
2. Place a wire on each side of the capacitor. This is to discharge the capacitor to zero potential.
3. Make sure the LabPro's USB cable is plugged into the computer. The Voltage/Current probe should be plugged into channel 1 and the leads should be attached on the outside of the capacitor.
4. On the computer load up Logger Pro. Choose File then open. Go to Physics with Computers then Capacitors.
5. Then choose setup then interface and choose Labpro/USB.
6. Choose setup again and go to data collection then choose sampling.
7. From the sampling menu type in 300 seconds for experiment length and 2 sample per second for sampling speed. Then choose OK.
8. Doing all of this will ensure that the capacitor has enough time to charge first.

9. On logger pro choose the CONNECT button then immediately throw the switch on the RC board to CHARGE.



10. Allow the capacitor to charge until your graph levels out. This mean you have reached 4 or 5 time constants. It should look like the graph to the left.

11. Once this graph has been produced use the examine function to determine the VOLTAGE at the part of the graph where it levels off. This is your EMF. Measure and record this value.

EMF = ____________

12. Repeat the experiment, but this time when you choose collect throw the switch to DISCHARGE on the RC board.
13. Allow the capacitor to discharge completely to ZERO.
14. Using the examine function, measure and record 10 different voltage and time data points.

V(t) [volts]	Time(s)

15. Repeat the same experiment for the constructed solar cell.
16. **Using the information at the beginning of this lab, make the appropriate graphs and find the slope of each.**

Calculations

1. Calculate the actual TIME CONSTANT of the circuit.

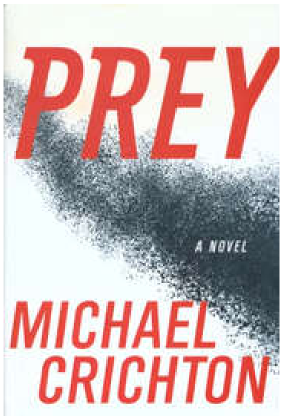
2. Using the inverse slope from your graph, determine the experimental time constant for both the battery and the solar cell.

3. Calculate the % error for both the battery and the solar cell

4. What would the time constant be if wired TWO identical capacitors together?

Reading across the curriculum: Nanotechnology in fiction and non-fiction

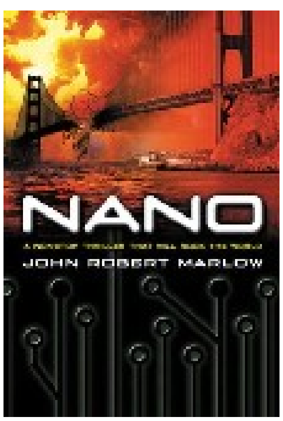
Here are a couple of books, which address topics in nanotechnology. All the listings below have editorial reviews from Amazon.com



PREY BY MICHAEL CRICHTON

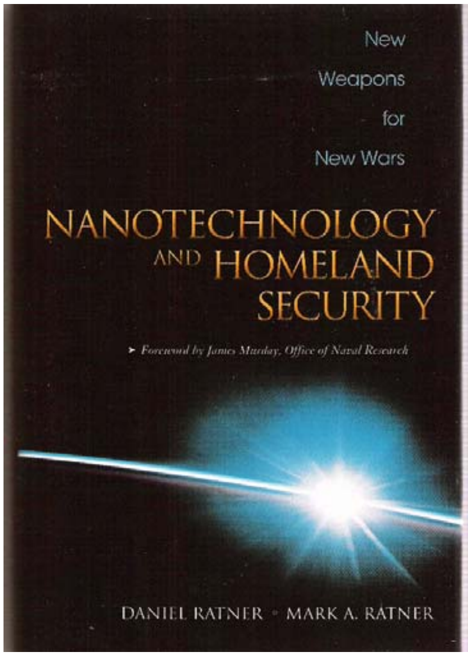
In *Prey*, bestselling author Michael Crichton introduces bad guys that are too small to be seen with the naked eye but no less deadly or intriguing than the runaway dinosaurs that made 1990's *Jurassic Park* such a blockbuster success.

High-tech whistle-blower Jack Forman used to specialize in programming computers to solve problems by mimicking the behavior of efficient wild animals--swarming bees or hunting hyena packs, for example. Now he's unemployed and is finally starting to enjoy his new role as stay-at-home dad. All would be domestic bliss if it were not for Jack's suspicions that his wife, who's been behaving strangely and working long hours at the top-secret research labs of Xymos Technology, is having an affair. When he's called in to help with her hush-hush project, it seems like the perfect opportunity to see what his wife's been doing, but Jack quickly finds there's a lot more going on in the lab than an illicit affair. Within hours of his arrival at the remote testing center, Jack discovers his wife's firm has created self-replicating nanotechnology--a literal swarm of microscopic machines. Originally meant to serve as a military eye in the sky, the swarm has now escaped into the environment and is seemingly intent on killing the scientists trapped in the facility. The reader realizes early, however, that Jack, his wife, and fellow scientists have more to fear from the hidden dangers within the lab than from the predators without.



NANO BY JOHN ROBERT MARLOW

Screenwriter Marlow's derivative, fast-paced debut, a near-future thriller, features the latest thing in tech menaces-nanotechnology. The assassination of billionaire Mitchell Swain, just as he's about to unveil microscopic robots that will solve all of humanity's problems, puts the inventor of Swain's revolution, the geeky John Marrek, in deadly peril. Agents of an evil U.S. government with their own nanobots try to stop Marrek from following through with Swain's program, but he finds supporters in a stereotypically beautiful female journalist, Jennifer Rayne, a virtuous president and an honest air force colonel. In chapter after cinematic chapter of dueling nanos, Marrek's disassembling nanobots wipe out whole teams of government hit men while the assembler bots cause redwoods to sprout in seconds to block pursuers. Along the way, Marrek delivers ethical and informational lectures to Jen, justifying high body counts and painting a nano-ified future in the brightest of colors as long as good guys like him are in control. Marrek and the government's nanos finally square off in the Bay Area, with the fate of the world at stake. If the politics or science were anything to take seriously, readers might have cause for alarm. As it is, the action is all that counts in this slick formula effort, which reads like a novelized screenplay.



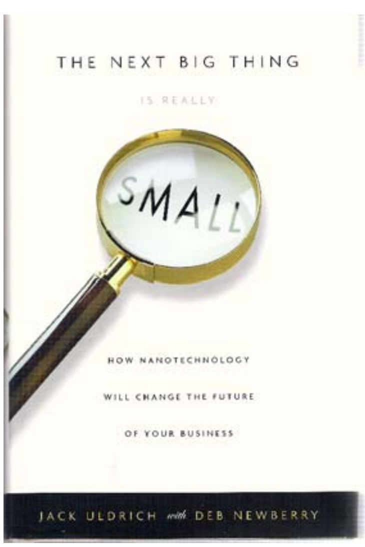
NANOTECHNOLOGY AND HOMELAND SECURITY BY DANIEL AND MARK RATNER

How nanotechnology will transform the war against terror.

Nanotechnology offers immense potential for fighting terrorism without sacrificing our open, free, and democratic society. This book covers the significant opportunity to use nanotechnology to prevent terrorism and other threats to security as well as mitigate their impact. Co-authored by one of the field's pioneers and featuring remarks from other nanoscience researchers and industry leaders, Nanotechnology and Homeland Security is written for every educated citizen who wants to understand the weapons of choice in the battle of our generation.

Coverage includes:

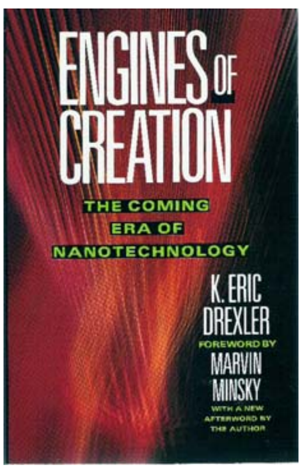
- Nanotechnology-based sensors: fast, cheap, accurate tests for explosives, radiation, weapons of mass destruction, and food/water contamination
- Nanotechnology-based smart materials: protecting homes, offices, and first responders
- Nanotechnology-based biomedical research: revolutionary treatments for chemical/biological attacks and trauma
- Nanotechnology-based energy generation technologies: ending the world's dependence on oil
- Nanotechnology-based remediation technologies: healing the effects of environmental damage and ecoterrorism.



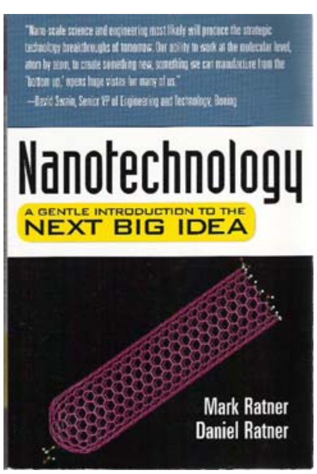
THE NEXT BIG THINGS IS REALLY SMALL: HOW NANOTECHNOLOGY WILL CHANGE THE FUTURE OF BUSINESS BY JACK ULDRICH AND DEB NEWBERRY

Ever heard of self-cleaning floor tiles and windows? Or mirrors that won't fog up in the shower? What about army uniforms that can "monitor a soldier's health, detect and detoxify chemical agents, heat and cool the soldier... and independently generate power so the soldier can remain in constant communication with headquarters"? According to Uldrich, director of the Minnesota Office of

Strategic and Long-Range Planning, and nuclear physicist and business consultant Newberry, if you haven't heard of these innovations already, you will-and soon. They're just a few products in development that were made possible by rapid advances in the field of nanotechnology. The authors explain, "Nanotechnology is, broadly speaking, the art and science of manipulating and rearranging individual atoms and molecules to create useful materials, devices, and systems." With this manipulation, products can be made with fewer imperfections and more durability, drugs can be more efficient and have fewer side effects, and energy sources can be cleaner and more cost-effective. Approximately $2 billion a year is being invested in nanotechnology worldwide in industries such as textiles, plastics and pharmaceuticals. To help determine how directly one's business will be affected by nanotechnology, the authors offer "nanopoints" at the end of each chapter, which raise questions about how to best prepare for change in any given field. The business advice is general and obvious, but the book clearly presents many intriguing and important applications of this burgeoning field, which may interest those looking to invest in nanotechnology.

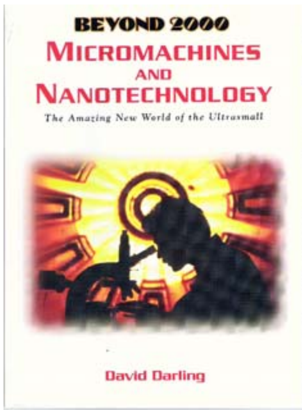


ENGINES OF CREATION BY ERIC DREXLER
Nanotechnology, or molecular technology, involves the manipulation of individual atoms and molecules, something the human body already does. In Engines of Creation , Drexler attempts to predict, justify, quantify, and caution us about this important new field in engineering. His book could have been the first and foremost discussion of this fascinating subject. But Drexler strays from the topic with annoying regularity. He devotes too little space to the possibilities of nanotechnology and too much to esoteric and opinionated discussions of philosophy, politics, information science, defense, human relations, etc. Nanotechnology will indeed become a reality, and the public needs to be informed.



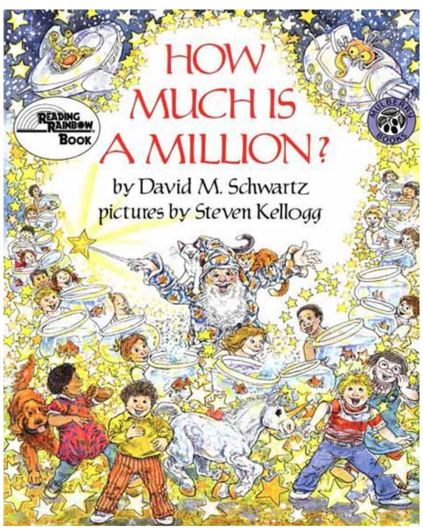
NANOTECHNOLOGY: A GENTLE INTRODUCTION TO THE NEXT BIG IDEA BY MARK AND DANIEL RATNER

Explaining how nanotechnology works and looking at recent advances and the future of the field, this book offers a simple, brief, almost math-free introduction for nonscientists. Early chapters give background on concepts needed to understand nanotechnology, and later chapters visit research laboratories, look at breakthroughs in smart materials, electronics, and optics, and discuss the relationship of nanotechnology to society.



MICROMACHINES AND NANOTECHNOLOGY BY DAVID DARLING

Grade 5-9?An excellent introduction to nanotechnology. After a brief historical overview of the science of making miniature machines, Darling discusses the development of the microchip and small mechanical motors. He clearly explains how a micromachine part is made and how a Scanning-tunneling microscope is able to see and manipulate atoms individually. The full-diagrams and illustrations add significantly to the understanding of the text. A fascinating look at an emerging technology.



HOW MUCH IS A MILLION? BY DAVID SCHWARTZ

An attempt to help children conceptualize the immensity of numbers is aided immeasurably by the artist's jovial, detailed, whimsical illustrations. Marvelosissimo the Mathematical Magician demonstrates the meaning of a million by showing his four young friends (plus two cats, a dog, and a unicorn) that it would take twenty-three days to even count to a million and that a goldfish bowl large enough to hold a million goldfish could hold a whale. Seven pages are printed with tiny white stars on a grid pattern against a blue sky -- adding up to only one hundred thousand stars! And after that, a billion and a trillion are discussed, all with equally or even more outstanding examples; a trillion children standing on each other's shoulders would almost reach to the rings of Saturn. The author concludes with several pages of the mathematical calculations, which support his examples, very clearly and humorously explained. An unusual idea, smoothly and amusingly presented.

Nanotechnology and Science Ethics

As a teacher who may be planning a whole group discussion it might be a good idea to consider the following:

(The following come from the National Board For Professional Teaching Standards)

- Engage students in discourse about a significant scientific theory, concept, principle, issue, or methodological approach;
- Set appropriate and worthwhile goals for student learning. There is evidence that this particular lesson has been placed in the larger context of instruction designed to enhance student learning in science;
- Display a strong command of science content linked with appropriate science pedagogy;
- Establish and manage a productive learning environment in which your questioning, prompting, and other instructional strategies elicits scientific reasoning and thinking on the part of students. Feedback in the classroom is frequent, supportive, and encourages and enhances student learning;
- Foster an equitable, accessible, and fair learning environment to ensure that all students are encouraged to participate in the study and discussion of science; and
- Engage in reflective thinking in which you describe your practice accurately, analyze it fully and thoughtfully, and reflect on its implications and significance for future teaching.

Try to anticipate rich discussions in which science concepts are interesting, accessible, and relevant to students. Though it can be a good choice to capture lessons in which students discuss social, political or other community contexts in which science operates, **make sure that discussions are grounded in scientific concepts**.

Effective science instruction can provide students with the opportunity to acquire scientific values and attitudes such as curiosity, openness to new ideas, acceptance of ambiguity, the ability to work cooperatively, the willingness to modify explanations in light of new evidence, and to take intellectual risks.

The following is just an outline of possible topics you can discuss with your students. It might be a good idea to provide the document for them to read outside of class and then have them come in for the class discussion

Overview (Feynman's "There is plenty of room at the bottom")

Super intelligence

Nanotechnology

Life Extension and Cryonics

Pharmaceutical Enrichment (Brave New World)

Threats to Global Security

Strategies for Global Security (I, Robot)

Automation

Enhanced humans and Immortality

Environmental Effects of nanotechnology

The Gap between science and ethics.

All of the following have roots in nanotechnology. PDF files and documents you can use as handouts can be downloaded from www.transhumanist.org . This website even has student worksheets.

Some of the questions you can ask are:

1. **What can be done to maximize the chances that humans will benefit from, rather than be harmed by, new developments?**

2. **If we can develop these technologies, should we? Why?**

Nanotechnology Websites for Educators

UW-Madison MRSEC

Probably the most impressive website devoted to nanoeducation on the NET. Five stars!

Mondo-tronics Inc. - Muscle Wires, Shape Memory Alloys, and Electronics

A place to buy shape memory alloys

Dynalloy, Inc. Makers of Dynamic Alloys for Electrically Driven Applications

Another place to buy SMAs

A View from the Back of the Envelope

A great website determine to help young children understand the size of things

Nanotechnology

A website devoted to up to date information on nanotechnology news.

Small Times: News about MEMS, Nanotechnology and Microsystems

A magazine devoted to reporting the news

Ethics Nanotechnology

Various papers one can use to spark some great discussions

MIT Institute For Soldier Nanotechnologies

Great information on current research. Send an email for their free DVD. It will WOW students.

NIRT at VT - Curriculum development programs

A nice list of educational resources in nanotechnology

ScienCentral: Making Sense of Science

An awesome website for articles to use to practice reading strategies. Do a search for nanotechnology to acquire the appropriate articles.

Welcome to Virtual Office Hour

A nice website with some downloadable activities in nanotechnology.

University of Wisconsin - Madison Internships in Public Science Education (IPSE)

A great place to start to learn about nanotechnology

Engines of Creation - K. Eric Drexler : Table of Contents

Yes! It is the entire book!

The Ethics and Policy of New Technologies

An ethics course focusing on nanotechnology from YALE. Very cool!

Feynman's Talk

His entire historic lecture.

Center for Responsible Nanotechnology

A website devoted to policy research.