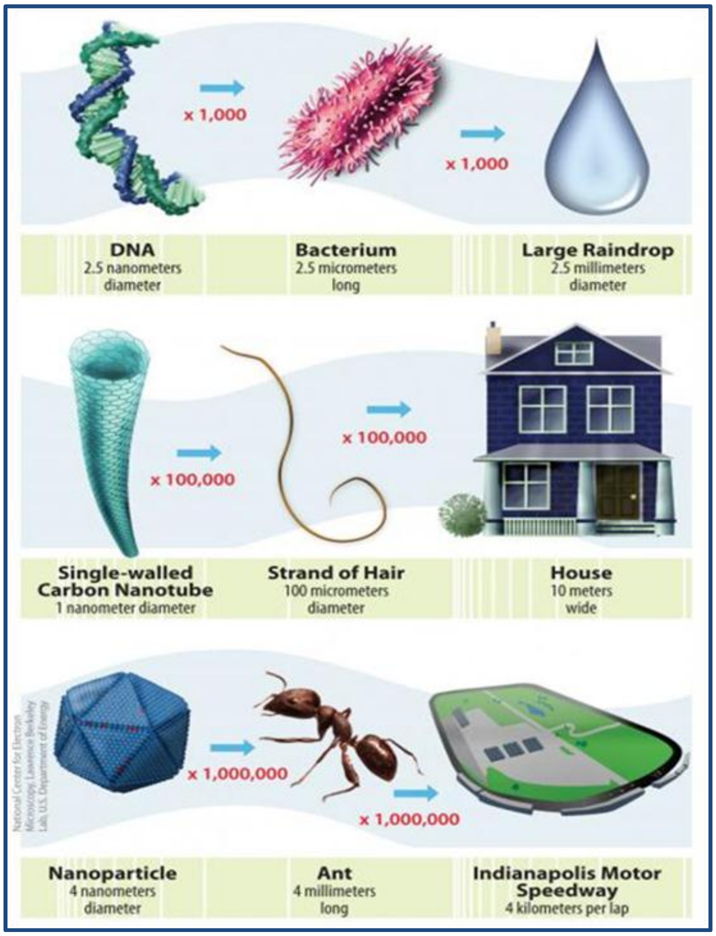
NEATEC Learning Module

Northeast Advanced Technological Education Center

What is Nanoscience?

Middle Level - Grades 6-8



Northeast Technological Education Center (NEATEC)
Hudson Valley Community College

STEM Introduction Topic

What is Nanoscience?

Middle Level - Grades 6-8

NEATEC Mission Statement

"The Northeast Advanced Technological Education Center (NEATEC) is a Regional Center for Semiconductor and Nanotechnology Education funded by the National Science Foundation (NSF DUE #1003574) to serve as a critical, sustainable resource to create and maintain a skilled technical workforce for the semiconductor and nanotechnology industries in New York State and Western New England. Through an extensive network of community college, university, and industry partners, NEATEC will identify the essential technician competencies and skills required by such a workforce. NEATEC will develop curricular components and delivery methods to impart those skills to students. NEATEC will also create and disseminate educational materials to support curricula implementation at its community college and high school partners and provide professional development activities for K-12 schools and community college faculty. Lastly, through partner internships, co-ops, shadowing opportunities and outreach activities, NEATEC will educate current and future students regarding technological career pathways and expand the pipeline of K-12 students interested in semiconductor and nanotechnology career options."

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Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and Creator(s) and do not necessarily reflect those of the National Science Foundation.

What is STEM?

With all the acronyms that determine hundreds of different areas of education, it is easy to confuse them all. Since 2001, the letters STEM have been a normal part of educational vocabulary.

The acronym STEM stands for Science, Technology, Engineering, and Mathematics. This program was started by Judith A. Ramaley, the former director of the National Science Foundation's education and human-resources division. This approach to education is designed to revolutionize the teaching of subject areas such as mathematics and science by incorporating technology and engineering into regular curriculum by creating a "meta-discipline."

There is more; STEM Education attempts to transform the typical teacher-centered classroom by encouraging a curriculum that is driven by problem-solving, discovery, exploratory learning, and requires students to actively engage a situation in order to find its solution.

Science, technology, engineering and mathematics (STEM) education often has been called a meta-discipline, "the creation of a discipline based on the integration of other disciplinary knowledge into a new 'whole'. This interdisciplinary bridging among discrete disciplines is now treated as an entity, known as STEM (Morrison, 2006)." STEM education offers students one of the best opportunities to make sense of the world holistically, rather than in bits and pieces. STEM education removes the traditional barriers erected between the four disciplines, by integrating them into one cohesive teaching and learning paradigm. Morrison and others have referred to STEM as being an interdisciplinary approach. "STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Tsupros, 2009)."

What is a NEATEC Learning Module (NLM)?

A NEATEC Learning Module (NLM) is self-contained unit that can be incorporated into existing science, math, and technology classes to supplement and enhance the content and the laboratory activities of the class. Each module includes all or some of the following sections:

- Background information about the topic of the unit
- A teacher's guide
- A student's guide
- List of lab materials for laboratory activities
- A list of teacher's and student's resources
- Power Point slides

The set of modules offered by NEATEC are divided into five categories based on the level of understanding of the participants:

1. NLM K-2: These are units suitable for students in grades Kindergarten to 2nd grades.
2. NLM 3-5. These are units suitable for students in grades 3rd to 5th grades.
3. NLM 6-8. These are units suitable for students in grades 6th to 8th grades.
4. NLM 9-12. These are units suitable for students in grades 9rd to 12th grades.
5. NLM for Community Colleges.

NEATEC Learning Modules include topics on Nanotechnology, Semiconductors, Photovoltaic, Alternate Energy, Mathematics, General Science and Technology.

Grade Level: Middle School Level – Grade 6-8

Essential Questions:

- What is a nanometer?
- How big is a nanometer?
- Why do objects at the nanoscale behave differently than in bulk?
- How does surface area affect reactivity?

Objective(s):

- Develop a general knowledge of nanoscience/nanotechnology
- Become familiar with concepts of scale particularly at the nanoscale
- Learn about interesting effects which take place at the nanoscale

New York State Curriculum Standards

New York State Standards are subject to change and will be modified accordingly.

New York State ELA Common Core Learning Standards

Reading Standards for Informational Text

RI. 1 Cite textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text.

RI. 2 Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments.

RI. 3 Analyze in detail how a key individual, event, or idea is introduced, illustrated, and elaborated in a text (e.g. through examples or anecdotes).

RI. 6 Determine an author's point of view or purpose in a text and explain how it is conveyed in the text.

RI. 7 Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

Writing Standards

W.1 Write arguments to support claims with clear reasons and relevant evidence.

W.1.a. Introduce claim(s) and organize the reasons and evidence clearly.

W.1.c. Use words, phrases, and clauses to clarify the relationships among claim(s) and reasons.

Speaking and Listening Standards

SL.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade level topics, texts, and issues, building on others' ideas and expressing their own clearly.

SL.1.b. Follow rules for collegial discussions, set specific goals and deadlines, and define individual roles as needed.

SL.1.c Pose and respond to specific questions with elaboration and detail by making comments that contribute to the topic, text, or issue under discussion.

SL.1.d Review the key ideas expressed and demonstrate understanding of multiple perspectives through reflection and paraphrasing.

SL.1.e Seek to understand and communicate with individuals from different perspectives and cultural backgrounds

SL. 2 Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study.

New York State Mathematics Common Core Learning Standards

Expressions and Equations

8.EE.3 Use numbers expressed in the form of a single digit times a whole-number power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other.

For example, estimate the population of the United States as 3 times 108 and the population of the world as 7 times 109, and determine that the world population is more than 20 times larger.

Geometry

8.G.9 Solve real-world and mathematical problems involving volume of cylinders, cones, and spheres. Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.

New York State Science Standards

Standard 6: Interconnectedness: Common Themes

Magnitude and Scale – Key Idea 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

3.1 Cite examples of how different aspects of natural and designed systems change at different rates with changes in scale.

3.2 Use powers of ten notation to represent very small and very large numbers.

Standard 4: The Physical Setting

Key Idea 3 – Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

3.1 a Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.

3.1b Solubility can be affected by the nature of the solute and solvent, temperature, and pressure. The rate of solution can be affected by the size of particles, stirring, temperature, and the amount of solute already dissolved.

Next Generation Science Standards

MS-PS1-1 Matter and its Interactions

Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-2 Matter and its Interactions

Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-3 Matter and its Interactions

Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-5 Matter and its Interactions

Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

New York State Technology Standards

Standard 5: Technology Education

5.5 History and Evolution of Technology

Key idea: Technology has been the driving force in the evolution of society from an agricultural to an industrial to an information base.

5.6 Impacts of Technology

Key Idea: Technology can have positive and negative impacts on individuals, society, and the environment and humans have the capability and responsibility to constrain or promote technological development.

Special Education Accommodations & Modifications:

- Experiments can be done as a whole group exploration rather than as individual small groups.
- Teacher may break the tablets into the appropriate sizes before providing them to the students.
- Use provided flash drive with audio file of student Activity Handout A for use with struggling readers prior to beginning lab.

Module Guide

What is Nanoscience?

Materials supplied in Kit: (Kit designed for a class of 33 students/11 groups)

11 (100 mL) Graduated cylinders
44 Plastic Cups
44 Small Plastic Cups
50 Antacid tablets
11 Timer/Stopwatches
11 Rulers
11 Squirt Bottles
11 Sets of Scale Cards
11Sets of Object Cards
Absorbent Pads
NEATEC Module Book
NEATEC Flash Drive

Materials NOT supplied in kit:

Water
Calculators (w/ π key)

Please refer to the "Kit Lending Supplies" sheet
for materials which must be returned (non-consumables)

Please complete feedback survey at
https://www.surveymonkey.com/s/NEATECLMSurvey

Day 1

Materials:

Per student

- Copy of “**What is a Nanometer”**

Per class

- SMARTboard or LCD projector for showing “**Nano in My Life**” http://www.youtube.com/watch?v=9PRSzkqFLEs&list=PL556DA4E9D467F799 (6:17 minutes)
- SMARTboard or LCD projector for showing “**Powers of Ten**” http://www.youtube.com/watch?v=0fKBhvDjuy0 (9:00 minutes)

Pre lesson set-up

Make copies of “**What is a Nanometer”?** worksheets (4 pages)

Procedure

1. Show video **“Nano in My Life”** (6:17) http://www.youtube.com/watch?v=9PRSzkqFLEs&list=PL556DA4E9D467F799
2. Show video **“Powers of Ten”** (9:00) http://www.youtube.com/watch?v=0fKBhvDjuy0
3. Begin **“What is Nanometer?”** worksheet. Students should be able to complete page 1 & 2 of the worksheets.

Day 2

Materials: None

Utilizing worksheet from previous day

Pre Lesson set-up: None

Procedure:

1. Review previous day 1 lesson.
2. Complete page 3 & 4 of the **"What is a Nanometer?"** packet.

Day 3

Materials:

Activity: How big is it?

Per group (3-4 students):

- Set of scale cards
- Set of object cards
- Computer or laptop **Scale of the Universe:** http://htwins.net/scale2/

Per student:

- One copy of **"How Big Is It?"** worksheet
- One copy of **"Scale of the Universe"** worksheet

Pre lesson set-up

- Make copies of **"How Big Is It?"** worksheet
- Make copies of **"Scale of the Universe"** worksheet

Procedure:

1. Review scientific notation

2. Tell student you are going to investigate size and scale using the metric system.

3. Complete the **"How Big Is It?"** activity.

4. Assign student groups to computers or laptops. Complete the **"Scale of the Universe"** activity.

Extension:

For a biological focus:

- See also this interactive comparison of objects smaller than 1 mm: www.cellsalive.com/howbig.htm
- See also this comparison of cells, viruses, and biological molecules: http://learn.genetics.utah.edu/content/begin/cells/scale/

Day 4

Materials:

Experiment: *Bubbling Tablets*

Per group (3-4 students):

- 100 mL graduated cylinder
- 4 Plastic Cups
- 4 Small Plastic Cups
- 4 Antacid Tablets
- Timer/Stopwatch
- Squirt Bottle with Water
- Ruler
- Calculator
- Absorbent Pad
- "**Activity Handout A**"

Pre lesson set-up

Make copies of **"Bubbling Tablets"** lab

Procedure:

1. Tell students they are going to investigate surface area and its effect on reactivity, as objects are made smaller and smaller.

2. Create lab groups. Provide students with **"Activity Handout A"** to read and discuss.

3. Complete **"Bubbling Tablets"** lab.

Teacher Information:

- Breaking a tablet into smaller pieces increases its surface area while keeping the total volume or the amount of antacid the same. The more surface area (or exposed area) results in more sites that contact water immediately, resulting in the antacid dissolving faster and the chemical reaction (fizzing) happening faster. The crushed tablet has the smallest pieces and thus the highest *surface area to volume ratio*, causing it to react the fastest.
- Small things have more surface area for their volume than larger things do. Some things that aren't reactive at all in big pieces are very reactive when they're tiny. Steel wool catches fire, but you can't easily light a lump of metal on fire!
- Things on the nanoscale have a lot of surface area, so they react much more easily and quickly than they would if they were larger. A material can act very differently when it's nanometer-sized. For instance, bulk platinum is used in wedding rings whereas nanoscale platinum is a catalyst used in chemical reactions, such as energy-releasing reactions in fuel cells. Nanotechnology takes advantage of different material properties at the nanoscale—like reactivity—to make new materials and tiny devices. Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Safety:

- The antacid tablets contain medication. Students should be supervised when doing this activity, and should not be allowed to consume the tablets or the water they are dissolved in.

Waste:

- You will need a place to dump waste water. If there is no sink near your activity area, you can dump waste water into a bucket and dispose of it periodically.

Post-Activity Questions:

- What happened to the reactivity of antacid tablets with water as the tablet was broken down smaller and smaller? Why?
- What happens to the surface area as the items get smaller and smaller?
- You should have observed that the rate of reaction increased when the tablet was broken down into smaller pieces. How is this relevant to nanotechnology?

Please refer to the "Kit Lending Supplies" sheet
for materials which must be returned (non-consumables)

Please complete feedback survey at
https://www.surveymonkey.com/s/NEATECLMSurvey

Teacher Resources

Background Information for Teachers:

This module serves as an introduction to nanoscience and nanotechnology. Nanoscience is becoming increasingly more prevalent in both society and industry. As a result, it is important to make students aware of what it is and how it can impact their lives. To enable discussion about nanoscience, students will first be introduced to the nanoscale. At the nanoscale, properties of materials differ from those of the same bulk material. In this module, these interesting effects that take place at the nanoscale will be discussed.

Nano is a new buzz word in the scientific community. The word is used a lot more in society and in products such as the iPod nano. Nano has been mentioned in films like Minority Report and Spiderman. It has been in the news with increasing regularity. Governments and private organizations are spending more and more money on research at the nanoscale. But what exactly is nanoscience and why all the hype?

What is nanoscience and nanotechnology?

Nanoscience is about studying how materials behave at a very small scale (at the nanoscale). A nanometer is one billionth of a meter. It is also one millionth of a millimeter, and one millimeter is the smallest measurement visible on a 30 cm ruler. Nanoscience works on a scale 1000 times smaller than anything that can be seen with a light microscope. It is not just one science, but a platform that includes biology, chemistry, physics, medicine, materials science and engineering.

Nanotechnology is the manufacture and development of materials, devices and structures by applying an understanding of how materials behave at the nanoscale. Nanotechnology is now applied widely in the ICT (Information and Communications Technology) industry in the manufacture of smaller integrated circuits (computer 'chips') and more efficient data storage mechanisms. It is also used in the medical devices industry to make smaller products. Several commercial examples of nanotechnology are on the market, and many more promising applications of nanotechnology are being investigated. Nanotechnology will impact virtually every industry in the future.

In practice, the words 'nanoscience' and 'nanotechnology' are used interchangeably.
'Nano' by itself, is often used as shorthand to refer to these activities.

All about size

- The word 'nano' comes from the Greek word, 'nanos', meaning dwarf. It is a prefix used to describe one billionth of something (1/1,000,000,000 or 10^{-9}). A nanometer is one billionth of a meter or one millionth of a millimeter.
- A human hair is about 50,000 – 100,000 nm wide. Typically nanoscientists work in the range of 1 – 100 nm. One nanometer is about one molecule or 3 – 10 atoms long (depending on the atom!).
- A red blood cell is about 10,000 nm wide.
- A common cold virus is about 30 nm tall.
- DNA is just 2 nm wide.

Why does size matter?

Objects at the nanoscale (less than 100 nm in at least one dimension) exhibit unexpected chemical and physical properties that are very different from the properties of bulk materials. For example, the optical properties of gold behave differently at the nanoscale compared to the macroscale. While gold at the macroscale is a yellow color, gold at the nanoscale can appear red.

The Lycurgus Cup, made by the Romans, dates to the fourth century AD. One of the very unusual features of the Cup is its color. When viewed in reflected light, (in daylight) it appears green. When a light is shone into the cup and transmitted through the glass, it appears red. Medieval artisans were the first nanotechnologists. They knew that by putting varying, tiny amounts of gold and silver in glass, they could produce the multi- colored effects found in stained-glass windows.

Large zinc oxide particles appear white, while at the Nanoscale they are clear. This property is used in newer clear sunscreens.

The chemical reactivity varies as the size of the particle changes. The purpose of the experimental activity outlined in this module is to demonstrate the different rates of reaction caused by particle size.

Why do properties change?
One reason why properties of structures are different at the nanoscale is because as particles get smaller, the ratio of surface area-to-volume of the structure increases. Most atoms are at or near the surface. Because chemical reactions take place on the surface of a particle, if there is an increased surface area available for reactions, the reaction can be very different.

Where can nanotechnology be used in our everyday lives?
Nanotechnology is becoming more and more prevalent and has the ability to affect all aspects of our lives; from clothing, cosmetics, computing and healthcare to futuristic ideas such as elevators to space. The study of materials behavior and properties can be manipulated to make more lightweight, robust structures and smaller, more efficient devices across a range of industries.

Where is nanotechnology already being used?
- Carbon nanotubes are being used in the sports industry to make lighter and more robust equipment such as tennis rackets and lightweight bikes.
- Nanotechnology is used in surface coatings which have special properties like water, fire or scratch resistance, or are self cleaning e.g. in waterproof and stain-resistant clothing, paint, self-cleaning windows.
- Face-creams and cosmetics also contain nanomaterials (also called liposomes/nanosomes), which help retain moisture and deliver active ingredients to cells.
- Nanotechnology is applied in the miniaturization of computers and other electronics and in more powerful and efficient data storage techniques.
- Nanoscience is applied in the development of faster and more sensitive medical testing devices and treatments.
- Sunscreens use nanoparticles of zinc oxide or titanium dioxide to absorb the harmful UV rays from the sun, while making the sunscreens appear ‘invisible’. Macro-sized particles are not transparent.
- Nanotechnology can help the environment – advances in nanoscience are producing more efficient solar cells and materials and devices which require lower operational energies. Nanoscience can also be used for water purification in developing countries.

Original Activities and References:

- CRANN module from Nano in My Life on What is Nanoscience?
- http://teachers.stanford.edu/activities/
- http://teachers.stanford.edu/activities/BubblingTablets/BubblingTablets-TeacherGuide.pdf
- http://www.trynano.org/pdf/whatisanano.pdf
- snf.stanford.edu/Education/Nanotechnology.SNF.web.pdf
- www.97.intel.com/en/TheJourneyInside/ExploreTheCurriculum/ EC_Microprocessors/MPLesson4/
- www.nanosense.org/activities/sizematters/properties/SM_ Lesson3Teacher.pdf
- www.computerhistory.org/timeline/?year=1980

Useful Resources:

General

- www.nanoandme.org/home
- www.nano.gov
- www.nisenet.org
- www.nanoyou.eu
- www.nanoed.org
- www.nanozone.org

On Nanoscale and Nanoruler

- www.nano.gov/html/facts/The_scale_of_things.html
- www.nanotech-now.com/basics.htm
- www.sciencemuseum.org.uk/antenna/nano/lifestyle/122.asp
- www.microcosm.web.cern.ch/microcosm/P10/english/P0.html

Nanotechnology Applications

- www.nnin.org/nnin_edu.html
- www.nanotechproject.org/inventories/consumer

Assessment:

- Students will be formatively assessed during group discussions. Students' observations and the data they record will be used as a summative assessment of students' learning and the extent to which they met the lesson objectives.

Extensions:

- Give examples of things at the meter, millimeter, micrometer and nanometer scales.
- Take a 1 cm^3 cube and calculate the surface area. If you were to chop it up into 1 nm^3 cubes, what would be the total surface area?
- Research and give an example of a material that behaves differently in bulk and at the nanoscale. Explain the difference in behavior in terms of surface area.
- Do statistical analysis on data collected during the antacid tablet experiment for the whole class and calculate mean, median or mode and standard deviation.
- Ask students to experiment with different environmental conditions that might affect the reaction rates. For instance, they could try shaking the cylinder or using hot/cold water. How does this affect the height of the reaction and the time it takes to reach that height?
- Ask students to experiment with adding different amounts of water to the cylinders. What is the minimum amount required to dissolve one tablet? What happens when water is a limiting factor?

Images Courtesy of:

- National Nanotechnology Coordination Office and the National Center for Electron Microscopy, Lawrence Berkeley Lab, U.S. Department of Energy

Name:________________________________ Date:_______________

Period:_________________

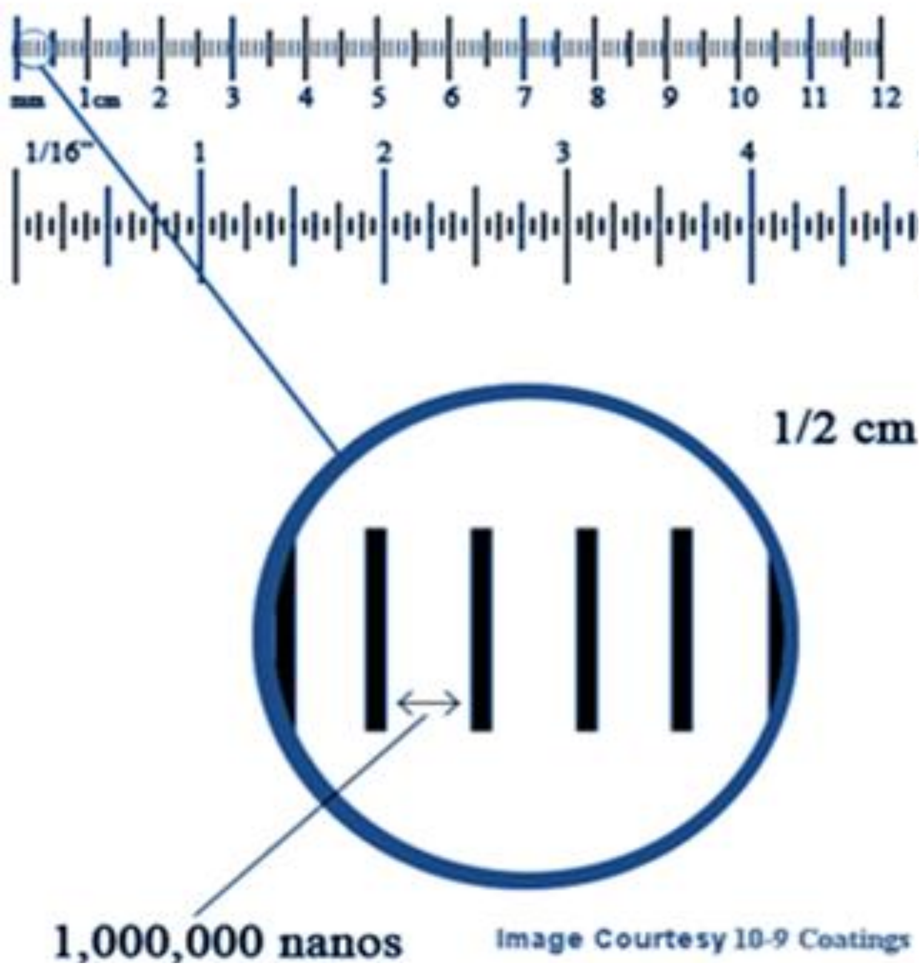
What is a Nanometer?

Adapted from an activity created by TryEngineering

The word ‘nano’ comes from the Greek word, ‘nanos’, meaning dwarf. It is a prefix used to describe one billionth of something (1/1,000,000,000 or 10^{-9}).

A nanometer is one billionth of a meter.
1 nm = 0.000000001 m = 10^{-9} m

But how big is that? The diagram to the right should help you understand how small a nanometer really is. Notice that a centimeter is 1/100th of a meter. That also means that a meter is 100 times as big as a centimeter. If an object were a meter wide, it would also be 1,000,000,000 nanometers wide. So something that is only 1 nm wide is very small indeed.



Explain in your own words what the diagram on the right represents.

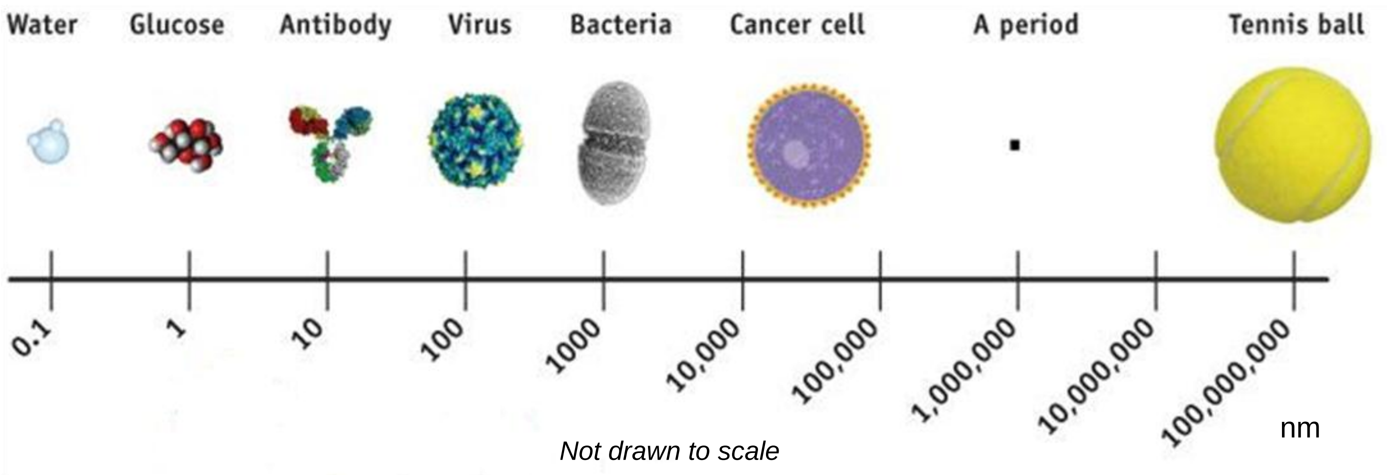
____

____

____

____

Look at the chart below that was developed by the National Cancer Institute (U.S.) and think about how much smaller the various items are…moving down from the familiar tennis ball.



Reference Table

	Symbol	In Meters	
kilometer	km	1000	10^3
meter	m	1	1
centimeter	cm	0.01	10^{-2}
millimeter	mm	0.001	10^{-3}
micrometer	μm	0.000001	10^{-6}
nanometer	nm	0.000000001	10^{-9}

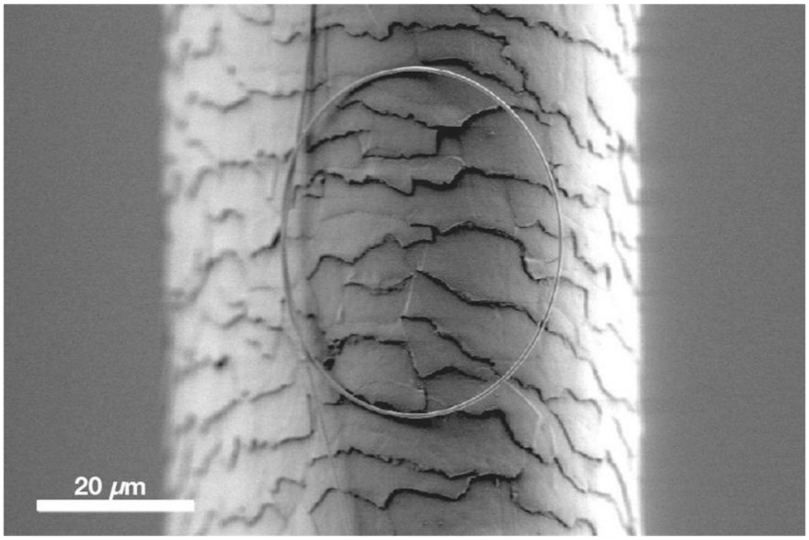
Use the diagram above and the reference chart to the left to complete the chart below.

Object	**nm**	**Scientific Notation (nm)**	**Scientific Notation (m)**
Water			
Glucose			
Antibody			
Virus			
Bacteria			
Tennis ball			

Complete the following based on the chart above:

1. A glucose molecule is ______________ times bigger than a water molecule.
2. A tennis ball is ______________ million times bigger than a glucose molecule and ______________ billion times bigger than a water molecule.
3. A tennis ball is ______________ times bigger than an antibody and ______________ times bigger than a virus.
4. A glucose molecule is ______________th of a bacteria.
5. A bacteria is ______________ th of a tennis ball.
6. A glucose molecule is ______________th of a tennis ball
7. If a student is 160 cm tall, how tall are they in meters ______________ and nanometers ______________.

Nanomaterials are also being made in laboratories. Here is an image of a silver nanowire resting on a human hair. Look at a strand of your own hair and imagine how small that is!



(Image Credit: CRANN, Trinity College Dublin)

Reference Table

	Symbol	In Meters	
kilometer	km	1000	10^{3}
meter	m	1	1
centimeter	cm	0.01	10^{-2}
millimeter	mm	0.001	10^{-3}
micrometer	μm	0.000001	10^{-6}
nanometer	nm	0.000000001	10^{-9}

Trace over the silver nanowire. Based on the image, how thick is the hair in μm (micrometers) and nm (Nanometers).

____________________________________μm ____________________________________nm

In your own words, how small is a nanometer compared to a meter?

____

Use the reference chart to above to complete the chart below.

Object	mm	nm	Scientific Notation (nm)	Scientific Notation (m)
Pencil led	0.5 mm			
Pin	2 mm dia			
Eyelash	0.15mm dia			
Paper (thickness)				1×10^{-4} m
Thread	.42 mm			

Quirky fun size facts

- Your fingernail grows about 1 nm in a second.
- Grass grows approximately 20 nm in a second.
- A man's beard grows 5 nm every second.

Nanoscience Preview

Directions: Describe the terms below in your own words. Use diagrams where appropriate. If you are unsure, do some research!

Nanometer: ____

____

Nanoscale: ____

____

Bulk: ____

____

Macroscale: ____

____

Nanoscience: ____

____

Property: ____

____

Chemical reactivity: ____

____

Surface area: ____

____

Constants: ____

____

Variables: ____

____

Name:____________________________________ Date:__________________

Period:____________________

How Big Is it?

Adapted from an activity created by Center for Probing the Nanoscale, Stanford University

Investigative Question:

How can we use scientific notation to order objects based on size?

Hypothesis: ____

____

____

Materials:

- Set of scale cards
- Set of object cards

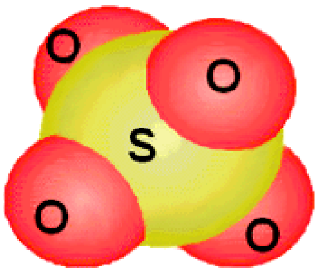
Procedure:

1. Arrange the scale cards in a line across the top of your table, from smallest to biggest.
2. Make a second row of object cards, placing the object card next to the scale card that best fits the measurement of the object.

Results: Record your results in the table below.

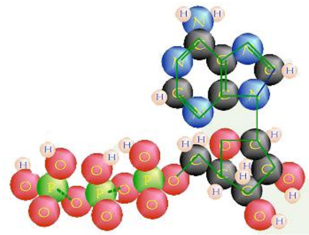
10^{-10} m	10^{-9} m	10^{-8} m	10^{-7} m
10^{-6} m	**10^{-5} m**	**10^{-4} m**	**10^{-3} m**
10^{-2} m	**10^{-1} m**	**10^{0} m**	**10^{1} m**
10^{2} m	**10^{3} m**	**10^{4} m**	**10^{5} m**

Sulfur atom



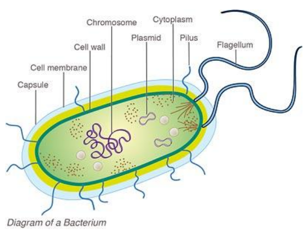
diameter of a
carbon nanotube

length of an
ATP molecule

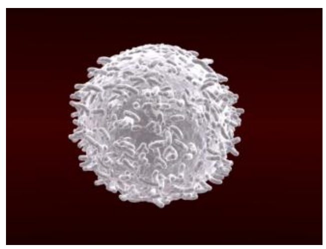


diameter of a
flu virus

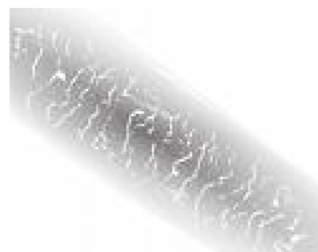
width of a
bacterium



diameter of
an average
white blood cell



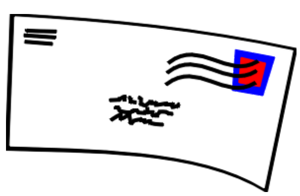
thickness of a
human hair



thickness of paper

approximate width
of a pinky fingernail

width of a
standard envelope



height of a typical
5-year-old child

length of a
standard city bus

length of a
soccer field

distance walked in
10 – 15 minutes

cruising altitude of
an airplane

distance a car can
travel on a
freeway in 1 hour

10^{-10} m (1 angstrom)	10^{-9} m (1 nanometer)	10^{-8} m (10 nanometers)	10^{-7} m (100 nanometers)
10^{-6} m (1 micrometer)	10^{-5} m (10 micrometers)	10^{-4} m (100 micrometers)	10^{-3} m (1 millimeter)
10^{-2} m (1 centimeter)	10^{-1} m (1 decimeter)	10^{0} m (1 meter)	10^{1} m (10 meters)
10^{2} m (100 meters)	10^{3} m (1 kilometer)	10^{4} m (10 kilometers)	10^{5} m (100 kilometers)

Name:__________________________________ Date:__________________

Period:____________________

Scale of the Universe

Directions: Using the Scale of the Universe 2 (http://htwins.net/scale2/), complete the table below. Order the objects in the table from largest to smallest. To obtain the measurement of the object, click on the object.

Description of Object	Measurement of Object in Scientific Notation (m)	Description of Object	Measurement of Object in Scientific Notation (m)
Average size of a Mist Droplet		Length of a Grain of Rice	
Height of Mt. Everest		Diameter of the Andromeda Galaxy	
Diameter of Sun		Diameter of a Hydrogen Atom	
Diameter of a Carbon Nanotube		Size of Largest Virus	
Diameter of Earth		Estimated size of the Universe	
Diameter of a Skin Cell		Distance from Sun to the nearest Star (Proxima Centauri)	

Directions: Order the objects from largest to smallest. To obtain the measurement of the object, click on the object.

Object **Measurement**

1. ____ ____________________
2. ____ ____________________
3. ____ ____________________
4. ____ ____________________
5. ____ ____________________
6. ____ ____________________
7. ____ ____________________
8. ____ ____________________
9. ____ ____________________
10. ____ ____________________
11. ____ ____________________
12. ____ ____________________

What is Nanoscience– Activity Handout - A

Adapted from an activity created by Center for Probing the Nanoscale, Stanford University

Background:

Objects at the nanoscale (less than 100 nm in at least one dimension) often show unexpected chemical and physical properties that are very different than properties when the objects are larger. For example, the optical properties of gold behave differently at the nanoscale compared to the macroscale. While a chunk of gold at the macroscale is a yellow color (left image), gold at the nanoscale can appear red (right image).

(Image Credit: CRANN, Trinity College Dublin)

Chemical reactivity is another property that is greatly affected by particle size, and reactivity of objects at the nanoscale can be very different than at the macroscale. One reason why properties of structures are different at the nanoscale is because as particles get smaller, the ratio of surface area-to-volume of the structure increases. Most atoms are at or near the surface. Because chemical reactions take place on the surface of a particle, if there is an increased surface area available for reactions, the reaction can be very different. In this experiment, you are going to investigate how decreasing particle size affects chemical reactivity or reactions rates and what causes the difference in reactivity.

Nanotechnology takes advantage of different material properties at the nanoscale—like reactivity—to make new materials and tiny devices. Nanotechnology allows scientists and engineers to make things like smaller, faster computer chips and new medicines to treat diseases like cancer.

Name:__________________________________ Date:________________

Period:__________________

Adapted from an activity created by Center for Probing the Nanoscale, Stanford University

Lab: Bubbling Tablets

In this experiment, you are going to investigate the reaction of antacid tablets with water. As you may know, when you put an antacid tablet in water, the tablet starts dissolving, reacting with water and starts fizzing.

Investigation Question:

Will breaking antacid tablets into smaller pieces affect the rate of reaction with water compared to a whole tablet?

Hypothesis: ____
____
____

Materials:

- 100 mL graduated cylinder
- 4 Small Plastic Cups
- 4 Plastic Cups
- At least 4 antacid tablets
- Timer/Stopwatch
- Squirt Bottle with Water
- Ruler
- Calculator (w/ π key)
- Paper towels
- Waste Bucket
- Absorbent pad

Procedure:

1. Carefully open packages of antacids. Tearing along the long side results in less accidental breakage.

2. Place one whole tablet into a small plastic cup. Break a second tablet in half, placing both pieces in a second small plastic cup. Break the third tablet into quarters, placing all pieces in a third small plastic cup. Place the fourth tablet back into the packaging, crush into tiny pieces and place all pieces in last small plastic cup.

3. Using the tablets in the small plastic cups, complete the ***Surface Area : Volume Table***.
   - Draw the tablet.
   - Shade in the additional, new surface area that is exposed by breaking the tablets in half and in quarters.
   - Use the ruler (cm) to measure the dimensions of each piece.
   - Calculate the total surface area (SA) for the whole tablet and broken tablets. Be sure to show all your work and include formulas and units.
   - Calculate volume of tablet.

- Calculate surface area: volume ratio.

4. Using the graduated cylinder pour 40 mL of water into all 4 of the plastic cups.

5. Dry the graduated cylinder. Make sure it is a dry as you can get it.

6. Assign roles within your group
    - Materials Handler – put tablet in the graduated cylinder and later pour the water.
    - Time Keeper - start and stop timer.
    - Observer - watching height of reaction and notify the time keeper when the reaction reaches full height.

7. **Read steps 8-11 before starting!**

8. Place whole tablet into the dry graduated cylinder.

9. Make sure the timer is ready.

10. Start the timer as you pour 40 mL of water into the graduated cylinder.

11. Observe the reaction. Be sure to notify the time keeper when the reaction has reached the maximum height (*Note: Once maximum height is reached, height will stop changing or begin to decrease.*). At the maximum height the timer should be stopped.

12. Record the results in the ***Reaction Height Table***.

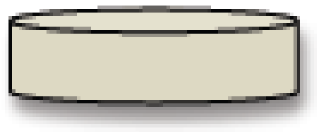
13. Empty graduated cylinder into the waste bucket or sink.

14. Rinse the graduated cylinder with water filled squirt bottle, then dry. Make sure the graduated cylinder is a dry as you can get it.

15. Repeat steps 8-11 for the halves (all contents of small plastic cup), then quarters (all contents of small plastic cup) and finally the crushed pieces (all contents of small plastic cup).

16. Clean-up

17. Complete the Observation Questions and graphs.

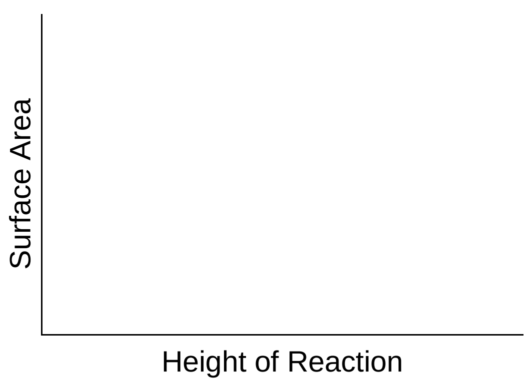
Surface Area : Volume Table			
Drawing/Sketch Make sure drawing resemble actual table pieces.	**Surface Area Calculations (SA)** *(Hint: Surface area of a cylinder = area of the top and bottom circles plus area of the rectangular wall)*	Volume $_{\text{(whole tablet)}}$=volume of a cylinder = area of the circle times height = $(\pi \times r^2) \times h$	**Surface Areas : Volume**
Whole Tablet  (not to scale)			
Half Tablets (draw both pieces) (not to scale)			
Quarter Tablets (draw all 4 pieces) (not to scale)			

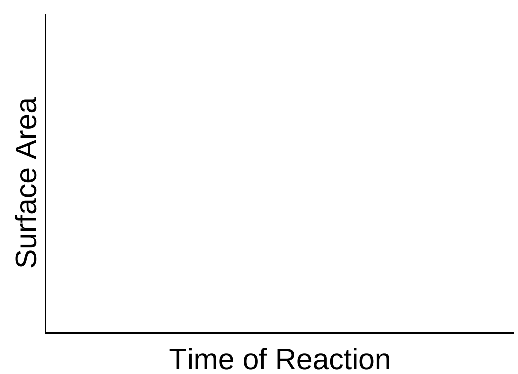
What do you notice about the ratio of surface area to volume?

Reaction Height Table		
Tablet Size (entire contents of plastic cup)	**Reaction Height (mL)**	**Time to Reach Maximum Height (seconds)**
Whole Tablet		
Halved Tablets		
Quartered Tablets		
Crushed Pieces of Tablet		

Observation Questions:

1. Which reaction occurred fastest? ____
2. Which reaction went the highest? ____
3. What is the correlation (relationship) between the speed of the reaction and the height of the reaction?
   ____
   ____
4. Which properties of this experiment were constants and which were variables?
   Constants: ____
   Variables: ____
5. What do you think a graph of surface area vs. height of reaction would look like? What about a graph of surface area vs. time of reaction? (Hint: Think about the curves in words first.)





Conclusions:

Be sure to include an explanation of your observations in terms of surface area and its relevance to nanoscience.

____

____

____

Name: **Answer Key** Date_______________

Period:__________________

What is a Nanometer?

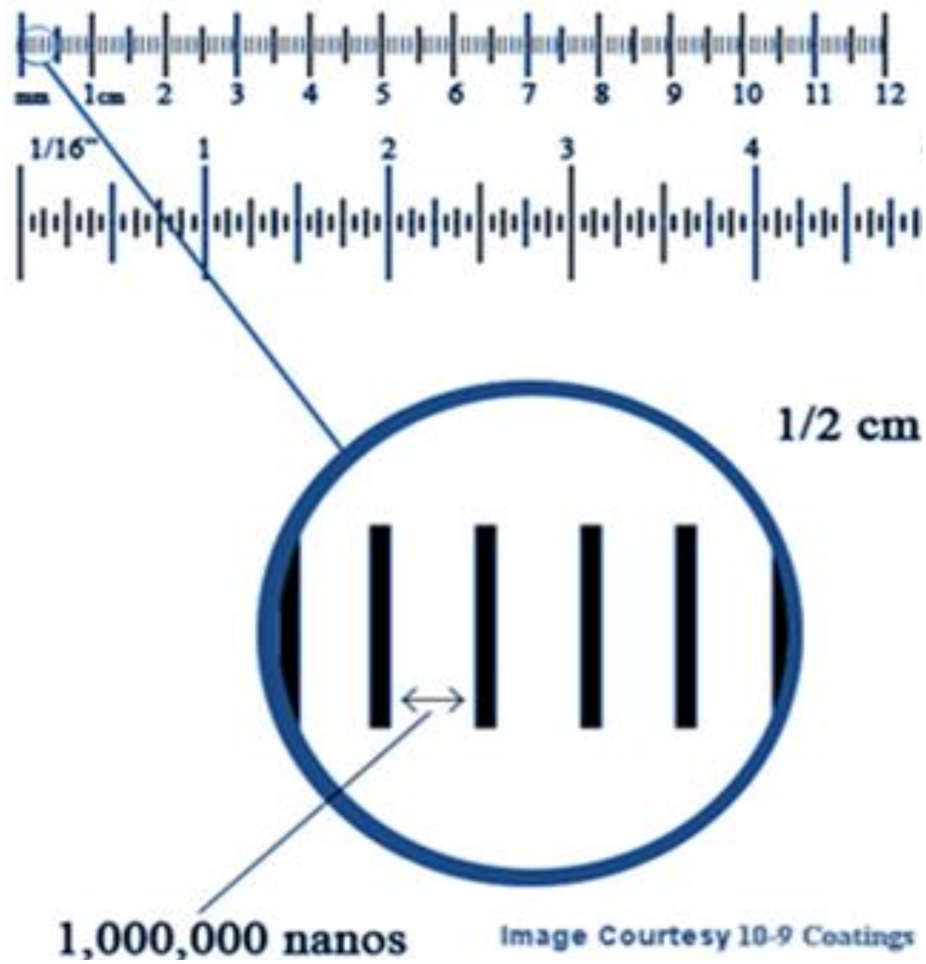
Adapted from an activity created by TryEngineering

The word 'nano' comes from the Greek word, 'nanos', meaning dwarf. It is a prefix used to describe one billionth of something (1/1,000,000,000 or 10^{-9}).

A nanometer is one billionth of a meter.

$$1 \text{ nm} = 0.000000001 \text{ m} = 10^{-9} \text{ m}$$

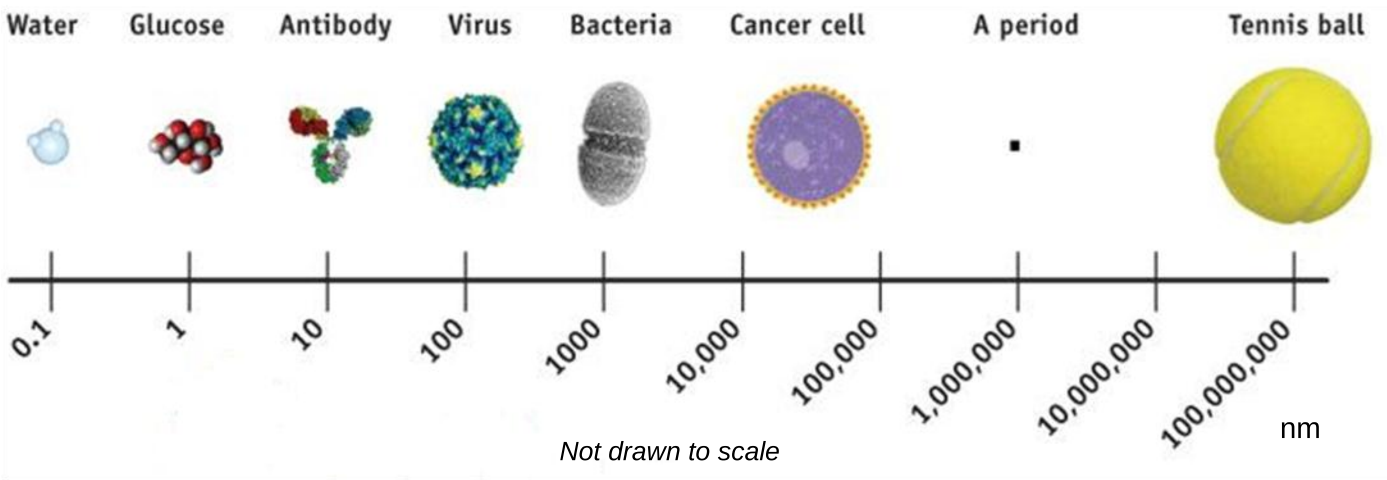
But how big is that? The diagram to the right should help you understand how small a nanometer really is. Notice that a centimeter is 1/100th of a meter. That also means that a meter is 100 times as big as a centimeter. If an object were a meter wide, it would also be 1,000,000,000 nanometers wide. So something that is only 1 nm wide is very small indeed.



Explain in your own words what the diagram on the right represents.

The top scale is a ruler in centimeters and the bottom scale is a ruler in inches for comparison. In the circle shows a close up of 5 mm or ½ cm where each interval is 1 mm, and the double arrow indicates that 1 million nanometers fit into that 1 mm space, keeping in mind that it is blown out from the original ruler at the top.

Look at the chart below that was developed by the National Cancer Institute (U.S.) and think about how much smaller the various items are…moving down from the familiar tennis ball.



Reference Table

	Symbol	In Meters	
kilometer	km	1000	10^3
meter	m	1	1
centimeter	cm	0.01	10^{-2}
millimeter	mm	0.001	10^{-3}
micrometer	µm	0.000001	10^{-6}
nanometer	nm	0.000000001	10^{-9}

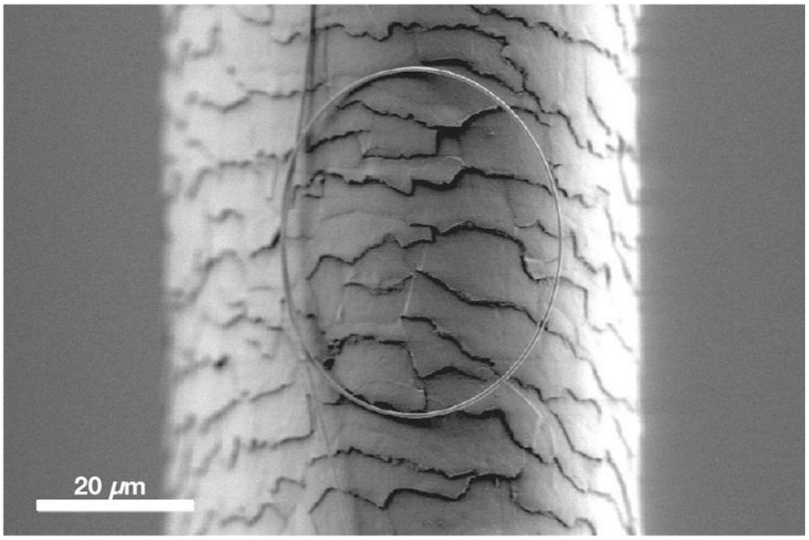
Use the diagram above and the reference chart to the left to complete the chart below.

Object	nm	Scientific Notation (nm)	Scientific Notation (m)
Water	*.1*	1×10^{-1}	1×10^{-10}
Glucose	*1*	1×10^{0}	1×10^{-9}
Antibody	*10*	1×10^{1}	1×10^{-8}
Virus	*100*	1×10^{2}	1×10^{-7}
Bacteria	*1,000*	1×10^{3}	1×10^{-6}
Tennis ball	*100,000,000*	1×10^{8}	1×10^{-1}

Complete the following based on the chart above:

1. A glucose molecule is ____*10*____ times bigger than a water molecule.
2. A tennis ball is ____*100*_____ million times bigger than a glucose molecule and ____*1*____ billion times bigger than a water molecule.
3. A tennis ball is _*1×10^7 = 10,000,000*__ times bigger than an antibody and _*1×10^6 = 1,000,000*__ times bigger than a virus.
4. A glucose molecule is _____*1000*_ th of a bacteria.
5. A bacteria is __*100,000*_ th of a tennis ball.
6. A glucose molecule is ___*100,000,000*_ th of a tennis ball
7. If a student is 160 cm tall, how tall are they in meters ___*1.6*___ and nanometers ___*1.6×10^9 = 1,600,000,000*___ .

Nanomaterials are also being made in laboratories. Here is an image of a silver nanowire resting on a human hair. Look at a strand of your own hair and imagine how small that is!



(Image Credit: CRANN, Trinity College Dublin)

Reference Table

	Symbol	In Meters	
kilometer	km	1000	10^{3}
meter	m	1	1
centimeter	cm	0.01	10^{-2}
millimeter	mm	0.001	10^{-3}
micrometer	µm	0.000001	10^{-6}
nanometer	nm	0.000000001	10^{-9}

Trace over the silver nanowire. Based on the image, how thick is the hair in µm (micrometers) and nm (Nanometers).

~3 scale bars or 60 µm *60,000* nm

In your own words, how small is a nanometer compared to a meter?

Answers will vary, but they should mention that it is a billionth of a meter and their interpretation of how small that is.

Use the reference chart to above to complete the chart below.

Object	**mm**	**nm**	**Scientific Notation (nm)**	**Scientific Notation (m)**
Pencil led	0.5 mm	***500,000 nm***	***5×10^{5} nm***	***5×10^{-4} m***
Pin	2 mm dia	***2,000,000 nm***	***2×10^{6} nm***	***2×10^{-3} m***
Eyelash	0.15mm dia	***150,000 nm***	***1.5×10^{-5} nm***	***1.5×10^{-4} m***
Paper (thickness)	***.1 mm***	***100,000 nm***	***1×10^{5} nm***	1×10^{-4} m
Thread	.42 mm	***420,000 nm***	***4.2×10^{5} nm***	***4.2×10^{-4} m***

Quirky fun size facts

- Your fingernail grows about 1 nm in a second.
- Grass grows approximately 20 nm in a second.
- A man's beard grows 5 nm every second.

Nanoscience Preview

Directions: Describe the terms below in your own words. Use diagrams where appropriate. If you are unsure, do some research!

Nanometer:

One billionth of a meter or $1x10^{-9}$ m or 1/1,000,000,000 m

Nanoscale:

Relating to or occurring on a 1-100 nm scale

Bulk:

In large quantities, not divided in parts such as atoms or nanoparticles

Macroscale:

Length scale on which objects or processes are of a size that is measurable and observable with naked eye

Nanoscience:

Study and manipulation of materials at the nanoscale

Nanotechnology:

Development of materials and devices at the nanoscale

Property:

Characteristics of a substance.

Chemical reactivity:

The rate at which a chemical substance tends to undergo a chemical reaction.

Surface area:

Total area of the faces and curved surface of a solid figure. Increased surface area → more area for chemical reaction → increased reactivity.

Constants:

Parameters that do not change in an experiment.

Variables:

Parameters that change in an experiment.

Name: **Answer Key** Date:____________

Period:____________________

How Big Is it?

Adapted from an activity created by Center for Probing the Nanoscale, Stanford University

Investigative Question:

How can we use scientific notation to order objects based on size?

Answers will vary, but a good answer may be that using scientific notation allows us to compare objects using the same unit of measurement even though numbers may be extremely large or small.

Materials:

- Set of scale cards
- Set of object cards

Procedure:

1. Arrange the scale cards in a line across the top of your table, from smallest to biggest.
2. Make a second row of object cards, placing the object card next to the scale card that best fits the measurement of the object.

Results: Record your results in the table below.

10^{-10} m	**10^{-9} m**	**10^{-8} m**	**10^{-7} m**
Sulfur atom	*diameter of a carbon nanotube*	*length of an ATP molecule*	*diameter of a flu virus*
10^{-6} m	**10^{-5} m**	**10^{-4} m**	**10^{-3} m**
width of a bacterium	*diameter of an average white blood cell*	*thickness of a human hair*	*thickness of paper*
10^{-2} m	**10^{-1} m**	**10^{0} m**	**10^{1} m**
approximate width of a pinky fingernail	*width of a standard envelope*	*height of a typical 5-year-old child*	*length of a standard city bus*
10^{2} m	**10^{3} m**	**10^{4} m**	**10^{5} m**
length of a soccer field	*distance walked in 10 – 15 minutes*	*cruising altitude of an airplane*	*distance a car can travel on a freeway in 1 hour*

Name: **Answer Key** Date:____________

Period:____________________ **Scale of the Universe**

Directions: Using the Scale of the Universe 2 (http://htwins.net/scale2/), complete the table below. Order the objects in the table from largest to smallest. To obtain the measurement of the object, click on the object.

Description of Object	Measurement of Object in Scientific Notation (m)	Description of Object	Measurement of Object in Scientific Notation (m)
Average size of a Mist Droplet	***2×10^{-5}m***	Length of a Grain of Rice	***5×10^{-3}m***
Height of Mt. Everest	***8.8×10^{3}m***	Diameter of the Andromeda Galaxy	***1.5×10^{21}m***
Diameter of Sun	***1.4×10^{9}m***	Diameter of a Hydrogen Atom	***3.1×10^{-11}m***
Diameter of a Carbon Nanotube	***1×10^{-9}m***	Size of Largest Virus	***4.4×10^{-7}m***
Diameter of Earth	***1.27×10^{7}m***	Estimated size of the Universe	***9.3×10^{28}m***
Diameter of a Skin Cell	***3.5×10^{-5}m***	Distance from Sun to the nearest Star (Proxima Centauri)	***4.2×10^{16}m***

Directions: Order the objects from largest to smallest. To obtain the measurement of the object, click on the object.

Object	**Measurement**
1. Estimated size of the Universe	9.3×10^{28} m
2. Diameter of Andromeda Galaxy	1.5×10^{21} m
3. Distance from Sun to nearest Star (Proxima Centauri)	4.2×10^{16} m
4. Diameter of Sun	1.4×10^{9} m
5. Diameter of Earth	1.27×10^{7} m
6. Height of Mt. Everest	8.8×10^{3}m
7. Length of a Grain of Rice	5×10^{-3} m
8. Diameter of a Skin Cell	3.5×10^{-5} m
9. Average size of a Mist Droplet	2×10^{-5} m
10. Largest Virus	4.4×10^{-7} m
11. Diameter of a Carbon Nanotube	1×10^{-9} m
12. Diameter of a Hydrogen Atom	3.1×10^{-11} m

Name: **Answer Key** Date:________________

Period:__________________

What is Nanoscience

Adapted from an activity created by Center for Probing the Nanoscale, Stanford University

Lab: Bubbling Tablets

In this experiment, you are going to investigate the reaction of antacid tablets with water. As you may know, when you put an antacid tablet in water, the tablet starts dissolving, reacting with water and starts fizzing.

Investigation Question:

Will breaking antacid tablets into smaller pieces affect the rate of reaction with water compared to a whole tablet?

Hypothesis:

Answers will vary, but a good answer may be that tablets broken down into smaller pieces will react faster, dissolve more quickly, produce more fizz, etc due to increased surface area.

Materials:

- 100 mL graduated cylinder
- 4 Plastic Cups
- 4 Small Plastic Cups
- At least 4 Antacid Tablets
- Timer/Stopwatch
- Squirt Bottle with Water
- Ruler
- Calculator (w/ π key)
- Paper towels
- Waste Bucket
- Absorbent pad

Procedure:

1. Carefully open packages of antacids. Tearing along the long side results in less accidental breakage.

2. Place one whole table into a small plastic cup. Break a second tablet in half, placing both pieces in a second small plastic cup. Break the third tablet into quarters, placing all pieces in a third small plastic cup. Place the fourth tablet back into the packaging, crush into tiny pieces and place all pieces in last small plastic cup.

3. Using the tablets in the small plastic cups, complete the ***Surface Area : Volume Table***.
   - Draw the tablet.
   - Shade in the additional, new surface area that is exposed by breaking the tablets in half and in quarters.
   - Use the ruler (cm) to measure the dimensions of each piece.
   - Calculate the total surface area (SA) for the whole tablet and broken tablets. Be sure to show all your work and include formulas and units.
   - Calculate volume of tablet.

- Calculate surface area: volume ratio.

4. Using the graduated cylinder pour 40 mL of water into all 4 of the plastic cups.

5. Dry the graduated cylinder. Make sure it is a dry as you can get it.

6. Assign roles within your group
   - Materials Handler – put tablet in the graduated cylinder and later pour the water.
   - Time Keeper - start and stop timer.
   - Observer - watching height of reaction and notify the time keeper when the reaction reaches full height.

7. **Read steps 8-11 before starting!**

8. Place whole tablet into the dry graduated cylinder.

9. Make sure the timer is ready.

10. Start the timer as you pour 40 mL of water into the graduated cylinder.

11. Observe the reaction. Be sure to notify the time keeper when the reaction has reached the maximum height (*Note: Once maximum height is reached, height will stop changing or begin to decrease.*). At the maximum height the timer should be stopped.

12. Record the results in the ***Reaction Height Table***.

13. Empty graduated cylinder into the waste bucket or sink.

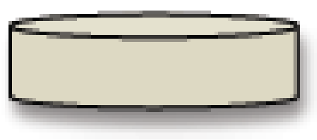
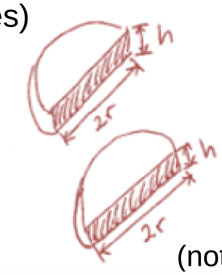
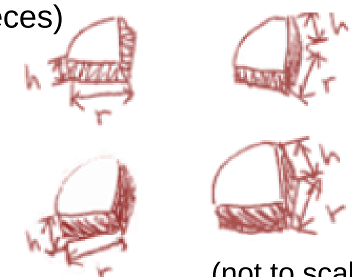
14. Rinse the graduated cylinder with water filled squirt bottle, then dry. Make sure the graduated cylinder is a dry as you can get it.

15. Repeat steps 8-11 for the halves (all contents of small plastic cup), then quarters (all contents of small plastic cup) and finally the crushed pieces (all contents of small plastic cup).

16. Clean-up

17. Complete the Observation Questions and graphs.

Surface Area : Volume Table

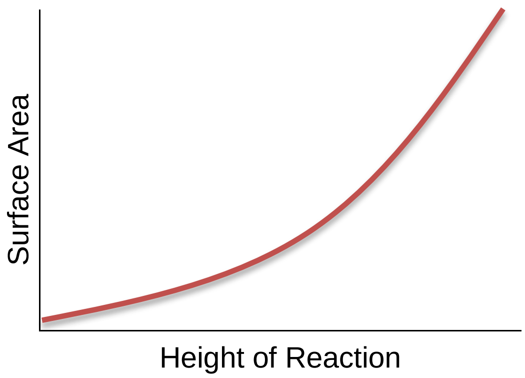
Drawing/Sketch Make sure drawing resemble actual table pieces.	**Surface Area Calculations (SA)** *(Hint: Surface area of a cylinder = area of the top and bottom circles plus area of the rectangular wall)*		**Surface Areas : Volume**
Whole Tablet  (not to scale)	***$SA_{whole\ tablet}$ = surface area of a cylinder = area of the top and bottom circles plus area of the rectangular wall = $2 \times (\pi \times r^2) + (2 \times \pi \times r) \times h$***	Volume $_{(whole\ tablet)}$ =volume of a cylinder = area of the circle times height = $(\pi \times r^2) \times h$	$SA_{whole\ tablet} : V_{tablet} = \frac{SA_{whole\ tablet}}{V_{tablet}}$
Half Tablets (draw both pieces)  (not to scale)	***$SA_{halved\ tablet}$ = surface area of a cylinder plus new surface area created from breaking tablet in half*** ***New surface area = $2 \times (2r \times h) = 4rh$*** ***Total surface area for the halved tablet = $2 \times (\pi \times r^2) + (2 \times \pi \times r) \times h + 4rh$***		$SA_{halved\ tablet} : V_{tablet} = \frac{SA_{halved\ tablet}}{V_{tablet}}$
Quarter Tablets (draw all 4 pieces)  (not to scale)	***$SA_{quartered\ tablet}$ = surface area of a cylinder plus new surface area created from breaking tablet in quarters*** ***New surface area = $4 \times (2r \times h) = 8rh$*** ***Total surface area for the quartered tablet = $2 \times (\pi \times r^2) + (2 \times \pi \times r) \times h + 8rh$***		$SA_{quartered\ tablet} : V_{tablet} = \frac{SA_{quartered\ tablet}}{V_{tablet}}$

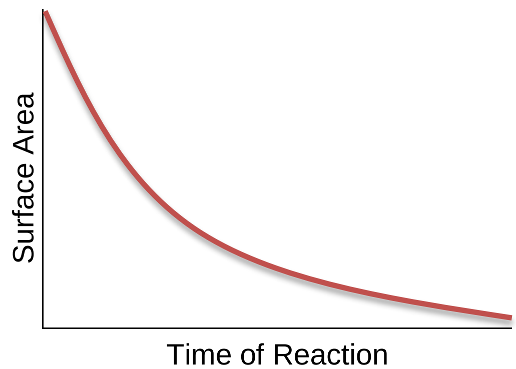
What do you notice about the ratio of surface area to volume?

Reaction Height Table *Data will vary*		
Tablet Size (entire contents of small plastic cup)	**Reaction Height (mL)**	**Time to Reach Maximum Height (seconds)**
Whole Tablet	*65mL*	*40 sec*
Halved Tablets	*70mL*	*28 sec*
Quartered Tablets	*71mL*	*26 sec*
Crushed Pieces of Tablet	*110mL*	*10 sec*

Observation Questions:

1. Which reaction occurred fastest? ***Crushed pieces of tablet***
2. Which reaction went the highest? ***Crushed pieces of tablet***
3. What is the correlation (relationship) between the speed of the reaction and the height of the reaction?
   Students should identify properties of the whole vs. broken tablets that might have caused the different reaction rates. Ideally, a guided discussion will lead to identifying the surface area as a variable and that more surface area results in a faster reaction.
4. Which properties of this experiment were constants and which were variables?
   Constants:
   Examples of constants include the mass of a tablet, size of the reaction vessel, temperature, etc.
   Variables:
   The main variable is surface area, though others include those factors contributing to the differences in collected data. Conclusions should use their data analysis to make an argument for or against their hypothesis.
5. What do you think a graph of surface area vs. height of reaction would look like? What about a graph of surface area vs. time of reaction? (Hint: Think about the curves in words first.)





Conclusions:

Be sure to include an explanation of your observations in terms of surface area and its relevance to nanoscience.

Conclusions should use their data analysis to make an argument for or against their hypothesis. Relevance to nanoscience might be that as things get smaller, surface area is greatly increased resulting in different properties than in bulk. As we learned in this module, things at the nanoscale are very tiny meaning very large surface areas with interesting properties which can be exploited for novel applications.

Summary

In this activity your students will have learned the correlation between color wavelengths and measurement. They will have effectively learned the formula for the volume of a sphere, and used it to solve real-world and mathematical problems.

Disclaimer

Activity Evaluation

The Northeast Advanced Technological Education Center (NEATEC) would like your feedback on this activity. Your feedback allows NEATEC to maintain the quality and relevance of this activity.

To provide feedback, please take the survey using the link
https://www.surveymonkey.com/s/NEATECLMSurvey

Your feedback is greatly appreciated.

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