Teacher's Preparatory Guide

The SI system and nanoscale science

Purpose: To provide opportunities for students to develop a working knowledge of the SI system of measurement as well as learn about the nanoscale and nanotechnology.

Time required: 2 Class Periods.

Level: Middle school

Teacher Background

The International System of Units (SI) was established 1960 as an improved version of the metric system with the final version we currently use established in 1971. The SI system is a modern version of the Metric System. The Metric System was developed in France during the 1790's. The metric system is based on the powers of ten. The metric system is used globally. This system uses a set of prefixes with seven base units. The SI system is accepted globally by all scientists and engineers. The SI system brought consistency to quantitative measurements made by the scientific community. For a concise history of the SI, please visit: http://physics.nist.gov/cuu/Units/history.html.

It is important for students to develop an understanding of the metric system. This unit provides activities for them to learn about the metric system of measurement. A connection to the nanoscale is made by having students read the *How Stuff Works* article –"How Nanotechnology Works" and answer questions about the article. Further connections of size and the nanoscale can be found in the Resources at the end of the unit.

Materials: Construction paper, notebook paper, several balls of different sizes, miniature candy bars and regular size candy bars, large and small stars, various size marbles, blank paper, glue sticks, pens, pencil, crayons, markers, rulers,

Advance Preparation: 10-15 minutes

Safety Information: There are no safety concerns for this unit.

Directions for the Activity: Part I. This activity is designed to introduce the topic of measurement and how it relates to size. Have the students do one or two of the following:

1. Students come in different sizes. Have several (four to six) students go to the white board in the classroom. Have them arrange themselves from shortest to tallest. Have them draw a line representing their height on the board so that they can have an idea of what the other students observed in the classroom. Discuss the relative sizes and how they would be measured and graphed. Would they use the metric scale to do this?

Developed by Lind Duke
*Development and distribution partially funded by the **National Science Foundation***

NNIN Document: NNIN-xxxx
Rev: mm/yy

2. To enhance the students understanding of the concept of size set up a demonstration using a series of objects that range from largest to smallest For example, fruits could be used such as grapes, kiwi, tangerine, orange, grapefruit, melon, etc. Or you could arrange comparisons of large and small items such as candy, chips, toys, balls, wrenches, etc.
    a. Have the students compare the objects in terms of size by arranging them from smallest to largest. What measurement did they use to sort the objects by size? Now ask the students to describe the objects in terms of other measurements such as weight or volume.
    b. Explain to each student that the differences between each item can be measured and through exact measurements. Ask them if they know any terms that could be used to describe the differences in size.
    c. Introduce the students to the SI system of measurement especially that there are seven base units and the prefix system used.

Have students read the *How Stuff Works* article "How Nanotechnology Works" at:
http://science.howstuffworks.com/nanotechnology.htm

Have students complete the worksheet on "How Nanotechnology Works."

Part II.

Give the students the tables below. From the table below have students make a foldable using the vocabulary. Two helpful websites on foldables are:

- http://wrhs.pasco.k12.fl.us/wordpop/WordPOP/Foldables.html
- http://foldables.wikispaces.com/

To make a foldable, fold a sheet of notebook paper, construction paper, or copy paper vertically (lengthwise). On the front of the paper, about 2.5 centimeters down make a title for the foldable Called SI System. Have the students cut the paper every 2.5 cm on the front to make a flap. Do this for each word. Several sheets of paper may have to be used. Next, on the area in back of the flap write the definition or any facts you may know about each word. Make the foldable colorful and add visuals examples for each prefix.

Give students the tables explaining the Key Vocabulary Words

Nano	Micro	Milli	Centi	Deci
Deka	Hecto	Kilo	Mega	Giga
Mole	Candela	Temperature	Length	Meter
Current	SI	Second	Ampere	

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Table I: SI Units There are seven (7) SI base units: meter, kilogram, mole, second, Kelvin, candela, and ampere.

Quantity	Name of Base Unit	Symbol
Mass	Kilogram	Kg
Length	Meter	m
Volume	Cubic Meter*	m^3
Amount of A Substance	Mole	mol
Time	Second	s
Temperature	Kelvin	K**
Luminous Intensity	Candela	cd
Electric Current	Ampere	A
Pressure	Pascal	Pa
Energy	Joule	J

***1 liter=10^3 cubic meters ($m^{3)}$**
1milliliter (ml) =1cubic centimeter (cm^3)

****Kelvin (K) = Celsius (C)+273**
Celsius (C) = (5/9) (^{0}F-32)
Fahrenheit (F) = (5/9 Celsius) + 32

Table II: International System of Units/Metric Prefixes

Prefix	Symbol
Nano-	n
Micro-	u
Milli-	m
Centi-	c
Deci-	d
Deka-	da
Hecto-	h
Kilo-	k
Mega-	M

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Table III: Length

	Exponential Factor	Meaning	Multiples of
Nanometer (nm)	1×10^{-9} meters	Billionth	0.000000001
Micrometer (um)	$1x\ 10^{-6}$	Millionth	0.000001
Millimeter (mm)	$1x\ 10^{-3}$	Thousandth	0.001
Centimeter(cm)	$1x10^{-2}$	Hundredth	0.01
Decimeter(dm)	$1x10^{-1}$	Tenth	0.1
Basic Unit	Meter		
Dekameter (dam)	$1x10^{1}$	Ten	10
Hectometer (hm)	$1x10^{2}$	Hundred	100
Kilometer (km)	$1x10^{3}$	Thousand	1,000
Megameter(Mm)	$1x10^{6}$	Million	1,000,000
Gigameter(Gm)	1×10^{9}	Billion	1,000,000,000

Table IV: Mass

	Exponential Factor	Meaning	Multiples of
Nanogram (ng)	1×10^{-9} grams	Billionth	0.000000001
Micrograms (ug)	$1x\ 10^{-6}$	Millionth	0.000001
Milligrams (mg)	$1x10^{-3}$	Thousandth	0.001
Centigrams(cg)	$1x10^{-2}$	Hundredth	0.01
Decigrams(dg)	$1x10^{-1}$	Tenth	0.1
Basic Unit	Grams		
Dekameter (dag)	$1x10^{1}$	Ten	10
Hectometer (hm)	$1x10^{2}$	Hundred	100
Kilometer (Km)	$1x10^{3}$	Thousand	1,000
Megameter(Mm)	$1x10^{6}$	Million	1,000,000
Gigameter(Gm)	1×10^{9}	Billion	1,000,000,000

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Table V: Volume

	Exponential Factor	Meaning	Multiples of
Nanoliter (nl)	1×10^{-9}	Billionth	0.000000001
Microliter (ul)	$1x\ 10^{-6}$	Millionth	0.000001
Milliliter (ml)	$1x10^{-3}$	Thousandth	0.001
Centiliter(cl)	$1x10^{-2}$	Hundredth	0.01
Deciliter(dl)	$1x10^{-1}$	Tenth	0.1
Liter is a unit of volume.			
Dekaliter (dal)	$1x10^{1}$	Ten	10
Hectoliter (hl)	$1x10^{2}$	Hundred	100
Kiloliter (Kl)	$1x10^{3}$	Thousand	1,000
Megaliter(Ml)	$1x10^{6}$	Million	1,000,000
Gigaliter(Gl)	1×10^{9}	Billion	1,000,000,000

Vocabulary Flash Cards

Have the students use the vocabulary cards below to further develop their understanding of the terms. The cards below maybe printed and used to aid the student in mastery of the SI prefix. These cards are to be used as a graphic organizer for the SI

Nano	**Billionth**

Micro	**Millionth**

Milli	**Thousandth**

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Centi	**Hundredth**
Deci	**Tenth**
Deka	**Ten**
Hecto	**Hundred**
Kilo	**Thousand**
Mega	**Million**

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Giga	**Billion**

SI	**International System of Units**

Mole	**Amount of substance**

Candela	**Luminous intensity**

Mass	**Kilogram**

Length	**Meter**

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Volume	**Cubic Meter**

Liter	**Unit of volume**

Kelvin	**Unit of temperature**

1 cubic centimeter (cm^3)	**1 milliliter (mL)**

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Part III. Have students read the *How Stuff Works* article –"How Nanotechnology Works" and complete the worksheet

Student Worksheet

"How Nanotechnology Works"

1. **What's the smallest thing you can imagine?** Students may say a grain of sand, dust particle, atom, electron

2. **How small is an atom?** 0.1nm

3. **Define by measurement:**
   a. **Nanoscale** 1-100nm
   b. **Microscale** >100nm
   c. **Atomic Scale** <1nm

4. **Can you use a light microscope to see nanoscale objects?** No
   a. **If no, what would you use to observe the nanoscale?** Scanning Tunneling Microscope and Atomic Force Microscope

5. **What is a carbon nanotube?** a nano-sized cylinder of carbon atoms
   a. **What are some of its properties?** 100 times stronger than steel, six times lighter than steel, semiconductor

6. **List some areas where nanotechnology is being used or may be used in the future:** consumer products – tennis rackets, sunscreens, clothing, electronics, molecular manufacturing, medicine

Extension:

Using the Internet research additional applications of nanotechnology and nanoscience.

7. List (5) additional applications of nanoproducts and explain what is nano about these.

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

NNIN Document: NNIN-xxxx
Rev: mm/yy

SI Prefixes Worksheet (with answers)

Complete the blank with the correct prefix or unit.

1. The SI base unit for amount of a substance is a (an)_____mole_____
2. The SI base unit for luminous intensity is a (an) _____candela_____.
3. The SI base unit for length is a (an)_____meter_____.
4. The SI base unit for time is a (an) _____second_____.
5. The SI base unit for electric current is a (an) _____ampere_____.
6. The SI unit for mass is a (an)_____kilogram_____.
7. The SI unit for energy a (an)_____Joule_____.
8. The SI unit for volume is a (an) _____cubic meter_____.
9. The SI unit for temperature is a (an)_____Kelvin_____.
10. The SI unit for pressure a(an)_____pascal_____.
11. One cubic centimeter is equal to _____milliliter (mL)_____.
12. One cubic meter is equal to _____Kiloliter_____.
13. List the seven (7) SI base unit. _____meter, kilogram, second, ampere,_____

    _____Kelvin, mole, candela_____

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

Metric Prefix Worksheet (with answers)

Fill in the blank

1 Megameter =____10^{6}_____meters	2) 1 Hectometer = ____10^{2}____meters
3) 1 Nanometer = ___10^{-9}____meters	4) 1 Kilometer = ____10^{3}_____meters
5) 1 Decimeter = ___10^{-1}____meters	6) 1 Dekameter = _____10^{1}____meters
7) 1 Centimeter = __10^{-2}_____meters	8) 1 Micrometer = _____10^{-6}_____meters
9) 1 Gigameter = __10^{9}____meters	10) 1 Millimeter = ____10^{-3}____meters

Fill in the blank using a metric prefix.

11) 1000g = ____10^{3}____ grams	12) 1,000,000meters =__10^{6}___meter
13) 0.000000001 g =__10^{-9}_gram	14) 0.1g = _____10^{-1}_____ gram
15) 0.01 grams = __10^{-2}____gram	16) 0.000001g = _____10^{-6}_____gram
17) 100 grams = ___10^{2}___gram	18) 10 grams = _____10^{1}_____gram
19) 1,000,000,000=___10^{9}___gram	20) 0.001 gram= ____10^{-3}_____gram
21) 1 Kiloliter = ____10^{3}_____liters	22) 1 nanoliter = ___10^{-9}_____liters
23) 1 millisecond =__10^{-3}_____seconds	24) 1 miliamps= ___10^{-3}_____amps

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***

NNIN Document: NNIN-xxxx
Rev: mm/yy

Resources: To learn more about units of measurement, scale and nanotechnology, here are some web sites with educational resources

- *The Si System* – http://physics.nist.gov/cuu/Units/indez.html
- *Powers of Ten* explores the relative size of things from the microscopic to cosmic – http://powersof10.com
- Teaching resources on the metric system can be found at the U.S. Metric Association – http://lamar.colostate.edu/~hillger/
- *Scale of Objects* by NanoSense offers a series of units designed for high school students – http://www.nanosense.org
- *How Small is Nanotechnology?* offers activities to explore the size of the nanoscale including the Nanometer Ruler - http://nanozone.org/How.htm
- *How Big is a?* is an interactive size comparison found at – http://www.cellsalive.com/howbig.htm
- *The Scale of Things* poster from the Office of Basic Energy Science is available at - http://www.er.doe.gov/bes/scale_of_things.html
- National Nanotechnology Initiative teacher resources – http://www.nano.gov/html/edu/home_edu.html
- National Nanotechnology Infrastructure Network education portal – http://www.nnin.org/nnin_edu.html.
- NNIN Nanotechnology poster is a simple poster about nanotechnology with a graphic on relative size of objects – http://www.mirc.gatech.edu/education.php/teacherresources.php
- Zoom and Re-Zoom by Istvan Banya are interesting picture bookds related to size and scale, Although designed for younger children, even adults enjoy the books.

National Science Education Standards

- Content Standard A
  - Understandings about scientific inquiry
- Content Standard E
  - Understanding about science and technology

Principles and Standards for School Mathematics

- Numbers and Operations
  - Understand numbers, ways of representing numbers, relationships among numbers, and number system

Developed by Linda Duke
*Development and distribution partially funded by the **National Science Foundation***