STUDENTS' GUIDELINES

NANOSCALE AND NANOTECHNOLOGY

READING BEFORE EXPERIMENT

Nanoscale

The prefix "nano" comes from a Greek word, which means "dwarf". In the International System of Units, the prefix "nano" means one-billionth, or 10^{-9}. If we have a nano "something" we have one billionth of that something including meters (length), seconds (time), litres (volume) and grams (mass) to represent what is understandably a very small quantity.

Activity – 1:

Watch the video "http://www.powersof10.com/film" in order to understand the measurement scale better.

Prefix	Measurement	Scientific Notation
Kilo-	1000 m	1×10^{3} m
Hecta-	100 m	1×10^{2} m
Deka-	10 m	1×10^{1} m
BASE	1 m	1×10^{0} m
Deci-	0.1m	1×10^{-1}m
Centi-	0.01 m	1×10^{-2} m
Milli-	0.001m	1×10^{-3} m
Micro-	0.000001 m	1×10^{-6} m
Nano-	0.000000001 m	1×10^{-9} m
Pico-	0.000000000001 m	1×10^{-12} m
Femto-	0.000000000000001 m	1×10^{-15} m

Table-1 SI Units of Measurements (1)

Activity – 2:

Measure various objects around the room and convert them to nano.

- ✓ The length and width of your table (or the radius, if your table is round)
- ✓ The length of your science book
- ✓ The length of your pencil
- ✓ The length of your rubber
- ✓ The length of your tooth brush
- ✓ The length of your single hair
- ✓ The diameter of a lentil
- ✓ The diameter of a button on your shirt

Some examples of nanoscale are;

- A sheet of paper is about 100000 nanometres thick.
- A human hair measures roughly 50000 to 100000 nanometres across.
- Your fingernails grow one nanometre every second.
- A single blink of an eye is about one-billionth of a year (a nano year).
- A single water molecule is about 1/4th of a nanometre across.
- 10 hydrogen atoms lined up next to one another spans 1 nanometre.
- A cell membrane is about 9 nanometres thick.
- A virus is approximately 70 nanometres wide.
- A strand of human DNA is 2,5 nanometers in diameter
- A single gold atom is about a third of a nanometer in diameter.

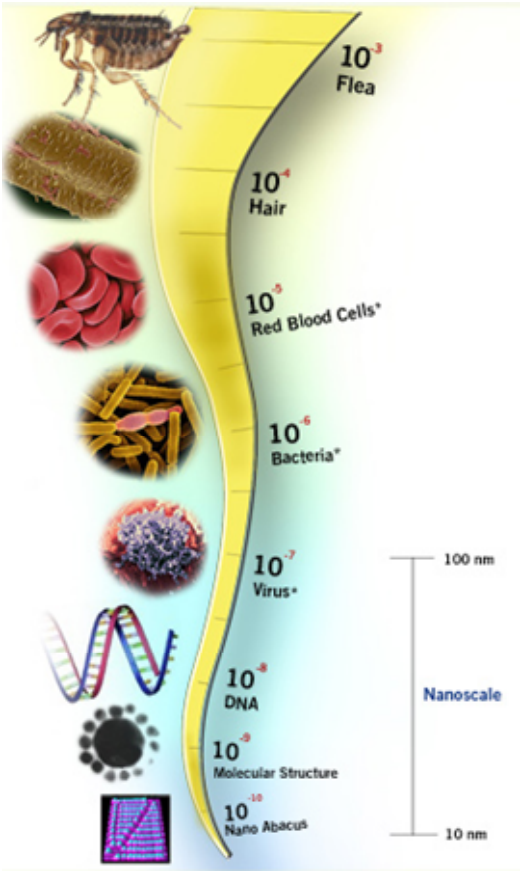


Figure 1: Scale of objects in metres. (2)

Activity – 3:

Examine the simulations in the links given below and discuss with your friends.

"http://htwins.net/scale/" and "http://htwins.net/scale2/"

In each link you can examine the properties and the dimensions of objects by clicking on the objects.

Nanotechnology

Atoms are the building blocks of matter. An atom has approximately a diameter of 1/10 nm (10^{-10} m). This means that; in order to form 1 nanometre length, about ten atoms should be placed side by side.

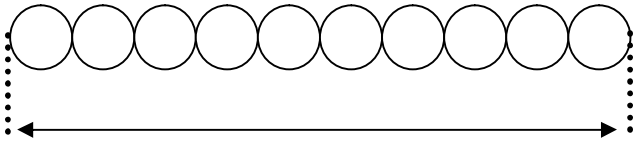


Figure 2: The total length of 10 atoms is ~1 nm.

Molecules are formed as atoms come together and make chemical bonds. For instance, two hydrogen atoms and one oxygen atom bond to form water (H_2O) molecule. A single water molecule is about $\frac{1}{4}$nm across.

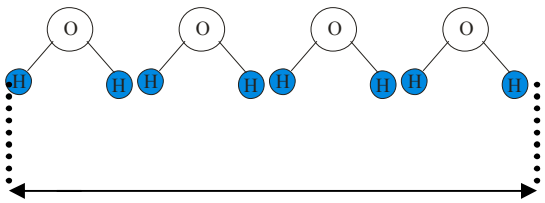


Figure 3: The total length of 4 water molecules is ~1 nm.

A water molecule is formed by the following chemical reaction.

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$$

As seen in the chemical reaction above, one volume of H_2 gas reacts with $1/2$ volume of O_2 gas and form one volume of H_2O. The size of the water molecule formed after reaction is in the nanoscale. Do you think the formation of water a nanotechnological application?

When the water molecule spontaneously formed at nanoscale, this phenomenon cannot be considered as nanotechnological application. But, when a new structure is formed by situating certain water molecules in defined positions, only then we can say nanotechnology is used to form this structure. For example, establishing the symbol of IBM at nanoscale by arranging Xenon atoms one by one on Nickel surface by using STM (Scanning Tunnelling Microscopes) is a nanotechnological application using bottom-up approach.

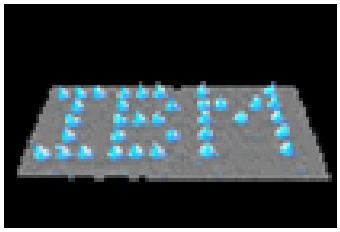


Figure 4: The symbol of IBM at nanoscale with the arrangement of Xenon atoms one by one on Nickel surface.(3)

In general, nanotechnology can be defined as the technology that deals with particles sized between 1-100 nm. Nanoparticles are considered a bridge between bulk materials and atomic or molecular structures.

A bulk material has constant chemical properties regardless of its size. As the size of the material changes, together with the increase in surface area, the physical properties change but chemical properties remain the same.

Think of a sugar cube with a certain volume. When the sugar cube is crushed, granulated sugar is formed. The surface area increases and the physical properties are changed. If granulated sugar is pulverized, powdered sugar is formed and physical properties changes again as the surface area increases. Here although the physical properties changed, the chemical properties did not change. (Figure 5)

One of the important characteristics of nanoparticles is their large surface area/ volume ratio (compared to bulk materials). As the particle size decreases, the physical and chemical properties change. When the particle size decreases to nano, the material may gain new physical and chemical properties (figure 6). The increase in surface area also leads to an increase in reactivity.

For example; when iron (Fe) powder is oxidised with the O_2 gas in the air, this oxidation reaction is an example for slow combustion (flameless). As the particle size of Fe powder is decreased to nanoscale, iron nanopowder gives the reaction of fast combustion (with flame) with O_2 gas in the air.

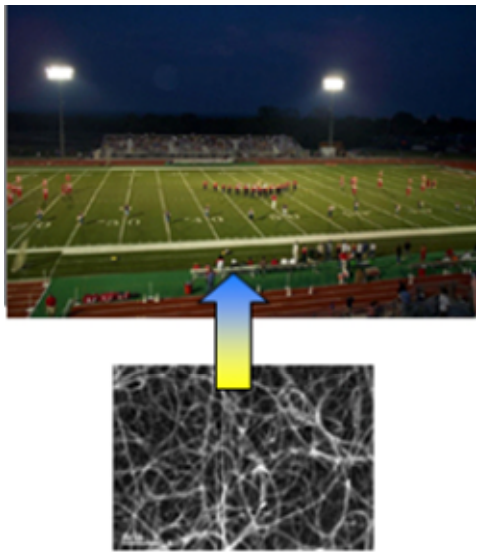


Figure 5: About 4 grams of single walled carbon nanotubes have the same surface area as a football field. [4]

Large surface area makes some nanoparticles highly soluble in liquids. This property is encountered in applications, such as paints, pigments, medicine pills, and cosmetics. Particle size can also affect the colour of the material.

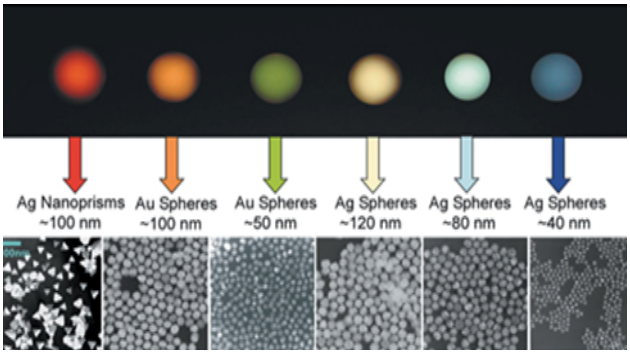
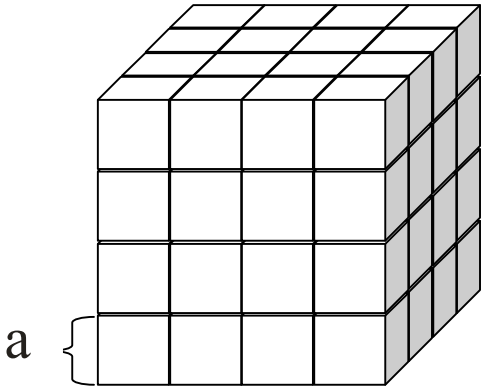


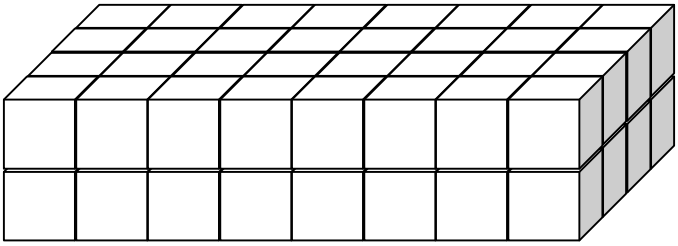
Figure 6: Silver and Gold particles have different colours depending on size and shape.[5]

Activity – 4:

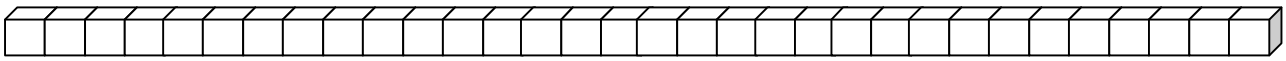
- ✓ By using sugar cubes make a cubic prism with dimensions of 10 cm x 10 cm x 10 cm. Calculate the surface area and the volume of the cube.



- ✓ Place the top two layers of the sugar cubes next to the layers at the bottom. Calculate the surface area and the volume. Compare the results with the first cube you have built.



- ✓ Place each cube side by side and calculate the surface area and the volume. Compare the results with the first large cube.



- ✓ Each time compare the surface area and the volume.

EVALUATION

A. Write (T) True or (F) False for the statements below. (5minutes)

1. 1 centimetre is 10^{-7} nanometres. ( )
2. Surface area affects both physical and chemical properties. ( )
3. Nanotechnology is the technology that deals with particles sized between 1-1000 nm. ( )

B. Fill in the blanks with an appropriate expression.(10minutes)

1. A single blink of an eye is about …….. of a year.
2. A virus is approximately …….. wide.
3. As the particle size …….. to nanoscale , the physical and chemical properties of a material changes.
4. A single strand of human DNA is ……...in diameter.
5. ……hydrogen atoms lined up next to one another spans 1 nanometre.
6. …… is the first scientist to mention nanotechnology.
7. Please convert the following measurment units into nano:
   a) 1 kg =……..ng
   b) 15 cm =……..nm
   c) 250 ml =……nlt
   d) 250 m =…….nm
   e) 40 mg =……ng

REFERENCES

(1) http://mrsec.wisc.edu/Edetc/nanoscale/index.html
(2) http://www.discovernano.northwestern.edu/whatis/index_html/howsmall_html
(3) http://www.almaden.ibm.com/vis/stm/atomo.html
(4) Image Credit: NASA Ames Centre for Nanotechnology
(5) North-western University