Introduction to Nanotechnology Course

Module 1: History and Definition of Nanotechnology

Instructor Guide

Module 1 introduces students to nanotechnology at a high level and serves as the foundation for the following modules. It discusses briefly the history of the recent development of nanotechnology, briefly reviews the new tools that have been created which allow us to observe objects at the nanoscale, explains why it is important and exciting and, finally, defines how nanotechnology is a multi-disciplinary subject.

For this module, students should be familiar with:

- exponential notation
- foundational concept of atoms into molecules

Student outcomes:

- Recognize small scale units such as the micrometer and the nanometer
- List some of the tools of nanotechnology
- Recognize the contributions of Feynman, Taniguchi, Smalley, Roring and Bennig
- Be able to provide their own definition of “nanotechnology”

Nanotechnology is the ability to observe study, understand, measure and create at the molecular or atomic level. It has come about as a result of the development of new types of “microscopes,” which have been developed over the last 20 years. These new “scopes” allow us now to create images of molecules, viruses, cell structures, DNA and individual atoms. By observing and sometimes making measurements at this very small scale, we can better understand how biological and material systems interact, operate and obtain the properties that we observe in our everyday world.

The word “nano” is a prefix that means “one billionth” – from the Greek word. It is used just as “mega,” “giga,” “centi,” “milli” and other prefixes are used. Students are most likely familiar with some of these prefixes.

Nano, or one-billionth, can refer to many different units (time, mass, volume, length, etc.). You can have a nanogallon (one billionth of a gallon), a nanosecond, a nanoliter and so on.

Most often in the field of nanotechnology, the length scale is used. We talk about the dimensions of objects in terms of nanometers (one-billionth of a meter).

NOTE: About nanoscience and nanotechnology. Most often in scientific and engineering areas, the word “science” is used to define the experimentation, research and discovery phase or

activities. “Technology” is moving into the engineering phase—the application of the research ideas and discoveries to products, processes and the business world. Purists will often distinguish between nanoscience and nanotechnology, and the vocabulary used represents that distinction. In general, for an introductory course, it is not necessary to make this distinction – which can sometimes cause more confusion among students than clarification.

High school students already know the “secret “to understanding nanotechnology. This knowledge is the basic tenet of material science. That matter is made up of molecules, and molecules are made up of atoms. Atoms are made up of electrons, protons and neutrons. Electrons and protons are changed particles. Opposites attract and likes repel.

The properties that we observe at the larger scale are, in the end, the result of the fact that opposites attract and likes repel. The strength of different materials, the water repellency of a lotus leaf, the replication of cells, the water droplet on a windshield and the operation of an IPOD are all based on these interactions. What is new over the last few decades is our ability to observe the world at this scale—the nanoscale.

This ability has increased our understanding of biological and material systems and, in some cases, allowed up to replicate what is happening at the molecular scale. (This is an example of the transition from “science” (observing and understanding) to “technology/engineering” (applying that understanding to products).

Understanding of the properties and interactions that occur at the nanoscale are not just a matter of shrinking down what we can observe or create at the “macro” or human level—as we get down to the molecular and atomic scale—different forces and interactions will take a higher priority than they do at the larger (macro) scale.

Because understanding the nano scale is not just “shrinking,” researchers and teachers have developed a series of concepts that need to be understood in order to understand and appreciate what is occurring and observed at the nanoscale. These concepts have come to be referred to as the “Big Ideas” of nanotechnology.

In general, these “big Ideas” are:

- Sense of Scale
- Surface Area to Volume Ratio
- Pressure, force and density
- Surface tension
- Priorities of Forces and Interactions
- Atomic and material structures and material properties
- Tools of nanoscience
- Computer simulation
- Self-assembly

NOTE: The concepts have evolved over the last seven years or so and there have been multiple groups of people involved in the discussions. The list above represents a consolidation of the results from the various groups. There is a certain amount of debate that continues regarding specific areas and the level of detail associated with each area—as well as what age group of students the topics are best suited for. If you do a search on “Big Ideas of Nanotechnology” you will find several white papers that have been written as a result of many of these workshops or meetings.

This particular course will focus on the first six “big ideas” listed above. For each of these ideas, the depth and breadth of the material covered, as well as the activities and assignments, can be adjusted to fit the capabilities of the students.

Finally, it is important to acknowledge that nanotechnology is not a “new” science or discipline. Understanding nanotechnology requires understanding and concepts from all of the traditional basic sciences. AND nanotechnology is being used to enhance the understanding and promote research in all of those areas. Although nanotechnology draws on all aspects of the traditional sciences and math, there are certain aspects of each that have a greater contribution to understanding the world at the nanoscale. These concepts will be integrated into the following modules.