Big Idea: Quantum Effects [1]

(1)- The Big Ideas of Nanoscale Science & Engineering: A Guidebook for Secondary Teachers. S.Y. Stevens, L.M. Sutherland, & J.S. Krajcik, NSTA Press, 2009.

Different models explain and predict the behavior of matter better, depending on the scale and conditions of the system. In particular, as the size or mass of an object becomes smaller and transitions through the nanoscale, quantum effects become more important.[1]

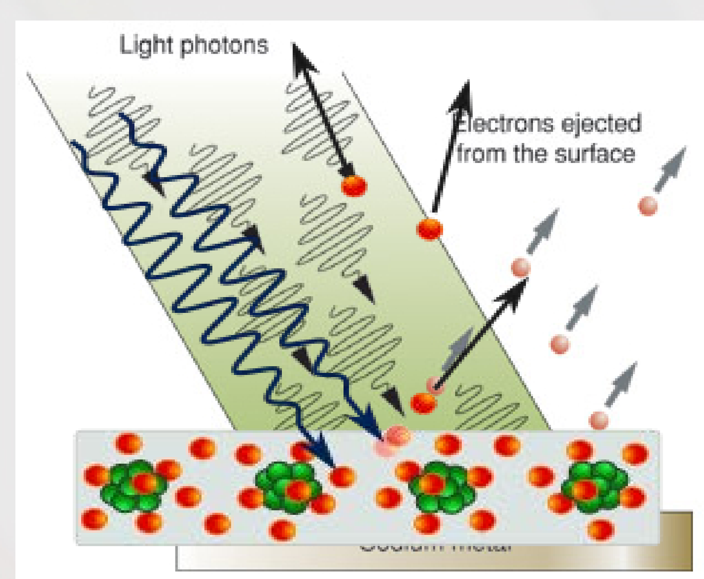
Learning Goals [1]

1. All matter behaves with both particle-like and wave-like character. As a material gets smaller and transitions through the nanoscale, the importance of the wave-like character increases, and quantum mechanics is needed to predict and explain its behavior.

2. Only discrete amounts of energy can enter or exit atomic and subatomic systems. This is also true for many nanoscale systems.

3. It is impossible to know exactly what did or will happen to matter on the nano-, atomic, and sub-atomic scales.

4. The quantum mechanical behavior of electrons helps to explain the arrangement of the elements in the Periodic Table. [1]



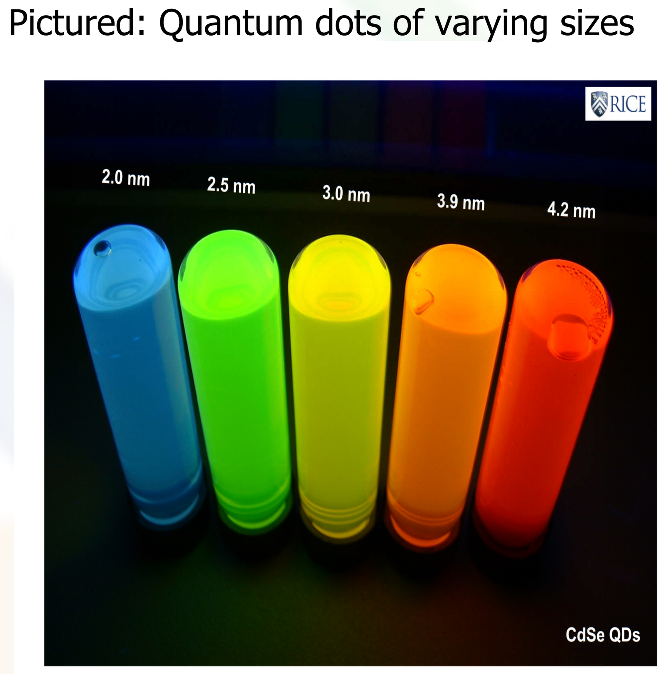
Pictured: Photoelectric effect

Wikipedia: wikipedia.org/wiki/Photoelectric_effect

Examples

As the size or mass of an object becomes smaller and transitions into the nanoscale, quantum mechanics becomes necessary to explain its behavior. The photoelectric effect is a phenomenon where ejection of electrons from the surface of a metal is dependent on the frequency of the incident light rather than on its intensity and illustrates the quantization phenomenon. The transition of conductors to semiconductors at the nanoscale is related to the quantization of energy levels.

Pictured: Quantum dots of varying sizes



Imaged: Wikipedia; M.S. Wong Rice University CC BY-SA3.0 commons.wikimedia.org/wiki/File:CdSe_Quantum_Dots.jpg

Cutting-Edge Application

Quantum dots, which are also known as nanocrystals, are nano-sized semiconductors that, depending on their size, can emit light in all colors of the spectrum. These nanostructures confine conduction band electronics, valence band holes, or excitons in all three spatial directions. Researchers are using quantum dots to visulaize proteins present on the surface of blood vessels when plaque is forming and to image cancer cells in tissues.

Questions to Ponder

What does wave/particle duality mean?

What are the implications of matter exhibiting both wave-like and particle-like behavior?

If all objects exhibit wave-like behavior, why don't we observe it in larger (macro) objects?

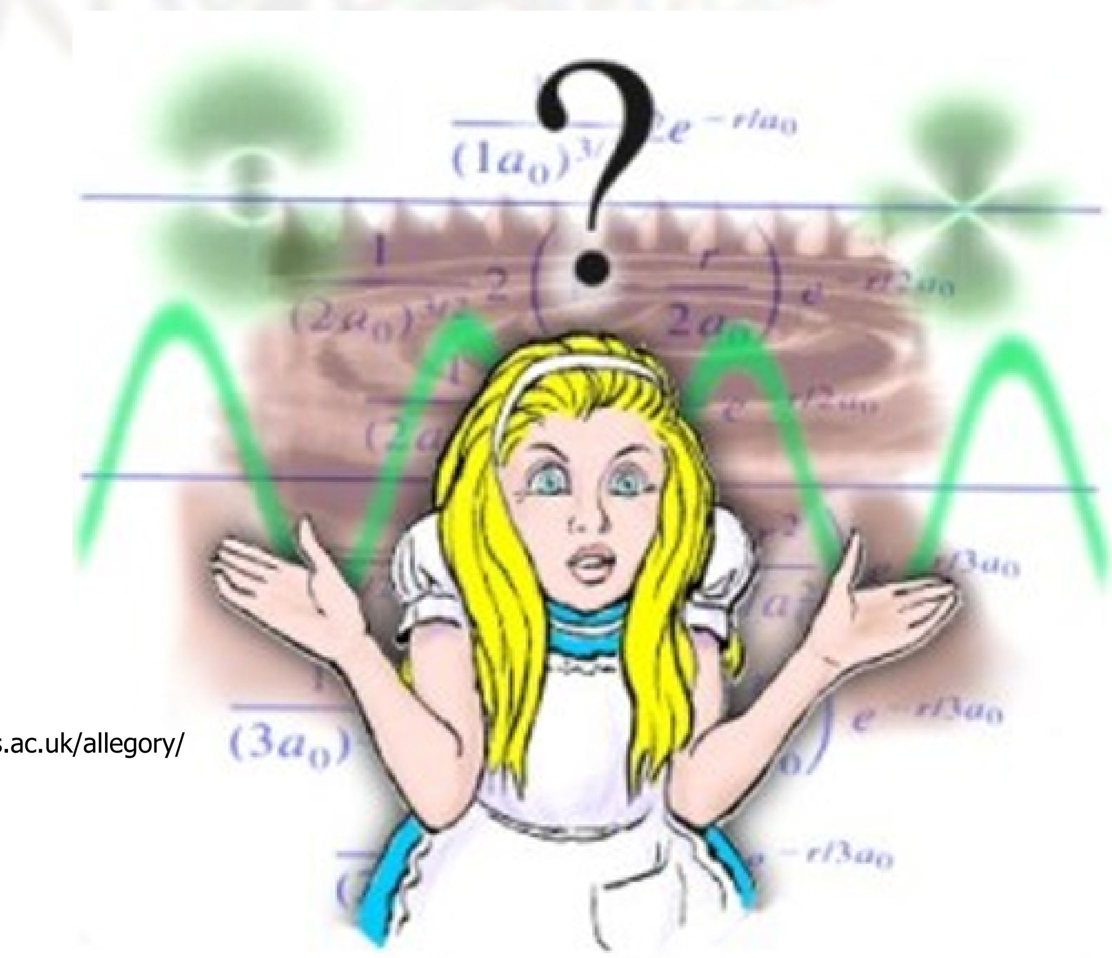
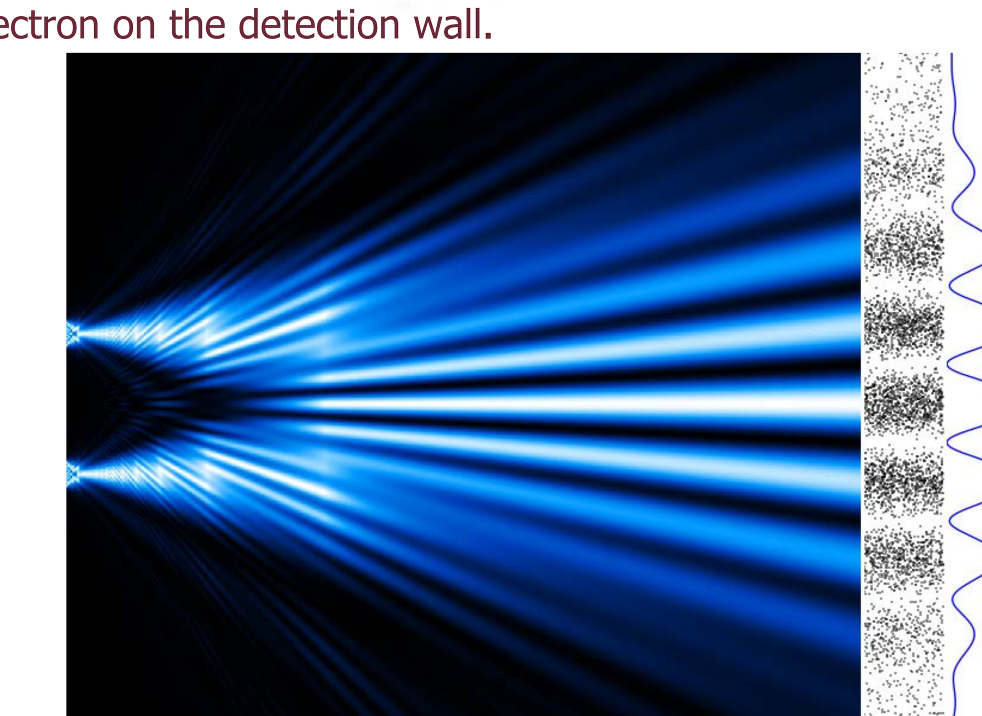


Image: www.physbris.ac.uk/allegory/quantum_fuzzy.jpg

Double-slit experiment with electrons. Each dot corresponds to the impact of one electron on the detection wall.



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NSF DRL 0822128