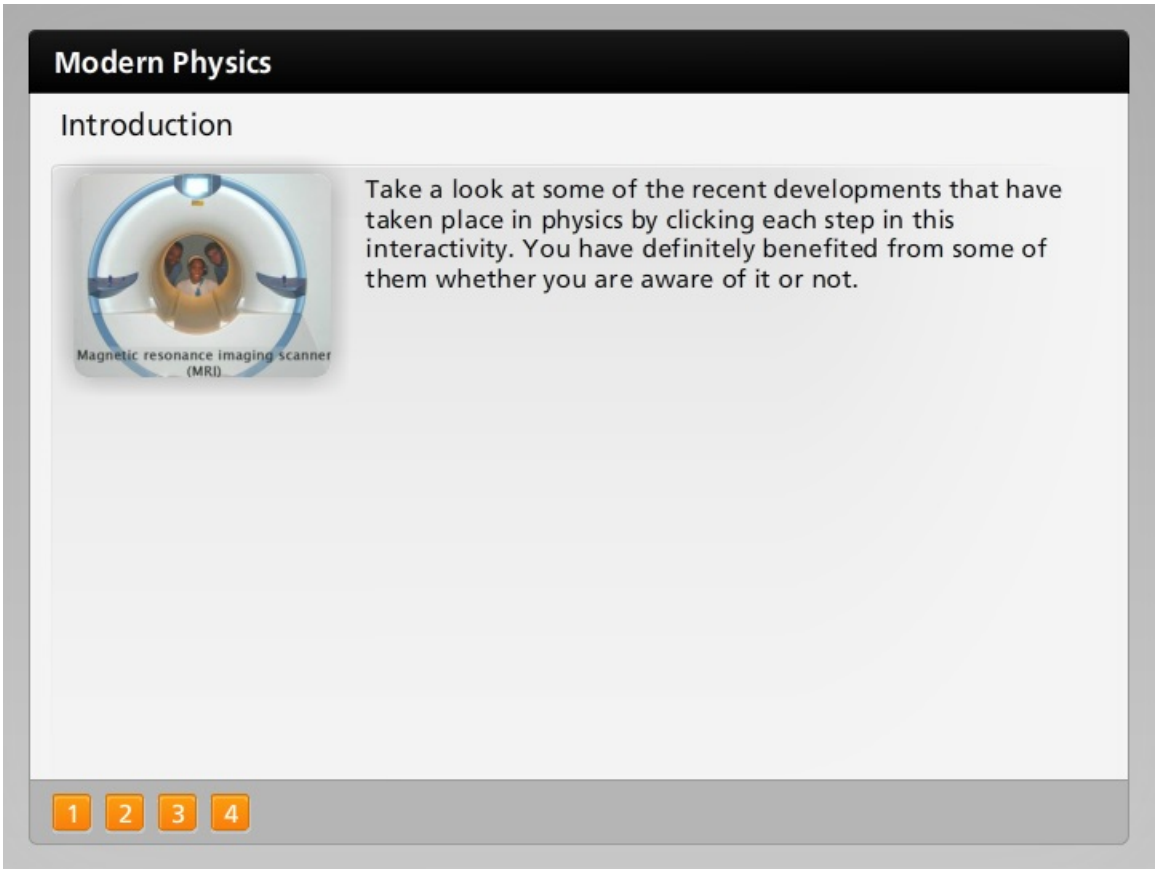
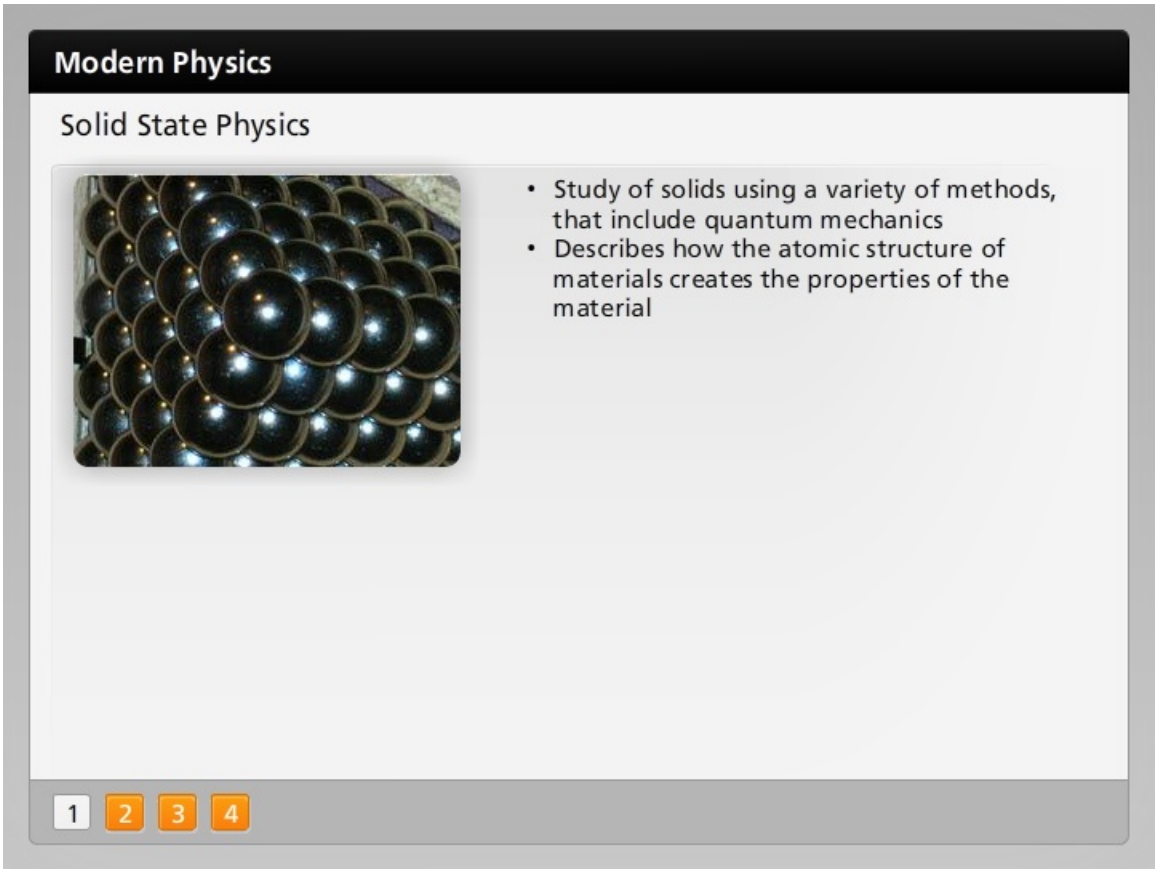
Module 8: 20th Century Physics
Topic 5 Content: Modern Physics

Introduction



Take a look at some of the recent developments that have taken place in physics by clicking each step in this interactivity. You have definitely benefited from some of them whether you are aware of it or not.

Solid State Physics

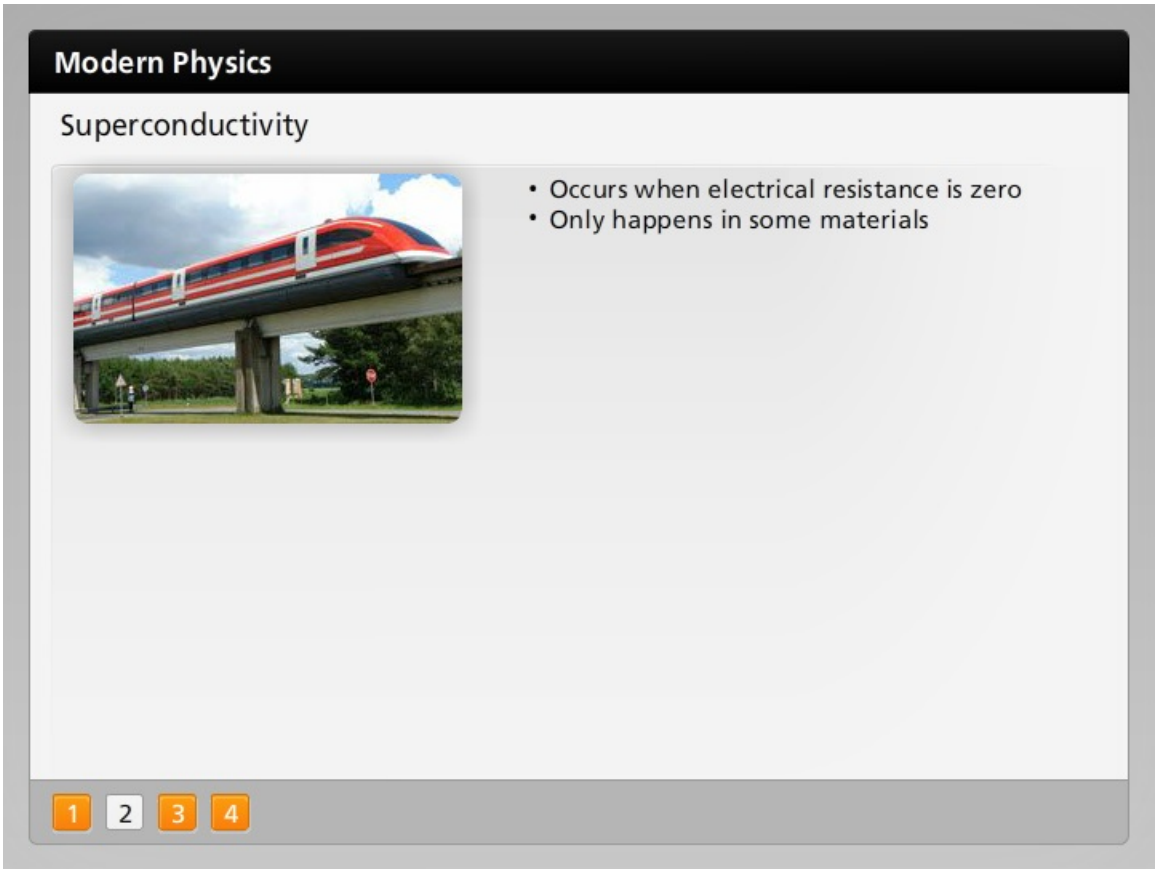


- Study of solids using a variety of methods, that include quantum mechanics
- Describes how the atomic structure of materials creates the properties of the material

Solid state physics is the study of solids using a variety of methods, that include quantum mechanics. This field of physics describes how the atomic structure of materials creates the properties of the material. Most of solid state physics is about crystals. Crystals have electrical, magnetic, optical, or mechanical properties that can be useful in engineering.

One useful property is the ability to conduct electricity. The crystal structure of metals reduces the resistance to electron flow. This is one reason why metals are good conductors.

Superconductivity



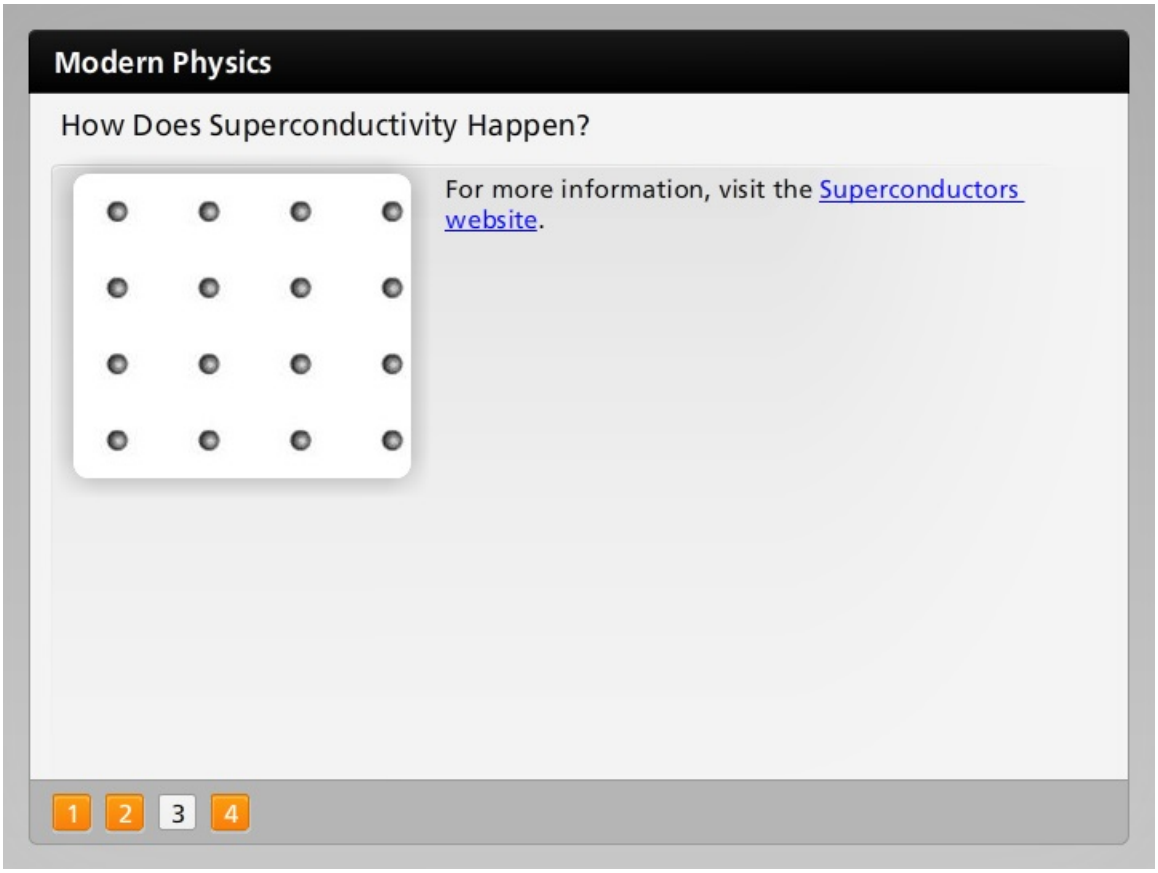
- Occurs when electrical resistance is zero
- Only happens in some materials

Superconductivity occurs when electrical resistance is zero. This only happens in some materials.

Superconductivity was discovered in 1911 by Heike Kamerlingh Onnes. He received the Nobel Prize in 1913 for his work.

Superconducting magnets are used to make some of the most powerful electromagnets in the world. They are used in magnetic resonance imaging (MRI), nuclear magnetic resonance (NMR) machines and in particle accelerators. Many applications of the future will use superconductivity such as electric power smart grids, electric motors for maglev trains and magnetic refrigeration.

How Does Superconductivity Happen?



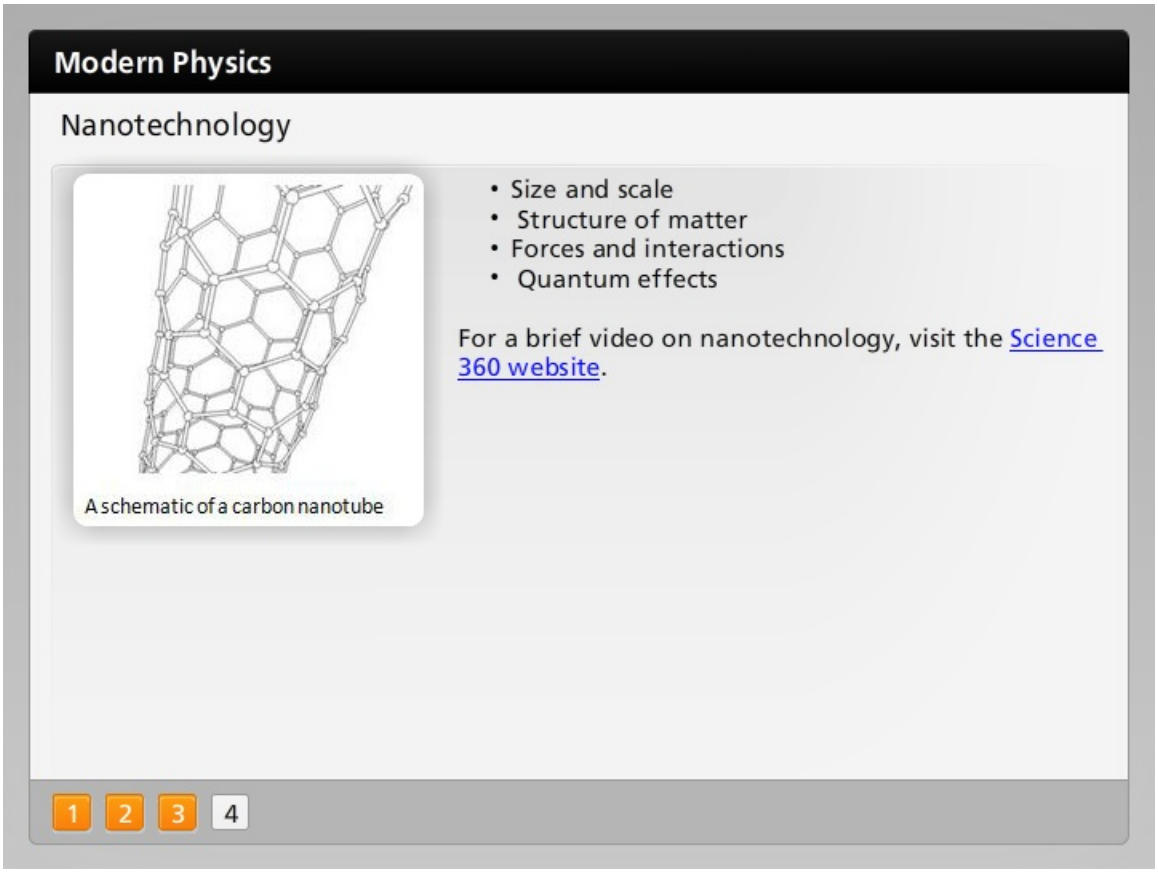
For more information, visit the Superconductors website.

How does superconductivity happen? When atoms form a solid material, a lattice structure is created. All of the atoms are linked together. Electricity can move through a lattice by using the electrons of the atoms. However, we know that when atoms have temperature, they are vibrating. This makes it harder for the electrons to get through the lattice. The atoms keep colliding with the electrons, causing resistance.

In superconductivity, the electrons pair up to travel through the lattice. At very low temperatures, something special happens that allows the electrons to move easily through the lattice with no resistance. The first electron affects the distribution of charge in the lattice so the second electron is attracted. The process continues as the electrons move through the lattice. The minimum temperature that this occurs at is called the critical temperature.

Superconductivity can only be explained using quantum mechanics, not by classical physics.

Nanotechnology



- Size and scale
- Structure of matter
- Forces and interactions
- Quantum effects

For a brief video on nanotechnology, visit the Science 360 website.

Nanotechnology is the study of manipulating matter on the atomic and molecular scale. Nanotechnology deals with structures that are between 1 and 100 nanometers in size. To get an idea of size, comparing a nanometer to a meter is like comparing the size of a marble to size of the Earth. At sizes this small, quantum mechanical effects are significant. Four big ideas represent the concepts behind nanotechnology: size and scale, structure of matter, forces and interactions, and quantum effects.

Doubling the size of an object affects surface area and volume in different proportions. For example, doubling the length of the sides of a cube increases the volume to eight times as big, but the surface is only four times as big. Some properties of materials depend on volume. Properties that depend on volume would be mass or heat capacity. Some properties depend on surface area such as cooling or porosity. Like when you cut up a hot potato and it cools faster. Small changes in size can create large changes in area and even bigger changes in volume.

The smallness of nanoscale objects means that the motion of molecules has a great effect on them, which is very different from normal sized objects. Gravity is overpowered by electrical forces at the nanoscale. As matter is reduced in size to the atomic scale, classical physics can no longer describe its behavior. Quantum mechanics must be used. Changes in the properties of nanoscale materials are explained by quantum mechanical principles.

You may have used the products of nanotechnology and not even known it. The cosmetic industry uses nanotechnology to improve sunscreens. By reducing the size of the zinc oxide particles, the white stuff in your sunscreen, the sunscreen appears colorless. You may have heard about carbon nanotubes, which are among the strongest and stiffest materials known, with a strength many times greater than steel. Carbon nanotubes are used to make very strong, but very light products.