Full STEM Ahead Long Island: Mechanical Engineering

Video: Mechanical Engineering - https://www.youtube.com/watch?v=3xLAntIsFBQ&feature=youtu.be

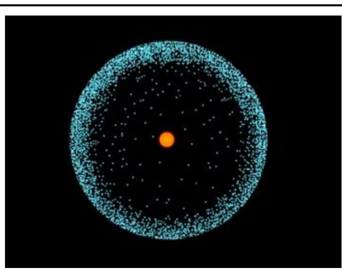
Background

Engineering and the development of new technologies are closely tied to science. Engineering involves applying scientific and mathematical knowledge to design and operate objects, systems and processes to help us solve problems or reach goals.

The history of modern technological development can be viewed as a series of investigations, with ever increasing resolution, into the microscopic structure of matter. Since the days of the early Greek philosophers, science has been on a continual quest to find the most fundamental particles forming the substance of the universe.

Engineers at Brookhaven National Laboratory designed and built the Relativistic Heavy Ion Collider (RHIC) to learn more about these particles. This facility led to the discovery of many beautiful and exotic properties of the subatomic world. Knowledge of these and many other properties discovered in the last century in the process of studying matter at ever smaller scales lets us use matter and energy in ways too fantastic to imagine just 50 years ago.

Atoms are those fundamental building blocks of matter that you've heard about since you were in the second grade. You've seen drawings of atoms with electrons in an orbital around the nucleus, made of protons and neutrons. How did people decide what those drawings should look like? Part of the answer has to do with experiments, like Rutherford's alpha scattering experiment, which showed the atom is mostly empty space with a dense nucleus. This led to the nuclear model we are familiar with today.



https://www.scienceabc.com/wp-content/uploads/2017/10/Hydrogen-atom.jpg

By firing high speed electrons or other elementary particles at atoms, scientists can learn more about them. By observing how the electron interacts or gets deflected when it hits an atom, scientists can learn about the location, size and shape of particles inside the atom. A simple analogy of this process is similar to rolling marbles at an unseen object and observing what happens when it's deflected.

Today's scientists enlist the expertise of engineers to build machines capable of moving elementary particles, or even atomic nuclei, to nearly the speed of light. These machines are called particle accelerators. Engineers must understand the combined effects of electric and magnetic fields in order to design particle accelerators.

Careers: Engineering (mechanical, electrical, materials, systems, computational), physics (experimental, theoretical), computational science (data collection, analysis, programming), technicians

Vocabulary: accelerator, atom, nucleus, proton, neutron, quark, gluon, indirect observation, direct observation

Learning Objective: Determine the shape of a mystery object using indirect observations.

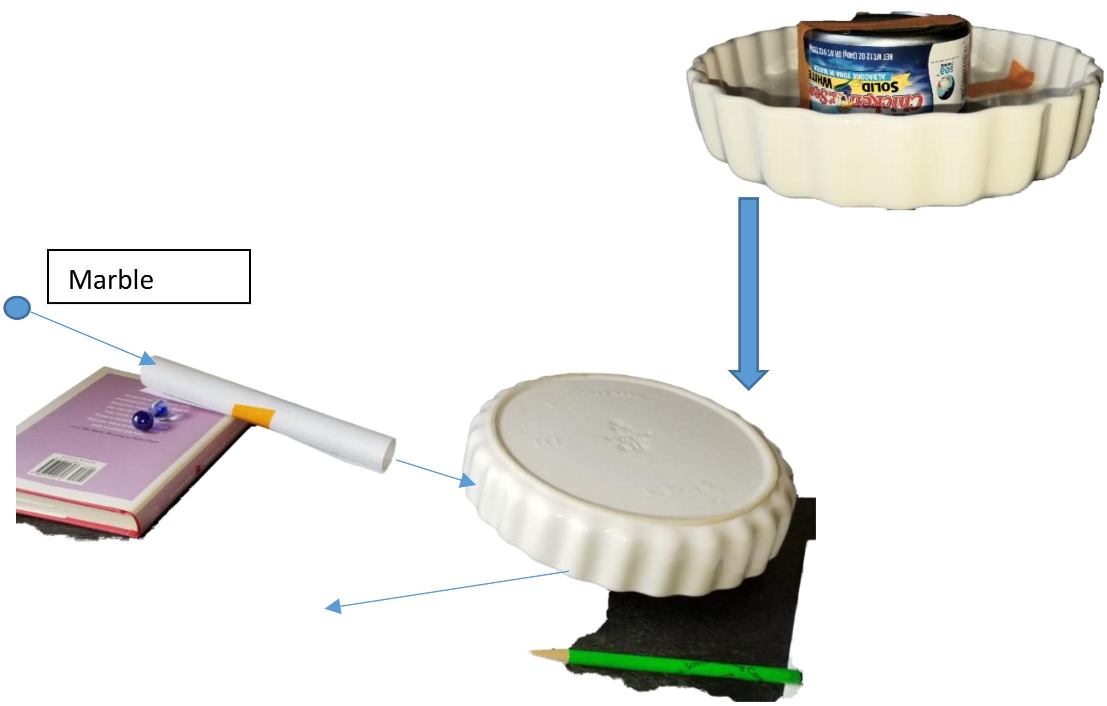
Activity

Your job is to identify the shape and location of a hidden object without ever seeing it. You can only roll marbles against the hidden object and observe the deflected paths that the marbles take. Use a piece of paper for sketching the paths of the marbles as they are rolled under a pan and bounce off of the object. Use arrows to indicate the direction of motion. Analyze this information to determine the object's actual shape.

Materials: Marbles, pie pan, cake pan, or other shallow pan, tape, sheet of paper, book, large table top or smooth floor. Several objects with different shapes: for example wood blocks (rectangle, circle, or triangle), tuna can, small gift box, baby food jar, etc.

Procedure:

1. Roll the paper into a tube that will allow the marble to roll through it. Tape the paper so it will not unroll.
2. Have someone secretly choose one of your different shaped objects and hide it under the shallow pan. They should tape it to the inside of the inverted pan then place the pan upside down on the smooth surface. The object should be thick enough to allow the marble to roll freely under the pan and bounce off the edges of the mystery object.
3. Prop up one end of the tube on a book. Aim the tube so that the marble will go through the tube and roll under the pan.



4. Let the marble roll through the tube. Does it strike the mystery object? If so, observe which direction the marble bounces off.
5. Move the tube to one side or the other and roll another marble aimed at the mystery object. Do this several times, observing how the marble bounces off the object. Can you determine the location of the mystery object? Can you also figure out the shape and size of the mystery object? (By looking at how the marbles bounce off you should be able to get information about the size and shape of the mystery object.)
6. Observe the deflected paths the marbles take. Draw what you think the size and shape of the mystery object is. Use arrows to indicate the paths of the marble. Roll a few more marbles at different places. Do you still think your prediction about the object is correct? If not, continue to roll the marble to get more information.
7. Reveal the mystery object. How does your prediction compare to the actual shape of the object?

8. Repeat the activity with a different object taped under the pan. Do you get better at predicting the location, size and shape?

Often we can look at or touch an object to learn about it. Sometimes, objects are too small or too large for us to learn about them this way. When this happens, we need to use indirect measurement techniques.

Evaluate:

1. How did your prediction compare to the actual shape of the mystery object?

2. What information gave you the best indication of shape?

3. Could you determine the size of the object as well as its shape?

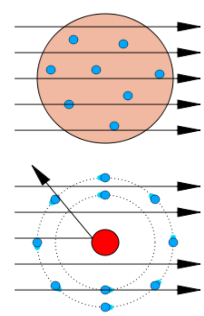
4. Are there other ways to test your prediction without looking?

5. How could you be sure of your conclusions without looking?

Many of the observations we make in science are indirect measurements like you just made! The approach we have been using is very similar in many ways to that used by scientists in studying the size, shape, and nature of elementary particles, atoms and molecules. Scientists use detectors to record information about particle interactions.

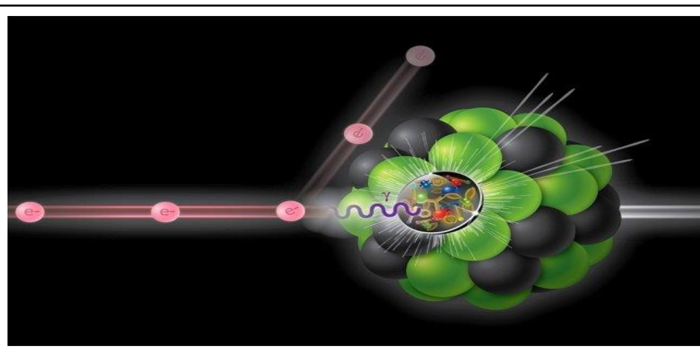
6. Think about the above statement and decide on a definition for the term “indirect observation”.

In a famous experiment performed in the early twentieth century, Ernest Rutherford fired alpha particles at gold foil and looked at the pattern the particles made after hitting the foil. This pattern indicated that the atoms of gold had a closely packed, positively charged nucleus. The reasoning behind this picture of an atom had to do with the fact that alpha particles are positively charged and would be repelled by a positively charged nucleus. Although most alpha particles went straight through the gold foil, some “bounced off” at sharp angles, even to the point of heading back in the direction from which they came. Only a closely packed, positively charged, nucleus of a gold atom could accomplish this.



http://explorationoftheatomicmodel.weebly.com/uploads/1/6/1/5/16157250/172889620.png

RHIC is designed to extend this frontier, providing access to the most fundamental building blocks of nature known so far — quarks and gluons. By colliding the nuclei of gold atoms together at nearly the speed of light, RHIC heats the matter in collision to more than a billion times the temperature of the sun. In so doing, scientists are able to study the fundamental properties of the basic building blocks of matter and learn how they behaved 15 to 20 billion years ago, when the universe was barely a split-second old.



https://3c1703fe8d.site.internapcdn.net/newman/gfx/news/2018/richardmilne.jpg

Acknowledgement: This lesson was created using the following resources:

Modeling Rutherford's Experiment A Teacher's Guide Cornell Laboratory for Accelerator-based Sciences and Education Author: Lora K. Hine file:///C:/Users/slc/Desktop/Modeling_Rutherfords_Experiment.pdf

Both Fields at Once! Lesson: "The source of this material is the *TeachEngineering* digital library collection at *www.TeachEngineering.org*. All rights reserved." https://www.teachengineering.org/lessons/view/van_mri_lesson_4

The science checklist applied: Engineering and technology development
https://undsci.berkeley.edu/article/technology_checklist

The Ghost Particle Classroom Activity *https://www.nsta.org/publications/news/story.aspx?id=51054*

Additional Resources:

Breakthrough: RHIC Explores Matter at the Dawn of Time

https://www.bnl.gov/rhic/video.php?v=270

Take a look inside this colossal machine where scientists propel electrons to 99.99% the speed of light

https://www.businessinsider.com/inside-brookhaven-laboratory-photos-particle-accelerator-2016-9

RHIC at BNL

https://www.bnl.gov/rhic/default.asp

My Road to Becoming an Engineer: Kimani Toussaint, a professor at Brown University, discusses his experiences in science and academia—and how culture has influenced his perspectives and career—during this talk hosted by the African American Advancement Group at Brookhaven Lab.

https://www.youtube.com/watch?v=maYMVh1KDLI