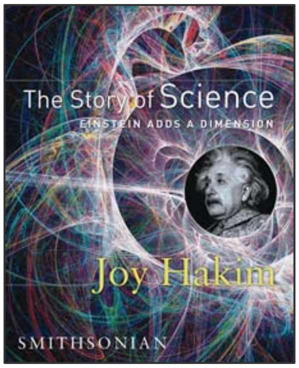
Chapter 24: The Fission Vision



Leo Szilard is the contrarian, constantly posing questions that seem unanswerable. Enrico Fermi is the hard worker, spending endless hours resolving his students' questions. As Adolf Hitler builds support for his Nazi agenda, these scientists build on the work of Frédéric and Irène Joliot-Curie, Lise Meitner (who was also fighting gender bias in the scientific world), and others. Ultimately, physicists find a self-sustaining process of nuclear fission that will change the world.

Teaching Tips

Although they may have heard the term many times, students often have difficulty conceptualizing the process of nuclear fission. The kinesthetic simulation below, as well as the two suggested applets, are worthwhile activities for clarifying the process of nuclear fission. Ask students to respond to what they model and observe in discussions and journal entries.

Another point of confusion is the source of fission energy—the nucleus rather than the electron shells. Remind students that before fission became a reality, even physicists were skeptical that bombarding a nucleus with neutrons could create significant energy. Labeled drawings can help clarify this concept.

Fission Simulation

Students can model nuclear fission in an open space. In the following simulation, students represent uranium atoms, either U-235 (which is fissile) or U-238 (which is nonfissile), while the teacher represents the neutron. Students draw roles at random, based on predetermined ratios. For the first simulation, 25% of students should draw fissile. Once roles have been assigned, students stand in a matrix formation, leaving 1 meter between one another. (Discuss this arrangement with students as they move to their positions: The rigid structure may remind them of atoms in a crystal.)

Make sure students understand the directions for their roles. The neutron (teacher) walks into the formation in a straight line and touches the first atom (student) he or she encounters. If the atom is nonfissile, nothing happens. The neutron continues on the same straight path and touches another atom at random. When a fissile atom is touched, that student silently counts, "One tomato, two tomato, three tomato," then shouts, "Bang," and quickly (but gently) tags all the other students within arms' reach. If one of the atoms touched is nonfissile, it remains still, but if it is fissile, it repeats the count and then tags surrounding atoms. Capture and playback the simulation via audio or video recorder. The class can count the number of "bangs" that occur until the process stops.

In the second round, students draw new roles. This time designate 50% of them fissile; in the third round designate 75 % fissile. Students should track the number of generations of reactions ("bangs") for each percent of fissile atoms using the following chart:

% Fissionable	# of Generations of Reactions
25%	
50%	
75%	

For Discussion
In discussing the data, students can compare the various ratios they have modeled, and answer the following questions:

1. What percentage of fissile atoms produced the longest/strongest chain reaction?
75%

2. Why? **The chain reaction is longer because the likelihood of finding a fissile atom is higher.**

You may also want to extend the discussion to incorporate current events. News stories often cite the role of governments in enriching uranium. Lead your class into a discussion of the high ratio of fissile to nonfissile isotopes necessary for the chain reaction to be perpetuated.

3. On the news you often hear the term "enriched uranium." Why do scientists enrich uranium before fission can occur? **The higher the percent of fissionable material the stronger the reaction.**

Encourage students to look carefully at the diagram on page 217 of the reader. Note that when the first neutron hits the Uranium-235, two neutrons are released in addition to the original one. In the next reaction, potentially nine neutrons are released. Have students complete the table showing the reaction number and number of free neutrons and answer the questions that follow.

Reaction	# Free Neutrons
1	3
2	
3	
4	
5	
6	
7	
•	
•	
•	
▼	
n	> 1 million

4. How many reactions are required to release at least one million free neutrons? **13**

5. Graph the number of free neutrons in each reaction. What is the shape? **The result is a curve in the shape of a "J."**

6. If each reaction takes about 10^{-7} second, how long will this process take? **13×10^{-7} seconds**

7. In fission reactors, rods are sometimes used to slow reactions. If a rod absorbed one of every three released neutrons, how would the shape of the graph change? **It slopes later but has the same "J" shape.**

Vocabulary
Fission
Fusion

Science Objects, Applets, and Animations
Chain Reaction: Mouse Trap Model
http://www.physics.umd.edu/lecdem/services/demos/demosp4/p4-62.htm

Nuclear Fission
http://www.lon-capa.org/~mmp/applist/chain/chain.htm

Extended Reading
Sullivan, E. 2007. *The ultimate weapon.* New York: Holiday House.
NSTA/CBC Outstanding Tradebook
ISBN: 978-0-8234-1855-8

Activities
Einstein's Big Idea: Messing With Mass
http://www.pbs.org/wgbh/nova/teachers/activities/3213_einstein_03.html

Nuclear Science in Society: Student Fission Activity
http://old-www.ansto.gov.au/edu/pdf/stu_act1_9.pdf

Evaluation
The student page includes the following scenario as a tool for assessing students' understanding of nuclear fission:

Physicists love to do rough, "back of the napkin" estimates. These are often called Fermi Questions after Enrico Fermi. Here's a Fermi Question for you: Look at the chart below. It shows the energy needed to get from Earth to the dwarf planet Pluto, at the edge of our solar system, if we were to harness the energy of a fission reaction. Compare that to the energy available in gasoline. If we could somehow create a gasoline-powered rocket, how much fuel would we need to get to Pluto? How much mass would that represent? (Answers are provided in **bold**.)

Fuel	Mass (g) per Molecule or Reaction	Energy Released per Molecule/Reaction (eV)	# of Reactants/Reactions needed to get to Pluto	Total Mass of Fuel needed
Fission	4×10^{-23}	2×10^{7}	3.5×10^{24}	680
Gasoline	1.9×10^{-22}	66	$\mathbf{1.2 \times 10^{31}}$	$\mathbf{2.3 \times 10^{9}}$

*Adapted from NOVA, "A Trip to Pluto," http://www.pbs.org/wgbh/nova/teachers/activities/3213_einstein_05.html where complete answers, explanations, and extensions can be found.