

# The Building of Ideas

## Activity Summary

Students create a time line of scientists involved with  $E=mc^2$ .

## Materials for each team

- copy of “The Building of Ideas” student handout
- four 4 x 6 file cards
- small binder clip
- tape

## Background

For centuries prior to Albert Einstein’s development of  $E=mc^2$ , men and women the world over dedicated their lives to understanding the concepts that underlie each part of the equation. Their investigations into the nature of energy, mass, light, and velocity provided Einstein with the foundation he needed to draw his astonishing conclusions about the equivalence of mass and energy. Scientists have confirmed Einstein’s equation countless times since its creation and continue researching its implications today.

In this activity, students will learn more about the lives and work of some of the men and women involved with  $E=mc^2$ .

## Procedure

- 1 Organize students into six teams to take notes on one of the following categories: energy, mass, light, velocity (speed of light squared), the development of the equation, and the confirmation of the equation. Within their category, students should take notes on the following: name of scientist(s), nationality, concept, experiment, time period, and challenges faced.
- 2 Distribute the materials and watch the two-hour program with students. After students watch, have them record their assigned category and a summary of the information noted above on the file cards.
- 3 Place a 3-meter string across a classroom wall. Create a time line ranging from 1700 to 1950. Have a representative from each team clip the team’s time-line cards to the appropriate place on the string.
- 4 Discuss the people in the program who contributed to the equation. Encourage students to see how the equation was an outcome of the work of many scientists. Have students elaborate how each scientist approached his or her concept. What did the scientists do or see that allowed them to make their breakthroughs in thinking?
- 5 As an extension, have each student adopt the identity of a scientist, research his or her work, and create a class presentation to illustrate the scientific breakthrough or contribution the scientist made.

## LEARNING OBJECTIVES

Students will be able to:

- identify key scientists who contributed to the concepts in and confirmation of  $E=mc^2$ .
- describe experiments that led to an understanding of energy, mass, the speed of light squared, and the equivalence of mass and energy.
- relate challenges scientists have faced as they pursued their research.
- place in sequential order discoveries of the past two centuries.

## STANDARDS CONNECTION

“The Building of Ideas” activity aligns with the following National Science Education Standards (see [books.nap.edu/html/nses](http://books.nap.edu/html/nses)).

GRADES 5–8

### Science Standard

- History and Nature of Science
- Science as a human endeavor
  - Nature of science
  - History of science

GRADES 9–12

### Science Standard

- History and Nature of Science
- Science as a human endeavor
  - Nature of scientific knowledge
  - Historical perspectives

## FIND OUT MORE

For more on the scientists, see the “Who Did What When? A Time Line of  $E=mc^2$ ” at the end of this guide and “Ancestors of  $E=mc^2$ ” online at [www.pbs.org/nova/einstein/ancestors.html](http://www.pbs.org/nova/einstein/ancestors.html)



## ACTIVITY ANSWER

### Energy

**Scientist:** Michael Faraday

**Nationality:** English

**Concept:** Invisible lines of force flow around electricity and magnets; electricity and magnetism are linked.

**Experiment:** Faraday placed a magnet beside a copper wire suspended in mercury and passed an electric current through the wire. The wire spun in a circle around the magnet, thus demonstrating the interaction of lines of electric and magnetic force.

**Time Period:** Early 1800s

**Challenges Faced:** Accused of plagiarism by Sir Humphry Davy; refuted claim and was later elected to the Royal Society.

### Mass

**Scientists:** Antoine-Laurent and Marie Anne Lavoisier

**Nationality:** French

**Concept:** Matter is always conserved in a chemical reaction regardless of how it is transformed.

**Experiment:** Lavoisier transformed a number of different substances. He carefully measured all the products of the reactions to show that matter is conserved.

**Time Period:** Late 1700s

**Challenges Faced:** The French Revolution; Antoine-Laurent Lavoisier was captured and executed by guillotine.

### Light

**Scientists:** Michael Faraday and James Clerk Maxwell

**Nationality:** English (Faraday) and Scottish (Maxwell)

**Concept:** Electromagnetism can be described mathematically; Maxwell's equations supported Faraday's long-held claims that light was just one form of electromagnetism.

**Experiment:** Maxwell's ideas were theoretical.

**Time Period:** Mid-1800s

**Challenges Faced:** Scientists did not agree with Faraday's belief that light was an electromagnetic wave.

### Velocity (Speed of Light Squared)

**Scientists:** Gottfried von Leibniz and Emilie du Châtelet

**Nationality:** German (Leibniz) and French (du Châtelet)

**Concept:** The energy of an object is a function of the square of its speed.

**Experiment:** Du Châtelet analyzed experiments in which brass balls were dropped into clay; measuring their impacts demonstrated that an object's energy is a function of its velocity squared. She clarified Leibniz's original ideas about velocity.

**Time Period:** Early to mid-1700s

**Challenges Faced:** Scientists discounted Leibniz' ideas; du Châtelet died during childbirth when she was 43.

### Development of $E=mc^2$

**Scientist:** Albert Einstein

**Nationality:** German, Swiss, and American

**Concept:** Mass and energy are the same and can be converted one to the other using the speed of light squared.

**Experiment:** Einstein's ideas were theoretical.

**Time Period:** Early 1900s

**Challenges Faced:** At first no one responded to Einstein's ideas; he patiently answered letters for four years. His genius began to be recognized when his work gained the endorsement of German physicist Max Planck.

### Confirmation of $E=mc^2$

**Scientists:** Otto Hahn, Fritz Strassmann, Lise Meitner, and Otto Robert Frisch

**Nationality:** German (Hahn, Strassmann) and Austrian (Meitner, Frisch)

**Concept:** The confirmation of  $E=mc^2$ .

**Experiment:** Hahn and Strassmann bombarded uranium with neutrons and discovered barium in the resulting products; Meitner and Frisch realized the results indicated that Hahn and Strassmann had split the uranium nucleus.

**Time Period:** Mid-1900s

**Challenges Faced:** Because she was Jewish, Meitner was forced to flee Germany and compelled to collaborate by mail with Hahn and Strassmann; Hahn never acknowledged Meitner's work.

## LINKS AND BOOKS

### Links

NOVA—Einstein's Big Idea

[www.pbs.org/nova/einstein](http://www.pbs.org/nova/einstein)

*Hear top physicists explain  $E=mc^2$ , discover the legacy of the equation, see how much energy matter contains, learn how today's physicists are working with the equation, read quotes from Einstein, and more on this companion Web site.*

American Institute of Physics  
Historical Information

[www.aip.org/history/exhibits.html](http://www.aip.org/history/exhibits.html)

*Detailed online exhibits of Einstein and other famous physicists, plus a history of the discovery of fission.*

Contributions of Twentieth-Century  
Women to Physics

[cwp.library.ucla.edu](http://cwp.library.ucla.edu)

*Profiles pioneering women in physics.*

### Books

**Lise Meitner: A Life in Physics**

by Ruth Lewin Sime.

University of California Press, 1997.

*Investigates Meitner's life and work, including her vital role in the discovery of nuclear fission.*

**The Man Who Changed Everything:  
The Life of James Clerk Maxwell**

by Basil Mahon.

John Wiley & Son, 2003.

*Relates the story of the Scotsman whose brilliant mathematics helped to define the nature of light.*

**Michael Faraday and the Discovery  
of Electromagnetism**

by Susan Zannos.

Mitchell Lane Publishers, 2004.

*Profiles Faraday and explains, in simple terms, his concept of electromagnetism.*

**Science: 100 Scientists Who  
Changed the World**

by Jon Balchin.

Enchanted Lion Books, 2003.

*Provides two-page profiles of 100 scientists from around the world from ancient times to the present-day, including Lavoisier, Faraday, Maxwell, and Einstein.*

# The Building of Ideas

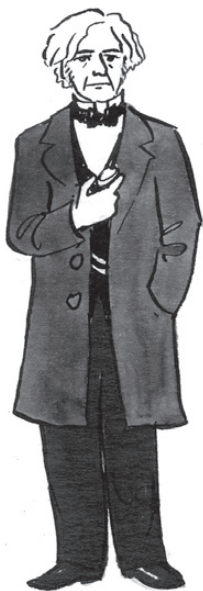
Albert Einstein was able to make his leap of understanding about mass and energy because of the many scientists before him who had worked hard, seen problems in a new light, and fought to make their ideas heard. Today's scientists continue to build on Einstein's work and the work of others to reveal new understanding about the world. In this activity, you will learn about some of the people who contributed to the concepts in and confirmation of  $E=mc^2$ .



Albert Einstein

## Procedure

- 1 Your team will be assigned to take notes on one of the following categories: energy, mass, light, velocity (speed of light squared), the development of the equation, and the confirmation of the equation.
- 2 Once you have received your assignment, you will watch the program and take notes on the areas listed below. Work out among your team members who will be responsible for each of the following areas:
  - Name of Scientist(s)
  - Nationality
  - Concept
  - Experiment
  - Time Period
  - Challenges Faced
- 3 After watching the program, summarize and record your notes onto time-line cards. When you have finished, tape your team's cards together.
- 4 When your cards are complete, clip them to the appropriate place on the time-line string.



Michael Faraday



Antoine-Laurent Lavoisier



Emilie du Châtelet