Pi-Day Fun

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What Is Pi?

Pi is the circumference of a circle (the distance around the circle) divided by its diameter (the distance across). In other words, the circumference of any circle is approximately 3.14 times its diameter. Because pi is an irrational number, it has an infinite number of digits. No matter how many decimal places we calculate, pi will always be an approximation.

Because pi is the same for every circle, we can use it to determine the diameter if we know the circumference, or vice versa. And when we know the diameter, it's easy to calculate the area.
This gif (animated sequence) that "unrolls" pi will give your students a quick visual of how a circle's diameter, circumference, and pi are related.

A Brief History of π

***Pi* has been known for almost 4000 years—but even if we calculated the number of seconds in those 4000 years and calculated *pi* to that number of places, we would still only be approximating its actual value. Here's a brief history of finding *pi*:**

The ancient Babylonians calculated the area of a circle by taking 3 times the square of its radius, which gave a value of *pi* = 3. One Babylonian tablet (ca. 1900–1680 BC) indicates a value of 3.125 for *pi*, which is a closer approximation.

In the Egyptian *Rhind Papyrus* (ca.1650 BC), there is evidence that the Egyptians calculated the area of a circle by a formula that gave the approximate value of 3.1605 for *pi*.

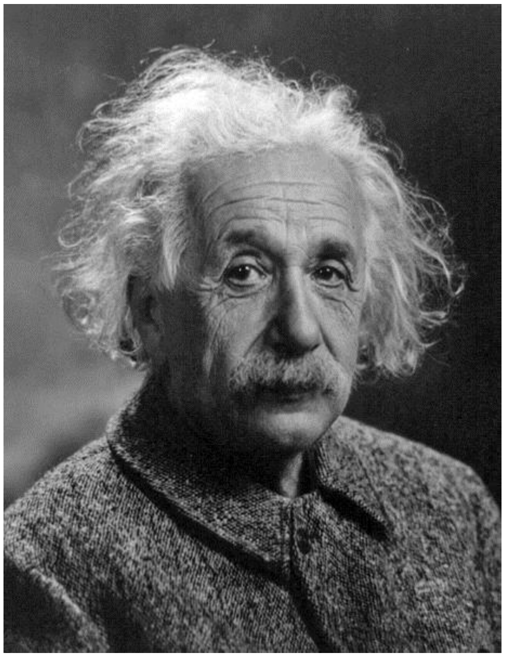
The ancient cultures mentioned above found their approximations by measurement. The first calculation of *pi* was done by Archimedes of Syracuse (287–212 BC), one of the greatest mathematicians of the ancient world. Archimedes approximated the area of a circle by using the Pythagorean Theorem to find the areas of two regular polygons: the polygon *inscribed within the circle* and the polygon *within which the circle was circumscribed*. Since the actual area of the circle lies between the areas of the inscribed and circumscribed polygons, the areas of the polygons gave upper and lower bounds for the area of the circle. Archimedes knew that he had not found the value of *pi* but only an approximation within those limits. In this way, Archimedes showed that *pi* is between 3 1/7 and 3 10/71.

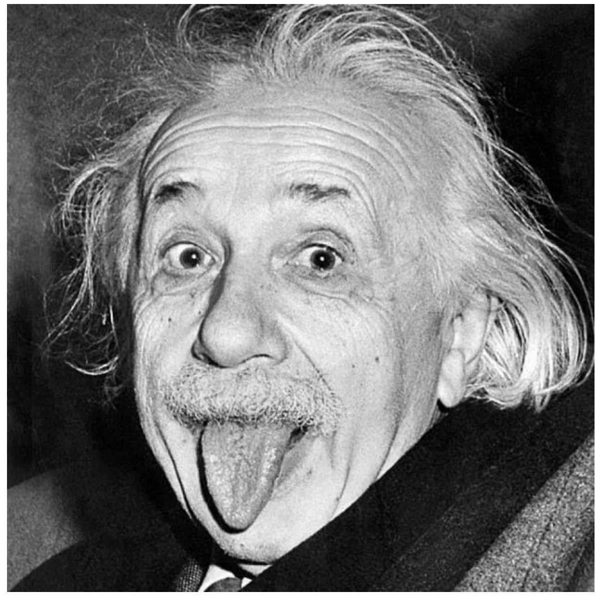
A similar approach was used by Zu Chongzhi (429–501), a brilliant Chinese mathematician and astronomer. Zu Chongzhi would not have been familiar with Archimedes' method—but because his book has been lost, little is known of his work. He calculated the value of the ratio of the circumference of a circle to its diameter to be 355/113. To compute this accuracy for *pi*, he must have started with an inscribed regular *24,576-gon* and performed lengthy calculations involving hundreds of square roots carried out to 9 decimal places.

Mathematicians began using the Greek letter **π** in the 1700s. Introduced by William Jones in 1706, use of the symbol was popularized by Euler, who adopted it in 1737.

An 18th century French mathematician named Georges Buffon devised a way to calculate *pi* based on probability. You can try it yourself at the Exploratorium exhibit *Throwing Pi*.

Albert Einstein





Albert Einstein's Birthday is on March 14th 1879 (3-14). He was born in Germany and was theoretical physicist who developed the general theory of relativity!

Introduce Albert Einstein

http://www.brainpop.com/science/famousscientists/alberteinstein/preview.weml

How does a scientist become a household name? In this BrainPOP movie, Tim and Moby introduce you to the astounding career of Albert Einstein, the physicist who revolutionized our understanding of space and time. You'll learn where and when he was born and why no one thought he would grow up to be one of the smartest people ever! You'll find out why he couldn't get a job after college and what he did in his spare time. You'll also learn what major accomplishment he made in 1905, and you'll get a brief introduction to his theory of relativity. Plus, find out when he won the Nobel Prize, to what use he put his celebrity, and why he left Europe for the United States. They just don't come any smarter!

Teaching Albert Einstein

http://www.bookrags.com/lessonplan/albert-einstein/

The *Albert Einstein* lesson plan contains a variety of teaching materials that cater to all learning styles. Inside you'll find 30 Daily Lessons, 20 Fun Activities, 180 Multiple Choice Questions, 60 Short Essay Questions, 20 Essay Questions, Quizzes/Homework Assignments, Tests, and more. The lessons and activities will help students gain an intimate understanding of the text; while the tests and quizzes will help you evaluate how well the students have grasped the material.

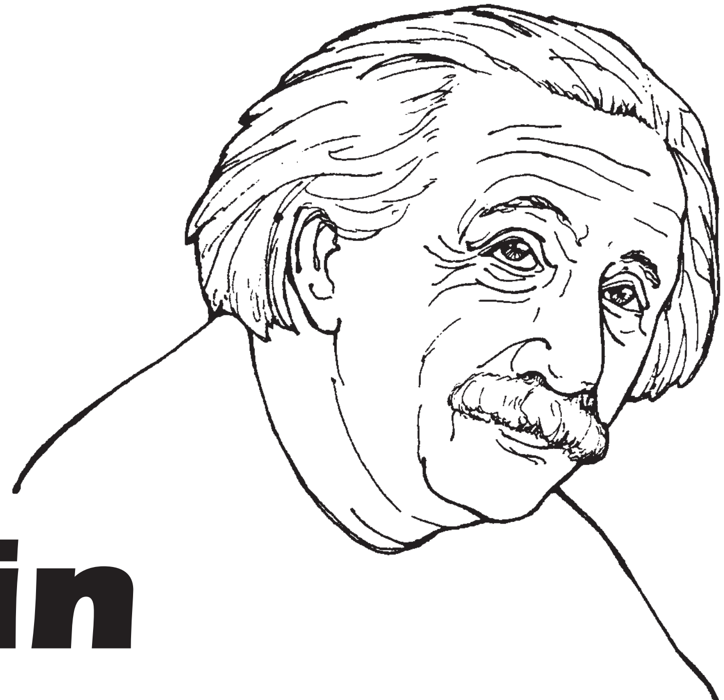
Albert Einstein Labs & Activities: PBS NOVA ONLINE

http://www.pbs.org/wgbh/nova/education/activities/3213_einstein.html

Albert Einstein's famous equation, $E = mc^2$, is known to many people but understood by few. This guide—which includes five lesson plans and a time line—is designed to help you and your students learn more about the stories and science behind this renowned formula. Intended for middle and high school students, the lessons look into the lives of the innovative thinkers who contributed to the equation, investigate the science behind each part of the equation, and explore what the equation really means.

Each activity includes a teacher activity setup page with background information, an activity objective, a materials list, a procedure, and concluding remarks. Reproducible student pages are also provided. Most activities align with the National Science Education Standards' Physical Science standard, Structure of Atoms and Structure and Properties of Matter sections.

Following are a few interesting classroom activities to share with your students:



Albert Einstein

Physicist

As a student, Albert Einstein showed little intellectual promise. He was so slow to learn verbal skills that his teachers predicted he would never be successful at anything. Albert went on to the Swiss Polytechnic Institute in Zurich, Switzerland where he was brilliant in math and physics. However, he refused to study anything else.

Nine years later, in 1905, Albert wrote five papers describing his own ideas about math and physics. Three of these papers were of major importance: one that described the photoelectric effect, a second which worked out a mathematical analysis of Brownian motion, and a third outlining the theory of relativity. By 1916, Albert Einstein had completed work on his Special Theory of Relativity and General Theory of Relativity. These theories were concerned with physical properties such as mass, energy, time, and space. Previously, scientists held that these forces were separate and could not be changed, but Einstein proved that they were related. In 1921, he received the Nobel Prize for physics.

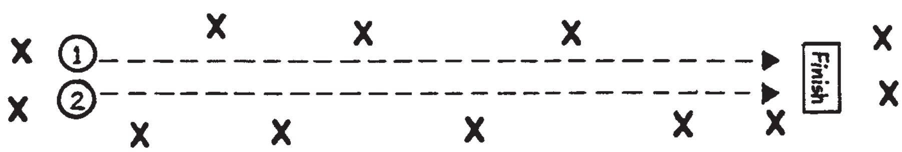
While Einstein was visiting the United States in 1930, Hitler came to power in Germany. Since he was a Jewish pacifist, Einstein decided not to return to his homeland. Instead he set up permanent residency in Princeton, New Jersey. He became a United States citizen in 1940. Einstein accepted a position at Princeton University where he continued to work on his theories until his death on April 15, 1955.

Einstein has been described as an absent-minded man, interested only in his work, classical music, and playing the violin. His ideas, so far ahead of their time, went mostly unproven during his lifetime. Since his birth on March 14, 1879, many new advances in technology have been made which are allowing scientists to rediscover this scientific genius.

Suggested Activities

1. **Frame of Reference.** Einstein's Theory of Relativity reflects the fact that all motion is measured relative to some observer. Furthermore, Einstein said that measurements of time depend on the frame of reference of the observer.

   To help students understand the concept of frame of reference, stage an activity and position students randomly so the event is viewed from a variety of angles. For example, direct two students to run towards a finish line. Have some students view the race from the back, front, and sides of the runners. Afterwards, discuss what was seen from each point of view.

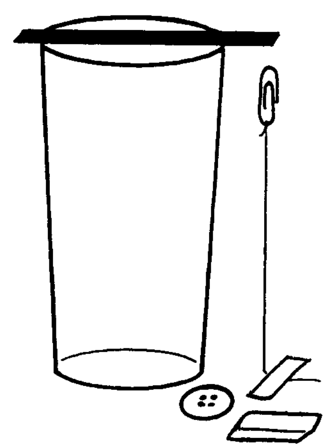


   (The x's stand for students as they watch two runners race to the finish line.)

   For a concise explanation of Einstein's theories, read David Fisher's *The Ideas of Einstein* (Holt, Rinehart and Winston, 1980).

2. **Defying Gravity.** Einstein's theories about gravity are both astounding and controversial. Here is an antigravity experiment that will amaze students.

   Materials: strong bar magnet; clear glass (may be plastic); paper clips; thread; tape; assorted objects such as coins, plastic chips, paper, another paper clip, etc.



   Directions: Place the glass on a flat surface; lay the magnet across the top of the mouth of the glass as shown. Attach thread to one end of a paper clip. Bring the paper clip up to the magnet and allow it to stay in that position. Loosely apply a piece of tape over the free end of the thread and onto the table. Pull on the free end of the tape until the paper clip is still attracted to the magnet yet leaves a space between the paper clip and the magnet. Firmly press the tape onto the table to keep the paper clip suspended. Predict what will happen when an object is placed in the space between the paper clip and the magnet. Experiment with a variety of objects.

Teacher References

Hunter, Nigel. *Einstein.* Bookwright Press, 1987.
Kahan, Gerald. *$E=mc^2$ Picture Book of Relativity.* Tab Books, 1983.
Lightman, Alan. *Einstein's Dreams.* Pantheon Books, 1993.

Student Reading
Bradbury, Pamela Zanin. *Albert Einstein.* Little Simon,1988.
Cwiklik, Robert. *Albert Einstein and the Theory of Relativity.* Barron's Educational Series, Inc., 1987.
Ireland, Karin. *Albert Einstein.* Silver Burdett Press, 1989.
Laurence, Santrey. *Young Albert Einstein.* Troll Associates, 1990.
Wood, Robert W. *Physics for Kids: 49 Easy Experiments with Mechanics.* TAB Books, Inc., 1989.

NOVA PBS

Who Did What When?

A TIME LINE OF $E = mc^2$

Science is a human endeavor that builds on the contributions and efforts of many people. The following are a few of the key scientists who helped lay the groundwork for Albert Einstein's incredible insight into the equivalence of energy and mass.

1600s

GALILEO GALILEI 1564–1642

Facing the Inquisition for his scientific beliefs, Galileo developed many important ideas about the science of motion, such as inertia. Isaac Newton built on many of Galileo's insights when developing his laws of motion. These ideas would later play a critical role in Einstein's thinking about energy, mass, light, and motion.

Galileo Galilei

SIR ISAAC NEWTON 1642–1727

A prodigy in mathematics and physics, Newton began many revolutionary advances about matter, motion, and light while he was a university student. These are the foundation for much of today's science. He developed calculus and proposed the laws of motion as well as the law of universal gravitation. He also studied the nature of light. His laws were the starting point for Einstein's own investigations of matter, motion, and energy.

GOTTFRIED WILHELM VON LEIBNIZ 1646–1716

Leibniz, a German philosopher, was a polymath—he was equally at home in abstract studies of logic as he was with mathematics, physics, and philosophy. He invented calculus independently of Newton, and also suggested that an object's ability to do work was proportional to the square of its speed, rather than its speed alone. Squaring an object's speed would become crucial to Einstein's own ideas about $E=mc^2$.

Gottfried Wilhelm von Leibniz

1800s

MICHAEL FARADAY 1791–1867

Faraday grew up the poor apprentice to a bookbinder, but his excitement about science soon brought him to the very forefront of his field. He hypothesized that invisible fields of electricity and magnetism carried these forces through space, and that these "lines of force" need not always move in straight lines as Newton would have predicted. He further showed that electricity could create magnetism, and that magnetism could generate electricity. His ideas laid the groundwork for the modern scientific concept of energy that would be crucial to Einstein's later work.

Michael Faraday

JAMES CLERK MAXWELL 1831–1879

Maxwell learned all the latest mathematics while a university student, and quickly brought his new skills to bear on many of Faraday's conceptual ideas. Maxwell provided the mathematical backbone for electromagnetism—a single physical force that could sometimes appear as electricity and sometimes as magnetism, but which was at root a deep interconnection of the two. He also demonstrated that light was nothing other than a wave of electric and magnetic fields.

James Clerk Maxwell

1700s

EMILIE DU CHÂTELET 1706–1749

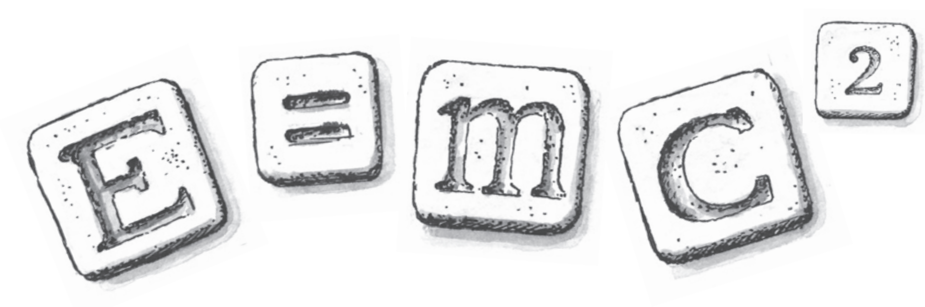
Emilie du Châtelet

This talented woman mastered the mathematics and physics of her day. She was the first person to translate Newton's great works into French. She also clarified Leibniz's ideas about objects in motion. In particular, by analyzing Dutch researcher Willem 'sGravesande's experiment of dropping balls into soft clay, du Châtelet helped champion the idea that squaring an object's speed determined how much work it could do. She thus helped put in place a crucial piece of Einstein's $E=mc^2$.

ANTOINE-LAURENT LAVOISIER 1743–1794
MARIE ANNE PAULZE LAVOISIER 1758–1836

Antoine-Laurent Lavoisier

This husband-and-wife team helped usher in a new era for the science of chemistry. Antoine-Laurent demonstrated that the total amount of matter is conserved in any chemical reaction—some of it might change form from solid, liquid, or gas, but the total amount remains the same before and after the reaction takes place. Working at her husband's side, Marie Anne made detailed drawings and engravings of laboratory apparatus and experiments, and translated the works of other scientists.



Time Line Author
Written by David Kaiser, an associate professor in the MIT Program in Science, Technology, and Society, and a lecturer in the MIT physics department.

TUNE IN

"Einstein's Big Idea"
airs on PBS
October 11, 2005

www.pbs.org/nova/einstein

1900s

PIERRE CURIE 1859–1906
MARIE SKLODOWSKA CURIE 1867–1934

This husband-and-wife team helped to reinvent modern physics, much as the Lavoisiers had done for chemistry many years earlier. Pierre and Marie Curie studied radioactivity and discovered new radioactive elements, such as radium and polonium. Their work led to a new understanding of radioactivity—a process in which matter decays and releases energy—made possible by $E=mc^2$.

ALBERT EINSTEIN 1879–1955

Albert Einstein

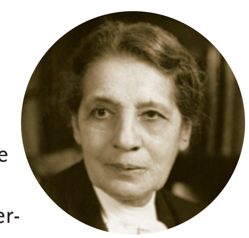
A stubborn visionary, Einstein developed some of the most revolutionary ideas in the history of science. While working as a patent clerk, he introduced a fundamentally new basis for understanding the most basic ideas of physics—space, time, matter, and energy. Among his major insights: energy and mass are two forms of the same thing. Each can be transformed into the other, with c^2 as the conversion factor—a number so huge that a tiny amount of mass is equal to an enormous amount of energy.

OTTO HAHN 1879–1968
FRITZ STRASSMANN 1902–1980

Otto Hahn

These two chemists had worked closely with physicist Lise Meitner in Berlin, until Meitner was forced to flee Nazi Germany. They experimented by bombarding uranium's heavy nuclei with neutrons. Expecting the nuclei to simply absorb the incoming neutrons, they could not explain their subsequent results—lighter elements, such as barium, were produced. Hahn wrote to Meitner for help explaining the puzzling results; she realized that Hahn and Strassmann had generated nuclear fission, early evidence that confirmed Einstein's $E=mc^2$.

LISE MEITNER 1878–1968
OTTO ROBERT FRISCH 1904–1979



Lise Meitner

Meitner, a physicist, worked for years with chemists Otto Hahn and Fritz Strassmann to study the behavior of nuclei. She was forced to flee Nazi Germany because of her Jewish ancestry. Soon after leaving Berlin, she received some reports from Hahn about the latest experimental data. With her nephew, physicist Otto Robert Frisch, Meitner was the first to understand that uranium nuclei could be split when bombarded by neutrons. Meitner and Frisch calculated how much energy would be released each time a uranium nucleus underwent fission, a dramatic example of $E=mc^2$ at work.

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).

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

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
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
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
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

Energy's Invisible World

Activity Summary

Students explore the meaning of *E* in $E=mc^2$ by investigating the nature of fields and forces at different stations in the classroom.

Materials for each station

Station 1
(electric field)
- several plastic spoons
- 10 cm x 10 cm piece of wool or rabbit fur
- pieces of plastic foam cup, crumbled into bits
- pieces of paper, about 0.5 cm by 1 cm each

Station 2
(magnetic field)
- bar or horseshoe magnet
- small shallow cardboard box
- piece of white paper (cut to fit box)
- iron filings in small jar or beaker

Station 3
(electromagnet)
- 40 cm of well-insulated copper wire
- 6V lantern battery
- 2 large nails
- small paper clips

Station 4
(mechanical to heat energy)
- 8 oz bottle of glycerin
- two 8 or 10 oz plastic foam cups
- 2 metal spoons
- 2 alcohol thermometers
- clear tape
- magnifying glass
- paper towels

Station 5
(electrical to heat energy)
- 2 pieces of insulated wire, each 20 cm long
- one 1.5V battery
- small light-bulb socket and 4W bulb

Station 6
(potential to kinetic to mechanical energy)
- 2 metal pendulum bobs
- 60 cm string, cut in half
- ring stand, ruler, or meter stick

Station 7
(chemical to heat energy)
- 2 wood splints of same weight
- two 500 ml beakers
- pan or triple-beam balance
- long wooden matches and goggles (for teacher only)

Materials for each team

- copy of "Energy's Invisible World" student handout
- copy of "Station 1–3 Instructions" student handout
- copy of "Station 4–7 Instructions" student handout

LEARNING OBJECTIVES

Students will be able to:

- explain what the *E* in $E=mc^2$ represents.
- name different kinds of energy.
- show examples of how one kind of energy can be converted into another kind of energy.
- describe how a field can exert a force and cause an object to move.

KEY TERMS

conservation of energy: A law stating that the total amount of energy in a closed system stays constant.

electric field: A region of space characterized by the presence of a force generated by an electric charge.

electromagnet: A magnet created when an electric current flows through a coil of wire; magnetism does not occur when the current is off.

field: A region of space characterized by the existence of a force.

kinetic energy: The energy due to the motion of an object.

magnetic field: A region of space characterized by the presence of a force generated by a magnet. A magnetic field is also produced by a flowing electric current.

potential energy: The energy an object has due to its position or condition rather than its motion.

work: The amount of energy involved in exerting a force on an object as it moves.

Background

$E = mc^2$ sprang from the work of men and women dedicated to revealing the secrets of nature. One of the scientists integral to the equation's *E* was a young bookbinder named Michael Faraday. A self-taught scientist, Faraday helped reshape the idea of energy. In the early 19th century, scientists saw nature in terms of individual powers and forces, like wind or lightning. Scientists were puzzled when they placed a compass next to a charged wire and its needle was deflected at right angles. Faraday visualized an answer no one could believe—that the compass was being affected by invisible lines of force flowing around the wire. Through a groundbreaking experiment involving electricity and a magnet, Faraday demonstrated the existence of these lines of force. His work served as the basis for the electric engine. It was Faraday's ability to see a problem in a new way that led to this breakthrough.

In this activity, students explore different aspects of energy, energy fields, the forces that fields exert on other objects, and how energy is transferred from one form to another. Students move through a series of stations where they do mini-activities and make observations.

Energy can be a difficult concept to define for younger students. Usually defined as the ability to do work, the definition can be made clearer when students examine what energy *does* in a physical sense. Work is done when an object has a force exerted on it and the object moves a distance. So, in the simplest possible terms, energy is expended when work is done, and energy is often transferred and appears in a different form (i.e., electric potential heats up a light bulb filament; heating the filament produces light and heat energy).

A field is a region of space characterized by the existence of a force. The easiest field for students to understand is Earth's gravitational field, which is responsible for objects falling. When a ball is dropped, the field exerts a force that accelerates the ball, and moves it toward Earth in the same way that the north pole of a magnet exerts a force on the south pole of another magnet. The work that the field does is converted to energy of motion of the ball, and then to heat when the ball hits the ground. At several stations in this activity, students will examine what fields can do in terms of exerting forces and doing work. Conservation of energy is also explored.

STANDARDS CONNECTION

The "Energy's Invisible World" activity aligns with the following National Science Education Standards (see **books.nap.edu/html/nses**).

GRADES 5–8

Science Standard

Physical Science

- Transfer of energy

GRADES 9–12

Science Standard

Physical Science

- Motions and forces
- Conservation of energy and the increase in disorder

Procedure

1 Set up the stations in advance of the activity according to the Station Setup Instructions in the sidebar to the right. Place station labels (with station numbers only) at each location.

2 Organize students into teams and distribute the student handouts.

3 Brainstorm with students about different types of energy. Ask them how many energy sources they use each day. Review each kind of energy (and any associated fields) with students. Write the equation $E=mc^2$ on the board and ask students what kind of energy they think Einstein was referring to in the E in his famous equation.

4 Review safety protocols for Stations 3 and 5. Caution students not to leave wires connected to the battery for more than 30 seconds. The battery, the electromagnetic nail, and the wire in Station 3 will get fairly hot, as will the battery and light bulb in Station 5. Supervise students as they complete these stations.

5 Have student teams rotate through all the stations, and facilitate if needed. After completing all the stations, have students individually answer the questions on the "Energy's Invisible World" handout. Then have students discuss their answers as a team. Once all teams are done, go through each station, discuss what kinds of forces and energy transfers occurred, and reconcile any differences in student answers. *(See Activity Answer on page 10 for more information.)* If students are having trouble with the idea of conservation of energy, help them understand what parts are contained in each system they studied and clarify the differences between open and closed systems. Conclude by revisiting the $E=mc^2$ equation and asking students again what the E in the equation stands for. *(Any manifestation of energy in a system.)*

6 As an extension, have students further explore electromagnets. Announce a contest—a prize to whoever can pick up the most paper clips. Leave a pile of batteries, nails, and wire on the table and let students design their own electromagnets. The ones that catch on will use multiple nails as a core and place more coils of wire around their nails to strengthen their electromagnets.

STATION SETUP INSTRUCTIONS

Station 1 *(electric field):* Supply plastic spoons, wool or rabbit fur, bits of plastic foam cup, and paper.

Station 2 *(magnetic field)*: Place the piece of paper in the box and the box on top of the magnet. Situate the container of iron filings nearby.

Station 3 *(electromagnet)*: Using the center of the wire, tightly coil the insulated wire around one nail, leaving about the same amount of wire on either side, and place the battery nearby. (The strength of the nail's magnetic field is proportional to both the battery current and the number of coils of wire around the nail.) Place the second nail and the paper clips at the station.

Station 4 *(mechanical to heat energy)*: Place 100 milliliters of glycerin in each plastic foam cup. Place metal spoons, alcohol thermometers, tape, magnifying glass, and paper towels at the station. Have student teams alternate cups of glycerin (each with its own spoon and thermometer) so that one cup will have time to cool while the other is being used.

Station 5 *(electrical to heat energy)*: Set up a circuit similar to Station 3, but place a small socket and light bulb in place of the electromagnet.

Station 6 *(potential to kinetic to mechanical energy)*: Set up two pendulums of exactly the same length. Tie them from the same point on a ring stand or from a ruler or meter stick that can project over the desk edge.

Station 7 *(chemical to heat energy)*: Do as a demonstration before students visit stations. Put goggles on. Choose two splints of the same weight. Burn one in a beaker by lighting it at its center (relight if needed until the splint is completely burned). Ask students to share their ideas about any energy changes that took place. Place the unburned splint in a second beaker. Set up the balance so students can weigh each beaker.

ACTIVITY ANSWER

The following is a description of what is occurring at each station.

Station 1: Students are examining the effects of an electric field produced by rubbing a plastic spoon on fur. Once the spoon is charged (negatively), it will attract an uncharged object like a piece of paper through electrostatic induction. The large negative charge on the spoon repels the electrons in the piece of paper and leaves the side of the paper near the spoon slightly positive. (Positive charges—in the nucleus of each atom within the paper—hardly move at all.) Then, the negative spoon attracts the now positive side of the paper. If students are careful in their approach to the paper, they should be able to make it "dance."

Plastic foam becomes instantly negatively charged when in contact with another negatively charged object. The bits of plastic foam acquire a negative charge when they touch the spoon and are repelled immediately. It is impossible to catch a piece of plastic foam, no matter how close to the spoon it is held. If students claim they can, have them recharge their spoons (the charge leaks away quickly on humid days).

Station 2: Students should realize that the field from the magnet is exerting a force on the iron particles. Student diagrams should show the filings aligning to the north and south field lines. Students may need to be generous with the iron filings to observe any patterns. If the magnet is weak, have students place it under the paper in the box rather than under the box.

Station 3: The point of this station is that the magnetic field can do work. It can lift objects as the energy of the field is transferred to the paper clips. The electromagnet at this station can be the catalyst for a discussion of how electricity and magnetism are linked.

Station 4: This station shows how mechanical energy (stirring of the glycerin) can be turned into heat energy. (Students' muscles also generate heat as they work to stir the glycerin.) Students need to read the thermometer very carefully. Temperature changes of only a few tenths to one degree are expected.

Station 5: The light bulb demonstrates how electrical energy can be converted to light and heat energy. Most of the light bulb's energy is given off as heat. If you have time, you may want to discuss how a battery works—that it hosts a chemical reaction and that the energy of that reaction supplies the electrical energy when a battery is connected to something.

Station 6: The pendulum presents an example of multiple energy transfers. The work students do when they lift the pendulum up is stored as potential energy. When released, the potential energy is converted throughout the arc to kinetic energy. At the bottom of the arc, the pendulum now has converted all its potential to kinetic energy. The kinetic energy is then converted into mechanical energy (plus a bit of heat and sound energy—the "click" heard on impact) when the moving bob hits the stationary one. The motionless bob, when struck, then transfers the mechanical energy to kinetic and moves in an arc until the kinetic is converted to potential energy and the bob stops and swings back down again. With each swing, the pendulum bobs swing lower and lower. This is due to friction at the pivot point, in which small amounts of energy are being converted to heat, and to air resistance (which also creates friction). If there were no friction, the pendulum would swing forever. (Students may miss the fact that, initially, it is the food they eat that gives them the energy to use their muscles to exert the force and supply the energy to lift the pendulum bob. Even earlier in the process, it is the sun—an example of $E=mc^2$—that provided the energy that made their food possible.)

Station 7: This demonstration is the most complex of the energy change scenarios in this activity. If students have had a limited exposure to chemical reaction, such as the combustion of wood, this would be a good time to review students' observations in detail. Discuss what the reactants of this combustion reaction are (wood and O_2), and what the products of the reactions are (carbon, CO_2, and water).

ACTIVITY ANSWER (CONT.)

Student Handout Questions

1 At which station(s) did you observe the following field effects?
a) a magnetic field exerted a force on an object (Stations 2, 3)
b) an electric field applied an attractive force on an object (Station 1)
c) an electric field applied a repulsive force on an object (Station 1)
d) an electric field caused the formation of a magnetic field (Station 3)

2 At which station(s) did you observe the following energy transfers?
a) mechanical energy to heat energy (Station 4) b) electrical energy to heat energy (Stations 3, 5) c) potential energy to kinetic energy (Station 6) d) mechanical energy to kinetic energy (Station 6) e) kinetic energy to mechanical energy (Stations 4*, 6) f) chemical energy to heat energy (Station 7) g) kinetic energy to sound energy (Station 6) h) electrical energy to light energy (Station 5)

*This one is a bit tricky. Students may not consider moving a spoon in glycerin to be energy but of course it is. At Station 4, mechanical energy (hand moving) is converted to kinetic energy (motion of the spoon) and then to mechanical energy (spoon moving through glycerin) and finally, to heat energy. Stepping back further, students eat food (chemical potential energy) that enabled their muscles to move the spoon.

3 At which of the stations did you observe one kind of energy being converted to more than one other kind of energy? Draw a simple diagram to show the steps in the conversion of energy at each of these stations.
Possible answers:
Station 5: electrical energy ⇒ heat and light energy
Station 6: mechanical energy (picking up the pendulum bob) ⇒ potential energy ⇒ kinetic energy ⇒ sound and mechanical energy (hitting the second bob) ⇒ kinetic energy ⇒ potential energy
Station 7: mechanical energy (to light the lighter) ⇒ chemical energy (burning gas) ⇒ light and heat energy ⇒ chemical energy (burning splint) ⇒ light and heat energy

4 The law of conservation of energy says that energy cannot be created or destroyed; the total energy in a closed system remains constant (a system is a group of interrelated parts that function together as a whole). Design a procedure showing how you would test this law by modifying the open-system setups at Station 5, 6, or 7.
Students may arrive at different ways to make these open systems closed. At Station 5, an experiment would need to be designed to capture and measure the heat escaping from the light bulb. At Station 6, friction must somehow be accounted for, both friction from the air and friction at the pivot. At Station 7, an experiment must be designed to capture and measure the energy given off by the burning splint.

LINKS AND BOOKS

Links

NOVA—Einstein's Big Idea
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.

All About Energy Quest
www.energyquest.ca.gov
Presents how energy is a part of daily life.

Energy Kid's Page
www.eia.doe.gov/kids
Features various sections about energy, including what it is and the forms it takes. Includes time lines, facts, and a quiz about energy.

Books

Energy Projects for Young Scientists
by Richard C. Adams and Robert Gardner.
Franklin Watts, 2002.
Offers instructions for a variety of projects and experiments related to solar, thermal, electrical, kinetic, and potential energy.

The Hidden World of Forces
by Jack R. White.
Putnam, 1987.
Discusses some of the forces at work in the universe, such as electromagnetism, gravitation, surface tension, and friction.

Kinetic and Potential Energy: Understanding Changes Within Physical Systems
by Jennifer Viegas.
Rosen Publishing Group, 2005.
Uses everyday examples to explain the concepts behind kinetic and potential energy.

Stop Faking It!: Energy
by William C. Robertson.
NSTA Press, 2002.
Provides information and activities to help teachers and students understand concepts related to energy.

Energy's Invisible World

You are probably familiar with the word *energy*. Besides the everyday use of the word to describe what you eat (energy foods, energy drinks) and how you feel (I had lots of energy, I completely ran out of energy), there are many other types of energy in the world around you. In this activity, you will examine different types of energy and how one type can be transferred into another. You will also observe how we know energy exists even though we cannot see it.

Procedure

1. In this activity, you will move around the room in teams to different stations where you will make observations about energy and its transfer.
2. Choose one team member to record your team's observations.
3. Start at the station designated by your teacher and follow the directions on your "Station Instructions" handouts for each station.
4. When you have completed all the stations, answer the questions on this handout individually. Then discuss your answers as a team.

Questions

Write your answers on a separate sheet of paper.

1. At which station(s) did you observe the following field effects?
   a) a magnetic field exerted a force on an object
   b) an electric field applied an attractive force on an object
   c) an electric field applied a repulsive force on an object
   d) an electric field caused the formation of a magnetic field
2. At which station(s) did you observe the following energy transfers?
   a) mechanical energy to heat energy
   b) electrical energy to heat energy
   c) potential energy to kinetic energy
   d) mechanical energy to kinetic energy
   e) kinetic energy to mechanical energy
   f) chemical energy to heat energy
   g) kinetic energy to sound energy
   h) electrical energy to light energy
3. At which of the stations did you observe one kind of energy being converted to more than one other kind of energy? Draw a simple diagram to show the steps in the conversion of energy at each of these stations.
4. The law of conservation of energy says that energy cannot be created or destroyed; the total energy in a closed system remains constant (a system is a group of interrelated parts that function together as a whole). Design a procedure showing how you would test this law by modifying the open-system setups at Station 5, 6, or 7.

Station 1–3 Instructions

Station 1

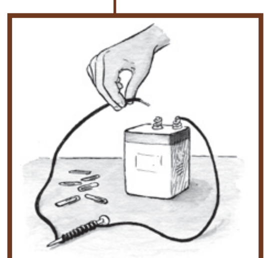
1. Rub a plastic spoon with a piece of wool, some fur, or your hair. Place the spoon next to a small piece of paper. Can you make the piece of paper stand on edge and move back and forth? Try to pick up several pieces of paper at the same time by touching the spoon to one edge of each.
2. Recharge the spoon by rubbing it again. Have a team member try to drop a small bit of plastic foam into the spoon from different heights above it.
3. Record your observations.

Station 2

1. Make sure the magnet is centered under the box. Sprinkle some iron filings on the center of the box. Tap on the edge of the box to distribute the filings evenly.
2. Draw a diagram of what you see.
3. Return the filings to their container.

Station 3

1. Pick up the loose nail and use it to try to pick up some of the paper clips. What happens?
2. Connect the wires to the battery. You have created an electromagnet. How many paper clips can you pick up with your electromagnet (nail)?
3. Record your data.
4. Carefully touch the head of the nail after the circuit has been connected for 30 seconds. What do you feel?
5. Disconnect the circuit and record your observations.



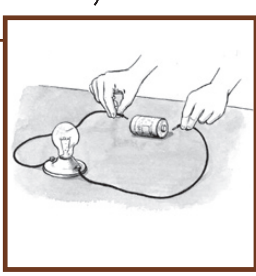
Station 4–7 Instructions

Station 4

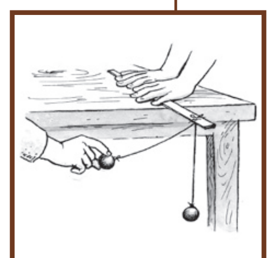
1. Designate a timer for the team. Use the cup at the front of the table. Insert the thermometer into the glycerin so that the thermometer tip is just above the bottom of the cup. Tape the thermometer to the side of the cup. After 1 minute record the temperature. (If needed, use the magnifying glass to read the scale; estimate to the nearest tenth of a degree.)
2. Holding the cup by the rim, vigorously stir the glycerin with the spoon the way you would beat an egg with a fork, striking the bottom of the cup. Do this for a total of 3 minutes.
3. Record the temperature of the glycerin as soon as you have finished stirring.
4. Remove your thermometer from the glycerin solution and place your cup, thermometer, and spoon at the back of the table. Move the other cup, thermometer, and spoon to the front for the next team.

Station 5

1. Connect the circuit that is set up at the station. Feel the light bulb for the first 15 seconds the circuit is closed.
2. Disconnect the circuit.
3. Record your observations.



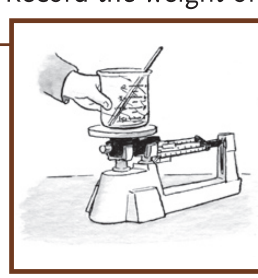
Station 6



1. If the pendulums are on a ruler or meter stick, have one team member brace the stick so that the pendulums are hanging over the side of the table. The pendulums should be touching one another.
2. Pull one of the pendulums back until it makes a 45-degree angle with the other pendulum. Release it. What happens to the other pendulum? Record your observations.
3. Now pull back one pendulum so that it is 90 degrees from the other (parallel to the table). Release it. Record your observations.

Station 7

1. Record your observations from the teacher demonstration of burning one splint.
2. Separately weigh the beaker with the wooden splint and the beaker with the remains of the splint that your teacher burned.
3. Record the weight of each beaker.



Pi Facts

On March 12, 2009 Congress passed and denoted that March 14th is officially National "Pi" Day.

The record has been broken (again)!

It's hard to imagine a trillion of anything (it's a million million), but Shigeru Kondo calculated 5 trillion digits of pi in August of 2011... and then blew that away with 10 trillion digits!

It was only a couple of years ago that Fabrice Bellard had calculated 2.7 trillion (2.7 thousand thousand million) decimal digits of pi. It took over 130 days, but he did it with a single PC (running Linux) and a very powerful algorithm. You can read about it on his Web site or in this BBC news article. Unfortunately, the digits have not been fully verified with a second run using a different algorithm.

Previous records: In September, 1999, Dr. Kanada of the University of Tokyo calculated 206,158,430,000 decimal digits of pi (approx.3*2^36). In September 2002, he and his team broke their own world record, calculating 1.2411 trillion digits (over six times more than before). Click here for another news report. And in August 2009, they calculated and verified 2.5 trillion digits.

For more on world records, see this Wikipedia entry.

Check out this amazing display of the first million digits of pi.

Pi Birthday

Here is a website that calculates your age in Pi Years
http://pidays.jtey.com/31/12/1968

π TRIVIA

1. Go to this site http://pamburke.wikispaces.com/Pi+Day It has three versions of "Are You Smarter Than a 5th Grader?" The format is the same for all three games, but they include different questions. There is also a pdf file with instructions for using and/or modifying the files.

2. Go to this site http://www.eveandersson.com/pi/trivia/?=and have students research and look up answers in one of these two books:
   The Joy of Pi by David Blatner or A History of Pi by Petr Beckmann.

Name: ______________________________________ Period: ________ Date: _______

PI SCAVENGER HUNT

1) What is the CIRCUMFERENCE of a circle?

http://www.math.com/school/subject3/lessons/S3U1L6GL.html

2) What is the DIAMETER of a circle?

http://www.mathgoodies.com/lessons/vol2/circle_area.html

3) What is PI the ratio of?

http://mathcentral.uregina.ca/RR/glossary/middle/

4) Is PI a rational or irrational number? Explain why.

http://www.mathisfun.com/irrational-numbers.html

5) What is PI to 30 decimal places?

http://gc3.net84.net/pi.htm

6) What value of PI did the Egyptians obtain 2000 years before Christ?

http://facts.randomhistory.com/2009/07/03_pi.html

7) What value of PI did the Babylonians obtain?

http://facts.randomhistory.com/2009/07/03_pi.html

8) About 150 AD, what value of Pi did Ptolemy of Alexandria (Egypt) figure?

http://www.ms.uky.edu/~lee/ma502/pi/MA502piproject.html

9) Find your birthday in PI. Type in your date of birth and record the location.

http://www.facade.com/legacy/amiinpi/

10) In the year 1997, D. Takahasi and Y. Kanada calculated PI to 51,539,600,00 decimal places. What type of computer did they use?

http://numbers.computation.free.fr/Constants/Pi/piCompute.html

11) Which fraction is closest to the actual value of PI... 337/120 or 22/7 or 355/113?
http://thestarman.pcministry.com/math/pi/pifacts.html

12) What does it mean to "Square a Circle"?

http://en.wikipedia.org/wiki/Squaring_the_circle

13) What is the symbol for pi? Who first used it and when? What Swiss mathematician was it popularized by?

http://www.ualr.edu/lasmoller/pi.html

14) Who were the first people known to find a value of pi? When was it?

http://thestarman.pcministry.com/math/pi/pifacts.html

15) In the first one million digits of pi, how many threes are there? How many nines?
http://www.eveandersson.com/pi/precalculated-frequencies

16) You can memorize PI by using things called "mnemonics". What is a "mnemonic"?
http://dictionary.reference.com/

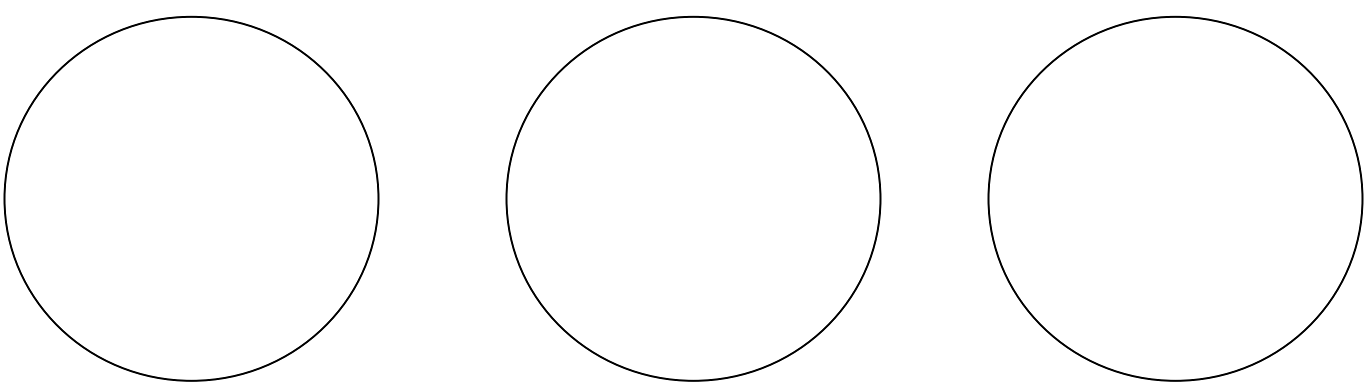
17) What was the most inaccurate version of PI? Explain who, when, and what the value was (sentence form). http://briantaylor.com/Pi.htm

18) Who memorized 42,195 digits of PI on Feb. 18, 1995? Where was the person from?
http://briantaylor.com/Pi.htm

19) What state in the US tried to pass a law to legislate the value of pi? When was it?
http://wwwmath.ucdenver.edu/~wcherowi/courses/history2/quad2.pdf

20) Label the circle(s) with the following vocabulary words: radius, chord, diameter, arc, semi-circle, inscribed angle, and central angle

http://www.math.com/school/subject3/lessons/S3U1L6EX.html



Pi Day Scavenger Hunt

3 Geometric solids which have circular cross-sections (turn in pictures, labeled with the names of the solids)
.
1 US city with a ZIP code containing the first 5 digits of pi – beginning with the 3 (name the city and state)
4 Capital letters of the alphabet – in block style – with rotational symmetry (list the 4 letters)
1 US state which tried to legislate a value for pi (name the state and the year in which the action was taken)
5 Formulas which include π (give the formulas in symbols and tell what each formula represents)
9 Labels or advertisements for products which use circles in their name or logo (turn in the actual labels or pictures from advertisements in newspapers, magazines, or from the internet)
2 US cities with names that have references to something circular – cities should not both be in the same state (name each city and state)
6 US state flags which include circles in their design (turn in pictures of the flags)
5 Sports or games which use a circle or a sphere in their play (turn in pictures of the circles or spheres from the games, labeled with names of the games)
3 Famous people with birthdays on March 14 (give name and year of birth)
5 Movie titles with references to something circular (list the movie titles)
8 Kinds of candy that comes in circular pieces (turn in packages or pictures of candy from advertisements or internet)
9 Song titles with references to something circular (list the song titles)
7 Recipes for different kinds of pie (turn in complete recipes)

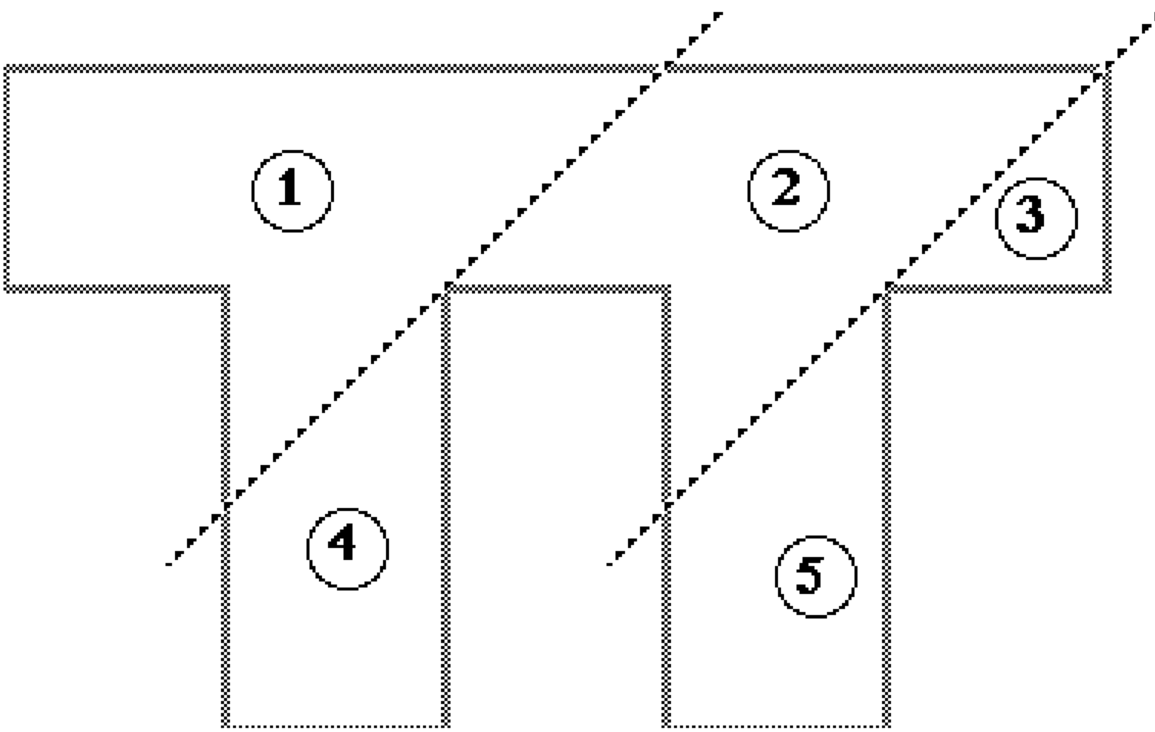
Warm-up problems

Roman Numeral

Review Roman numerals. Set up toothpicks like the problem below. Move only 1 toothpick to make the equation true. (Not allowed to make the equation unequal).

Pi Puzzle

Cut up the Greek letter Pi into five pieces. Rearrange the pieces to form a square.



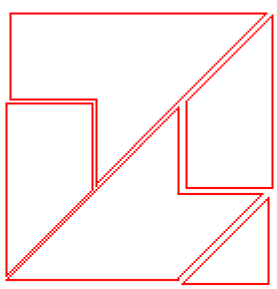
Puzzle Author: Stephen Froggatt

Answers:Warm-up problems

Roman Numeral

$$\frac{XXII}{VII} = \pi$$

Pi Puzzle



Tossing π

Materials
large sheet of drawing paper or cardboard
meterstick
pen
toothpicks (30 or more)
calculator

To Do and Notice
Draw a series of parallel lines on the paper or cardboard, as many as will fit, making sure that the distance between each line is exactly equal to the length of your toothpicks. Now, one by one, randomly toss toothpicks onto the lined paper. Keep tossing until you're out of toothpicks—or tired of tossing.

It's time to count. First, remove any toothpicks that missed the paper or poke out beyond the paper's edge. Then count up the total number of remaining toothpicks. Also count the number of toothpicks that cross one of your lines.

Now use this formula to calculate an approximation of pi:
Pi = 2 × (total number of toothpicks) / (number of line-crossing toothpicks)

What's Going On?
This surprising method of calculating pi, known as *Buffon's Needles*, was first discovered in the late eighteenth century by French naturalist Count Buffon. Buffon was inspired by a then-popular game of chance that involved tossing a coin onto a tiled floor and betting on whether it would land entirely within one of the tiles.

The proof of why this works involves a bit of meaty math and makes a delightful diversion for those so inclined. (See links at bottom of page.) Increasing the number of tosses improves the approximation, but only to a point. This experimental approach to geometric probability is an example of a *Monte Carlo method*, in which random sampling of a system yields an approximate solution.

Cutting π

Materials

circular object
string
scissors
tape

To Do and Notice

Carefully wrap string around the *circumference* of your circular object. Cut the string when it is exactly the same length as the circumference. Now take your "string circumference" and stretch it across the *diameter* of your circular object. Cut as many "string diameters" from your "string circumference" as you can. How many diameters could you cut? Compare your data with that of others. What do you notice?

What's Going On?

This is a hands-on way to divide a circle's circumference by its diameter. No matter what circle you use, you'll be able to cut 3 complete diameters and have a small bit of string left over. Estimate what fraction of the diameter this small piece could be (about 1/7). You have "cut pi," about 3 and 1/7 pieces of string, by determining how many diameters can be cut from the circumference. Tape the 3 + pieces of string onto paper and explain their significance.

Wearing π

Materials

cloth tape measures
calculators
hats with sizes indicated inside them

To Do and Notice

Most hat sizes range between 6 and 8. Brainstorm ideas for how such sizes could be generated. Then use measuring tape to measure people's heads. (As you do this, think of where a hat sits on a head). Use calculators to manipulate measurements. Now compare your results with the sizes written inside the hats. Do your numbers look like they could be hat sizes? (Hint: Try using different units of measurement.)

What's Going On?

Hat sizes must be related to the circumference of the head. The circumference of an adult's head usually ranges between 21 and 25 inches. The head's circumference divided by pi gives us the hat size.

Seeing π

Materials

can of three tennis balls
cloth tape measure

To Do and Notice

Which do you think is greater, the height or the circumference of the can? Measure to find out.

What's Going On?

If you were fooled (and we expect that most people are), blame pi.

You can see that the height of the can is approximately 3 tennis-ball diameters, or $h = 3d$. But the circumference is pi times the tennis-ball diameter, or $c = \pi d$. Pi—3.14—is a little greater than 3, so the circumference of the container is slightly greater than the height.

Measuring π

Materials

Circular Household items: cans, jars, glasses, lids, bowls, toilet paper rolls, pots, pans….

To Do and Notice

Measure the diameter and the circumference of many items. Divide the circumference "C" (all the way around) of the circle by the diameter "d" (the length from one side of the circle to the other).

$C \div d = \pi$

What's Going On?

You should have a clear understanding of the relationship between the circumference and the diameter. If you are giving other situations involving circles you should be able to apply this knowledge.

π Line Lab

Pi Line Lab http://illuminations.nctm.org/LessonDetail.aspx?id=L575

Students measure the diameter and circumference of various circular objects, plot the measurements on a graph, and relate the slope of the line to π, the ratio of circumference to diameter.

Learning Objectives

Students will:

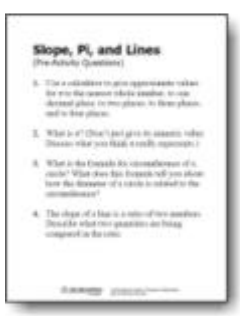
- Select appropriate scales to plot data collected.
- Write an equation of a line of the form $y = ax$.
- Interpret π as a ratio and as a slope.

Materials

Circular objects of various sizes
Masking tape (preferably, of bright color)
Scissors
Graph paper
Ruler or measuring tape
Graphing calculator (optional)

Instructional Plan

Display the first page of the Slope, Pi, and Lines overhead on the projector. Use these questions to conduct a brief discussion. Note that these questions are merely to set the stage for the activity; it is not necessary that each question be fully answered during the discussion.


Slope, Pi, and Lines
(Pre-Activity Questions)

Slope, Pi, and Lines Overhead

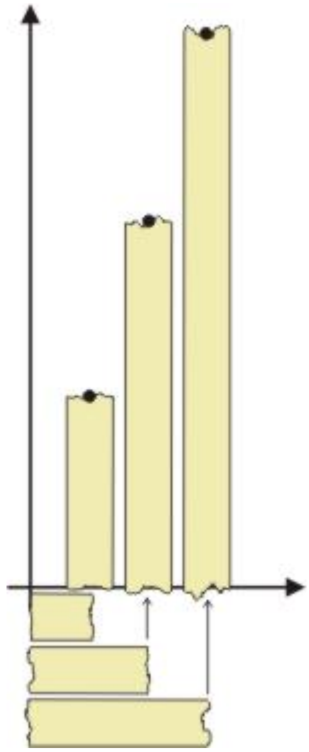
After the discussion, draw a coordinate plane on a whiteboard and label both axes with the same scale. (Actual measurements in centimeters or inches would be good, if the scale can go high enough to represent the circumference of the largest circle.) Points will only be plotted in the first quadrant.

Demonstrate the following process, which will be used during the lesson:

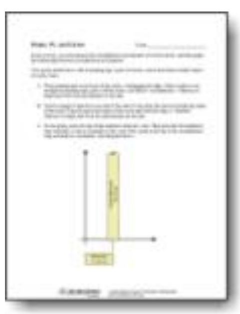
1. Wrap masking tape around the circle, overlapping the tape at the ends.
2. Cut the tape and put it on the whiteboard to display the circumference. Write the word **circumference** on the piece of tape.
3. Stretch another piece of masking tape across the widest part of the circle (the diameter) through the

center and cut off the ends. Write the word **diameter** on the strip of tape.

4. For each circle, stretch the tape for the diameter below the *x*-axis and parallel to it. At its end, position the tape for the circumference of that circle so that one end rests on the *x*-axis, and stretch the tape vertically. Plot and label the point at the top of the circumference strip. (See diagram below.)



Distribute the Slope, Pi, and Lines activity sheet. Students will answer the questions on this sheet as they proceed through the activity.



Slope, Pi, and Lines Activity Sheet

Divide students into groups of three students each. Each group will need several circular objects of different sizes, a roll of masking tape, a pair of scissors, and a whiteboard. Allow them to measure and record the diameter and circumference of at least three objects. More items can be used if time permits.

After all groups have plotted several points, reconvene the entire class. Ask students to use their data to predict the circumference and diameters of various circles if the other piece is known. For instance, ask them to predict the circumference if the diameter is 22 centimeters [approximately 69.1 centimeters], and ask them to predict the diameter if the circumference is 12 centimeters [approximately 3.8 centimeters]. Students should recognize that the points form a straight line and that the line can be extended to make predictions.

Discuss where the y-intercept of the line is likely to occur. Students should recognize that the points seem to be on a line that will pass through the origin. To reinforce the idea, ask the following questions:

- What is the *y*-coordinate of the *y*-intercept for any line? [0]
- In the context of this problem, what does an *x*-value of 0 mean? [In the graph, *x*-values represent the

diameter, so an x-value of 0 indicates that the diameter is 0.]

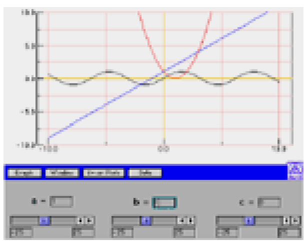
- For a circle with a diameter of 0, what is the circumference? [0]
- So, where *should* the y-intercept occur for the line in your graph? [At the origin.]

Have students estimate a line of best fit for their scatterplot. Note that this is best done *after* the discussion about the y-intercept. Although the masking tape measurements will give approximate points, students can be certain that the point (0,0) occurs along the line of best fit. Therefore, students can place a piece of uncooked spaghetti with one end at the origin, and move the other end to approximate the line.

Allow students to generate an equation that represents their line of best fit.

You may wish to have students enter the data that they gather into a graphing calculator and use the regression feature to find the line of best fit. Alternatively, students can use the Spreadsheet and Graphing Tool as follows:

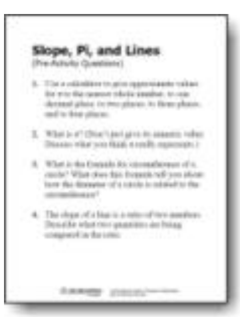
- Choose the **Data** tab. The diameters can be entered in Column A, and the circumferences can be entered in Column B.
- Select **Y= or Plots** and highlight *Plot 1: Column A, Column B*. A scatterplot of the data will appear when the **Graph** tab is selected. (The values in the **Window** tab may need to be adjusted to view all points in the scatterplot.)
- Return to the **Y= or Plots** tab. Students can estimate an equation for the line of best fit and return to the **Graph** to see how well their estimate approximates the data.


Spreadsheet and Graphing Tool

Discuss how the slope of the line relates to the circle. Ask, "What formula does the above equation of a line approximate; that is, what formula relates circumference to diameter?" Some students may know the answer to this question because they know the formula $C = \pi d$, and this question was discussed in the Pre-Activity Questions. Others may not, and this is a good opportunity to discuss the concept of "constant rate of change." If students have difficulty recognizing that the slope of their line is approximately π, it might be helpful to have them calculate the slope by hand using one of the data points and the y-intercept. Then, discuss what quantities are being compared.

Questions for Students

The following questions appear on the second page of the Slope, Pi, and Lines overhead.


Slope, Pi, and Lines

(Pre-Activity Questions)

Slope, Pi, and Lines Overhead

What does it mean to say that π is a ratio? What is being compared?

[Circumference is compared to diameter. Specifically, π is the ratio C:d.]

What does it mean to say that the slope of a line is a ratio? In this activity, what quantities were being compared?

[The slope of a line compares the ratio of change in y-values to change in x-values. In this activity, the change in circumference was compared to the change in diameter. Because this ratio is always equal to π, there is a constant rate of change.]

Does the ratio of circumference to diameter vary depending on the size of the circle or the type of measurement (in., cm)? Explain.

[No. The ratio of circumference to diameter is constant, because all circles are similar. What measurements are used has no impact on the ratio.]

How does your equation relating circumference and diameter relate to the slope intercept equation $y = mx + b$? What are the values of m and b in your equation?

[Written in slope-intercept form, the circumference formula would be $y = \pi x + 0$, meaning that $m = \pi$, and $b = 0$.]

Why are x and y considered variables, and why are m and b considered constants?

[The variables x and y represent quantities that change. Although also represented with lowercase letters, both m and b are not variables because their values do not change, so they are considered constants.]

Assessment Options

1. Use a "think-pair-share" strategy to have students discuss whether the ratio of circumference to diameter varies depending on the size of the circle. First, ask students to decide individually whether the ratio varies, and have the class vote. (You might want to use "two-finger voting" so that all students vote at the same time. Students raise one finger for the first choice or two fingers for the second choice.) If the voting reveals that some students think the ratio changes, pair those students with other students who think the ratio is constant. After discussion, have students revote. If some students still think the ratio varies, ask others to suggest ways of convincing the student that the ratio is constant. Suggestions might include calculating the ratio of circumference to diameter and calculating the slope of the line using various combinations of data points.
2. In their journals, allow students to summarize what it means that slope is a ratio and that π is a ratio.

Extensions

1. Allow students to consider the following situation:

   As a sports agent for athletes, June gets 15% of a player's earnings. Determine at least three different ordered pairs of the form (athlete's earnings, June's commission). Plot these points; find the equation of the line through the points; determine the slope of the line; and discuss the meaning of the slope of the line. Of what two quantities is the slope a ratio? How is this problem similar to the circle problem?
2. Give each group a sheet of centimeter graph paper with circles of different sizes drawn over the grid. Each group then estimates the radius of their circles as well as the area by counting squares. Students record the data for each circle as a point of the form (r,A) where $r$is the radius and A is the area. Students can then create a scatterplot of the points, but before they do so, have them speculate as to the shape of the graph; is it likely to be linear or quadratic? Students should then use the regression feature to find the equation of the graph and consider the coefficient of the variable. You might want to ask, "What would be a more accurate equation? How do you know?" [The area of a circle is given by the formula, $A = \pi r^2$, so the coefficient should be approximately π.] Use the formula to form at least six data points of the form (r, A). Plot the points and discuss why π is **not** the slope of a line in this situation. For a given area, have students use their graphs to estimate the

radius of the associated circle.

Teacher Reflection

- Did students develop a greater understanding of slope as a rate of change?
- Did students make the connection that pi is a ratio comparing circumference to diameter, no matter the size of the circle?
- How did you challenge the high-achievers in your class?
- Was your lesson appropriately adapted for the diverse learner?
- Did you set clear expectations so that students knew what was expected of them? If not, how can you make them clearer?

A Math Forum Web Unit   Jon Basden   jbasden@mac.com

The Derivation of π (Pi)

May	I	Have	A	Large	Container	of	Coffee
3	**1**	**4**	**1**	**5**	**9**	**2**	**6**

Jon Basden's Lessons || Teacher Exchange || TE: Grades 6-8

Grade Level

7th Grade

Approximate Time

Two forty minute class periods

Materials Required

- six or so circular objects of various sizes
- string
- meter sticks
- paper
- pencils
- student worksheets
- overhead transparency of student worksheet
- computer with spreadsheet program

Optional Materials

- Pre-made spreadsheet in Microsoft Excel 97
- Math Madness cassette tape -- the Pi Song
  (Can order from Bob Garvey for $8.50 at bgarvey@aol.com)
- First 1001 digits of Pi on overhead transparency

Sources

Modifications of:

- "Discovering Pi" lesson from Math in the Middle Handbook, Prentice Hall, 1993
- Circles - Diameter, Circumference, Radius and the Discovery of Pi

Description

1. Divide students into small groups.

2. Have each group measure diameter and circumference of each of the circular objects in the room. They should record their results on their student worksheets.
3. Students should complete the requirements on the worksheet. Hopefully, they will see the pattern that circumference divided by diameter is about 3.14159265358... (π).
4. Depending on time, space, and resources, the groups can begin taking turns entering their data into the spreadsheet, so that we can begin to see that the class averages for the C/d ratio is very close to pi each time.
5. From the generalizations that C/D = pi, the teacher can lead the students to see how we get the formulas $C = D\pi$ and $C = 2\pi r$.
6. To help the students avoid the common misunderstanding that the digits of Pi do not stop after 3.14, one may show them the first 1001 digits of Pi. This can aid them in visualizing the complexity of the number.
7. To reinforce the formulas that the students have generated, the teacher can assign an assignment that requires the students to apply the relationships between diameter, radius, and circumference.

Software

Microsoft Excel or other spreadsheet

Web sites

Pi Mathematics

Pi Pages

Pi through the ages

Assessment

The instructor will be able to informally assess the comprehension of the students as the lesson progresses. This will enable the instructor to determine if any additional lecture is needed concerning the relationship between circumference and diameter before additional examples are shown.

Also, before he or she assigns independent practice, he or she will check for understanding by asking questions of individual students, and he or she will have students work examples for the class.

More formal evaluation will come as a result of the students completing an independent assignment that allows them to practice using the formula for the circumference of a circle and to work backwards with the formula to find the radius and/or diameter if given the circumference.

Circumference vs. Diameter
Circle Measuring Activity

To complete these exercises, you will work in groups of three. Follow the directions on this sheet, beginning with the questions below. For questions, A, B, D, E, and F, you will need to write your answers on a separate sheet of paper. You may use this sheet to complete part C.

Questions:

A. Define *diameter.*

B. Define *circumference.*

There are six round items in the room. You will measure the circumference and diameter of each object. Give your measurements in **millimeters**. Fill in the table below for each item. Next, **add**,**subtract**, **multiply**, and **divide** the values in the "C" and "D" columns to complete the table.

C.

Number	Object	C (mm)	d (mm)	C + d	C - d	C * d	C / d
1.							
2.							
3.							
4.							
5.							
6.							

D. How do *circumference* and *diameter* appear to be related?

E. How are *radius* and *diameter* related?

F. How does this tell us that *radius* and *circumference* are related?

Spreadsheet for the Derivation of Pi

Below are the formulas that you could input into a spreadsheet to set it up so that the students can quickly enter their group's measurements. You can also **download a spreadsheet** in Microsoft Excel 97 format.

Row/Column Name	A	B	C	D
1	*Group*	*Circumference (mm)*	*Diameter (mm)*	*Ratio (C/d)*
2	R			=B2/C2
3	S			=B3/C3
4	T			=B4/C4
5	U			=B5/C5
6	V			=B6/C6
7	W			=B7/C7
8	X			=B8/C8
9	Y			=B9/B9
10	Z			=B10/C10
11	Averages	=AVERAGE(B2:B10)	=AVERAGE(C2:C10)	=AVERAGE(D2:D10)

Send comments to: Jon Basden - jbasden@mac.com

Finding the Square Root of π.

Objective: Students will use the Binary Search Method to find the approximate value of the square root of pi.

Materials:

-Worksheet
-Calculator

Pre-requisites:

-Definition of Rational and Irrational Numbers
-Squares/square roots of numbers
-Compare decimals: smallest to largest
-Finding averages

Procedure:

1. Review squaring a number and taking the square root of a number. Once they have mastered this concept have them use the calculator to find the square root of several numbers.
2. Explain to students that mathematicians wondered if it was possible to find the square root of pi. Because pi is irrational (definition: an irrational number cannot be written as a fraction. Irrational numbers are non-ending non-repeating decimals), it cannot have a rational (definition: a rational number can be written as a ratio (fraction)), square root. Then mathematicians started to look for a number that was close to a square root. In this activity students will go through the Binary Search Method and find a value that is close to the square root of pi $\sqrt{3.14}$
3. Use worksheet and go through a few of the sample steps as a whole group:

    - Assign values $S = 1$ and $L = 2$
    - $S^2 = 1$ and $L^2 = 4$
    - Since S^2 is farther away from pi then L^2, S gets replaced with the average of S and L [1 + 2 = 3 , 3 ÷ 2 =1.5]
    - Now assign values $S = 1.5$ and $L = 2$
    - $S^2 = 2.25$ and $L^2 = 4$
    - Since S^2 is farther away from pi then L^2, S gets replaced with the average of S and L [1.5 + 2 = 3.5, 3.5 ÷ 2 = 1.75]
    - Again assign values $S = 1.75$ and $L = 2$
    - $S^2 = 3.0625$ and $L^2 = 4$
    - Since L^2 is farther away from pi then S^2, L gets replaced with the average of S and L [1.75 + 2 = 3.75, 3.75 ÷ 2 = 1.875]
    - Have the students use the worksheet and continue this process until they find finer and finer bounds. Eventually they will get 1.77245… which is a good approximation. There is NOT an exact answer.
    -

Binary Search Method for Finding the Square Root of Pi

Mathematicians wondered if it was possible to find the square root of the irrational value of pi. They found by using the Binary Search Method they could get a good approximation.

Below is the process for the Binary Search Method use it to find the $\sqrt{3.14}$.

1. Pick a value smaller than the square root of pi and label it *S*.
2. Pick a value larger than the square root of pi and label it *L*.
3. Find S^2 and L^2
4. Which value is farther away from pi? If $S^2$is farther away then L^2 then replace *S* with the average of *S* & *L*., if not replace *L* with the average of *S* & *L.*
5. Repeat
6. Continue until there is a lower and upper bound for the square root of pi.

S = ____ *L* = ____

S^2 = ____ L^2 = ____

_____ is father from pi.

Find average of *S* & *L*

$\frac{S+L}{2}$ =______

Replace _____ with average.

S = ____ *L* = ____

S^2 = ____ L^2 = ____

_____ is father from pi.

Find average of *S* & *L*

$\frac{S+L}{2}$ =______

Replace _____ with average.

Calculating Pi

MATERIALS

- Pen and Paper
- Masking Tape
- Tape Measure
- Calculator
- Long, thin, straight, stiff food items, preferably a pack of frozen hot dogs between 15 to 20cm (6 to 8 inches) long
- Open Space about 180 to 300 cm (6 to 10 feet)

1. **Select a food item to throw**. There are a couple of qualifications. First, it must be long, thin, and straight, like a frozen hot dog, for example. Second, it must be a reasonably stiff item. Third, it should be somewhere between 15 to 20 cm (6-8 inches) long; the experiment can be performed otherwise, but read on, and you will see why this size is optimal. There are lots of other items that fit these criteria including Otter Pops, celery, and churros. (If you simply can't come to grips with throwing perfectly good food, see the Tips section for some additional ideas.)

2. **Select the spot from which to throw your mathematical cuisine**. You will probably need about 180-300 cm (6-10 feet) in front of you, as you will be throwing straight ahead.

3. **Clear the area**. The place at which you are throwing should be devoid of objects that your food item could possibly run in to.

4. **Measure the length of your projectile**. A tape measure should do the trick. Be as accurate as you can, even down to the millimeter, for best results. Since length is a factor, it’s best to choose food items that are all the same size. If you’ve chosen something that isn’t naturally uniform, such as celery sticks, cut them evenly beforehand.

5. **Lay down masking tape in parallel strips across the floor as far apart as your projectile is long**. The strips should be perpendicular to the direction you will be throwing. If your item is 15-45 cm (6-18 inches) long, lay down about 6-10 strips; lay down fewer if longer and more if shorter.

6. **Use the “Tosses & Crosses” Chart** The "Tosses" column is where you’ll keep track of how many times you throw your food item. The "Crosses" column is where you’ll keep track of how many times your item lands across one of the lines. (Note that landing is not the same thing as bouncing.)
7. **Get into position and THROW YOUR FOOD**! Throw just one item at a time. Once it is at rest, observe whether or not it is crossing one of the lines. If it is, put a tick under "Crosses" and a tick under "Tosses." If it isn't, just put a tick under "Tosses." When you’ve run out of hot dogs, pick them up and re-use them, making sure to throw from the same position. Repeat this as many times as you like. You should start seeing some interesting results by around 100 to 200 throws. (This doesn't take as long as it sounds.)

8. **When you’re done, divide the number of crosses by 2 and divide the number of tosses by that**. For example, if you threw 300 times, and it crossed 191 times, you would calculate 300/(191/2). And, to your amazement, you will now have an approximation for pi!

TIPS:

- If room is a concern, consider just drawing lines on a piece of paper and dropping toothpicks onto the paper from about 90 cm (3 feet) up. This definitely is not as refreshing as throwing food across the room, but it works.
- For those who are troubled by throwing perfectly good food, consider throwing sticks, dowels, or pencils. In fact, any item will do so long as it is long, thin, straight, stiff and hard. The thinner the better.
- This type of approach (essentially, using random numbers to experimentally solve a problem) is also known as Monte Carlo Simulation.
- The more the merrier! If two or three throw food together, you will get a better approximation faster because you will be able to get more throws in a shorter amount of time.
- A quick estimation of pi is 22/7; a much better one is 355/113 (note the memorable pattern of the digits); Or, you could just press the "pi" key on your calculator.
- For the mathematically-inclined, this experiment is actually real! The proof and other details can be found at mathworld.wolfram.com: Buffon Needle Problem.

TOSSES & CROSSES CHART

TOSSES	CROSSES	TOSSES	CROSSES	TOSSES	CROSSES	TOSSES	CROSSES
1		51		101		151	
2		52		102		152	
3		53		103		153	
4		54		104		154	
5		55		105		155	
6		56		106		156	
7		57		107		157	
8		58		108		158	
9		59		109		159	
10		60		110		160	
11		61		111		161	
12		62		112		162	
13		63		113		163	
14		64		114		164	
15		65		115		165	
16		66		116		166	
17		67		117		167	

18		68		118		168	
19		69		119		169	
20		70		120		170	
21		71		121		171	
22		72		122		172	
23		73		123		173	
24		74		124		174	
25		75		125		175	
26		76		126		176	
27		77		127		177	
28		78		128		178	
29		79		129		179	
30		80		130		180	
31		81		131		181	
32		82		132		182	
33		83		133		183	
34		84		134		184	
35		85		135		185	
36		86		136		186	

37		87		137		187	
38		88		138		188	
39		89		139		189	
40		90		140		190	
41		91		141		191	
42		92		142		192	
43		93		143		193	
44		94		144		194	
45		95		145		195	
46		96		146		196	
47		97		147		197	
48		98		148		198	
49		99		149		199	
50		100		150		200	

(2 ÷ ________________) × _______________ ≈ π (pi)

Total Crosses Total Tosses

___________ ≈ π (pi)

50 Minutes

Objective
The student will measure circumference and diameter with appropriate accuracy and precision. The student will graph circumference vs. diameter, determine the slope, and identify the physical significance of the slope.

TEKS
Physics 2E, 2F, 2H, 2J, 2L, and 3A

Guiding Questions
What is a testable hypothesis?
How will you get accurate and precise measurements?
How does a graph enable a prediction of a physically significant value?
What characteristics are present in a correct graph?

Materials
- Circular objects
- String
- Meter stick
- Ruler

Teacher Notes
- Work with partners or alone (not groups of 3).
- Allow students to design the experiment.
- Make sure they are measuring diameter and circumference not just calculating values.
- Make sure that there is a variety of different sized circular objects (different diameters).
- Classroom arrangement should include area for circular objects to be placed.
- Students should only take 2-3 objects at a time (allows for maximum time collecting data).
- At least 6 different objects will be measured.
- The student should find the slope of the c vs. d graph and realize that its physical significance is the value pi.
- First graph will be critiqued and students will be allowed to correct. (Corrected graph will be graded)
- Slope triangle or marked data points will be required on the graph as well as slope calculations.

Teaching Procedure
Graphing rules should be introduced before starting this lab. Ensure that AISD graphing rules are being followed to create graphs. Review how to find slope. Give a brief overview of the lab prior to placing students into lab partners. Teacher should be moving around the room reinforcing safety, answering questions, and helping guide discussion between partners.

Follow Up
-Teacher should be engaged in checking for understanding throughout the lab.
-Questions and answers section should provide proper formative assessment
-Teacher will show examples of correct and incorrect graphs, and allow students to critique and correct graphs.
-Peer grading of graphs will be done by using the rubric. After a peer has graded the graph the student will create a new final graph.

Testable Hypothesis:

Hypothesis should include what the relationship between circumference and diameter are (should include words such as directly related, indirectly related, inversely related etc.)

Questions and Answers

6. What is the value of your slope? ~3.14

7. What is the equation to find the circumference of a circle using diameter? $C= \pi d$

8. What is the slope-intercept equation for a line? $y = mx + b$

9. What is the physical significance of the slope? pi or π

Make sure that each student has had a peer grade(critique) his/her graph before making the corrected graph.

Name:______________________________ **Date:**____________

Period:____________

Objective

The student will measure circumference and diameter with appropriate accuracy and precision. The student will graph circumference vs. diameter, determine the slope, and identify the physical significance of the slope.

Materials

- Circular objects
- String
- Meter stick
- Ruler

Procedures

1. Sketch your prediction of a circumference vs. diameter graph below.

2. Plan and write a procedure to find the diameter and circumference of at least 6 different circular objects. (Measure to the nearest millimeter)

3. Perform your procedure to complete the data table below.

Data

Object #	Circumference (____) Your Group	Circumference (____) Other Group	Average Circumference (____)	Diameter (____) Your Group	Diameter (____) Other Group	Average Diameter (____)

Analysis

4. Construct a circumference vs. diameter graph following AISD graphing rules. (y-axis is circumference and x-axis is diameter).
5. On the graph calculate the slope of your line using a slope triangle.

6. What is the value of your slope? ___________________________

7. What is the equation to find the circumference of a circle using diameter? ________________

8. What is the slope-intercept equation for a line? y = _____________________

9. What is the physical significance of the slope? _________________________

Conclusion

Does you prediction graph match the graph of your data? Describe how circumference and diameter related? Are your results accurate and/or precise; how do you know?

π Geometry

Six Stations: Working in groups, ask students to find solutions to the problems presented at six stations. Spend approximately ten minutes at each station over a period of two days. The stations should be positioned in the classroom so that students can move from station to station in a clockwise fashion.

Station 1 - Pool Problem

Students are given the area of a circular pool and a distance from the edge where a circular fence will be constructed. They are to find the amount of fencing needed.

Station 2 - National Park Problem

Students are given sufficient information to find the circumference of a tree. They are to find the diameter of that tree.

Station 3 - Shaded Region Problem

Students are given three sketches involving the same square with a different number of circles within the square. They must determine which sketch has more shaded area.

Station 4 - Windshield Wiper Problem

Students are given the length of a windshield wiper, the length of a rubber wiping blade and the central angle of the sector. They must determine how much area is covered by the blade.

Station 5 - Pizza Problem

Students are given the diameter and the calories, per square unit, of a pizza. They must determine the measure of the central angle of a slice, given a restriction of number of calories per slice.

Station 6 - Tennis Can Problem

Students are given a tennis ball can filled with three tennis balls. They are to determine a relationship between the circumference of one tennis ball and the height of the can.

The Soda Can: Geometry in Industry:

1. Why is a soda can the shape or size that it is? One reason may be that the manufacturer wants to minimize the amount of aluminum used to make the can. This requirement involves finding the smallest surface area of the can whose shape is a cylinder. The volume of the soda can is fixed at 400 cubic centimeters. Use the volume with each radius to find the possible heights of different sized soda cans. Once the height column is completed calculate the surface areas. The results for r = 1 cm are already given. Round the height to the nearest tenth and the surface area to the nearest whole number.

Radius	Height	Surface Area
1cm		
2cm		
3cm		
4cm		
5cm		
6cm		
7cm		
8cm		

2. Graph the radii and the surface areas on a sheet of graph paper with the radius as the independent variable and the surface area as the dependent variable.

3. Based on the results of your research, what radius and height should you choose to minimize the amount of aluminum used in a soda can? Explain your conclusion.

4. Measure an actual soda can and record its dimensions (radius and height). How do these values compare to the results of your research?

π Algebra II

Objective - Students collect data and discover the functional relationships between varying quantities.

Collecting data - Students will be working in groups. They are provided with an assortment of cans, varying in height and radius. They will measure 10 different cans, using string and rulers, then record the measurements on a worksheet.

Activity - The students input this data into their TI-83 or 84. They then create a scatter plot and find the line of best fit and answer questions relating to the graph.

Explore π

1. Search pi for number combinations (birthdays, jersey numbers, lucky numbers) using the Pi Search Results Tool. It also allows you to view any section of pi in groups of 10 to 1000 digits.
   http://www.angio.net/pi/bigpi.cgi

2. Learn how to make a circle from three points on a plane and have fun manipulating nested circles with this interactive tool that shows students that circles are awesome.
   http://windowseat.ca/circles/

π Power Point Presentation

http://www.freeclubweb.com/powerpoints/math/pi.html

π Digit Distribution

Find the mean (average) of the first 100 digits.

π Puzzles

Try these one of the following Sudoku puzzles. Use these rules to complete: Each row, column, and jigsaw region must contain exactly the first twelve digits of pi, including repeats: 3.14159265358. Notice that each region will contain two 1's, two 3's, three 5's, and no 7's. Have Fun!

Pi Day Sudoku 2008

3			1	5	4			1		9	5
	1			3					1	3	6
		4			3		8			2	
5			1			9	2	5			1
	9			5			5				
5	8	1			9			3		6	
	5		8			2			5	5	3
				5			6			1	
2			5	1	5			5			9
	6			4		1			3		
1	5	1					5			5	
5	5		4			3	1	6			8

Rules: Each row, column, and jigsaw region must contain exactly the first twelve digits of pi, including repeats: 3.14159265358. Notice that each region will contain two 1's, two 3's, three 5's, and no 7's.

3	2	5	1	5	4	6	3	1	8	9	5
4	1	5	2	3	8	5	9	5	1	3	6
6	1	4	5	9	3	5	8	3	1	2	5
5	3	3	1	8	5	9	2	5	6	4	1
8	9	2	6	5	1	1	5	4	3	3	5
5	8	1	5	2	9	4	3	3	5	6	1
1	5	3	8	1	6	2	4	9	5	5	3
9	4	5	3	5	1	5	6	8	2	1	3
2	3	6	5	1	5	3	1	5	4	8	9
3	6	8	9	4	5	1	5	1	3	5	2
1	5	1	3	6	3	8	5	2	9	5	4
5	5	9	4	3	2	3	1	6	5	1	8

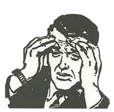
Pi Day Sudoku 2009

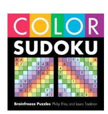
4	9	7	π	5							
	π		8			9	6	1	5	2	
	8		1				π		7		
							π		4		
5	3	9	6								
9	4		π	π	π	7					
					6	2	5	π		7	4
								π	π	3	8
	7	8	4	6	9						
		3		π			4	7	1	6	9
		4		1				6		π	
								4		5	

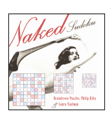
Rules: Fill in the grid so that each row, column, and jigsaw region contains 1-9 exactly once and π three times.

Submit your solution at brainfreezepuzzles.com to be entered in a drawing for a free puzzle book!

2009 Brainfreeze Puzzles







Pi Day Sudoku 2009

4	9	7	π	5							
	π		8			9	6	1	5	2	
	8		1				π		7		
							π		4		
5	3	9	6								
9	4		π	π	π	7					
					6	2	5	π		7	4
								π	π	3	8
	7	8	4	6	9						
		3		π			4	7	1	6	9
		4		1				6		π	
								4		5	

Rules: Fill in the grid so that each row, column, and jigsaw region contains 1-9 exactly once and π three times.

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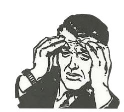
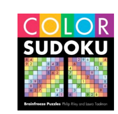
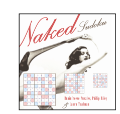
2009 Brainfreeze Puzzles







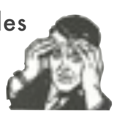
Pi Day Sudoku 2010

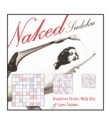
7	2							
	5				9			
				3	8			
			4			5		
		3				9		
		1			3			
			2	5				
			6				3	
							1	9

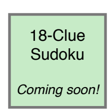
Rules: Fill in the grid so that each row, column, and block contains 1-9 exactly once.

This puzzle only has 18 clues! That is conjectured to be the least number of clues that a unique-solution rotationally symmetric puzzle can have.

To celebrate Pi Day, the given clues are the first 18 digits of $\pi = 3.14159265358979323...$







Pi Day Sudoku 2010

7	2							
	5				9			
				3	8			
			4			5		
		3				9		
		1			3			
			2	5				
			6				3	
							1	9

Rules: Fill in the grid so that each row, column, and block contains 1-9 exactly once.

This puzzle only has 18 clues! That is conjectured to be the least number of clues that a unique-solution rotationally symmetric puzzle can have.

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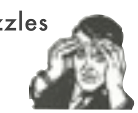
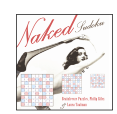
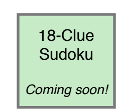
2010 Brainfreeze Puzzles

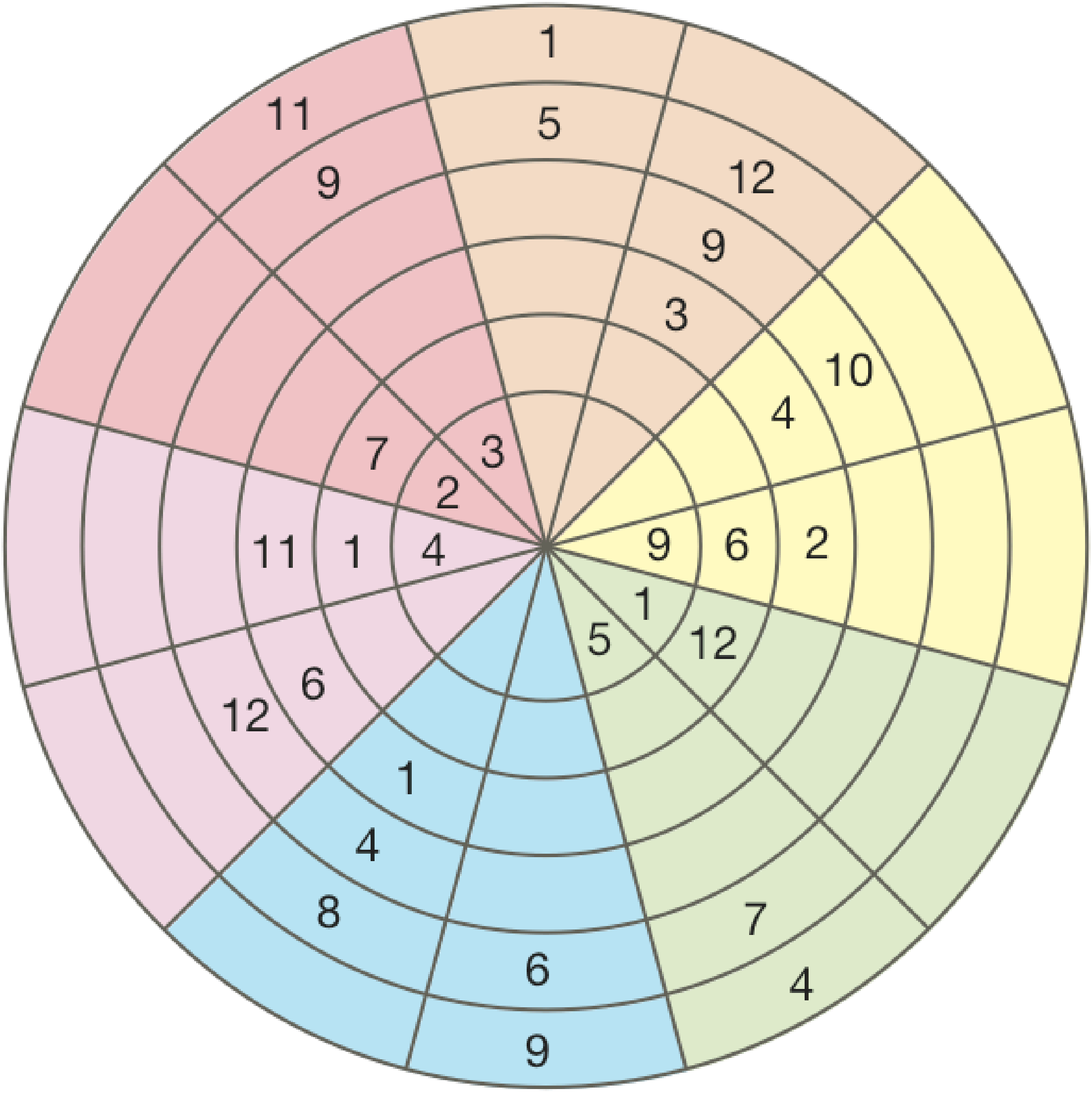






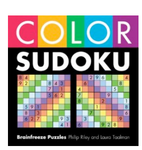
Does your school paper need Sudoku? Contact filora@brainfreezepuzzles.com.

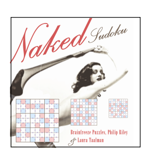
Pi Day Sudoku 2011 - PIE SUDOKU



Rules: This pie has 12 wedges. Fill in the grid so that the numbers 1-12 appear exactly once in each region of the pie. There are three types of regions in this pie, each containing 12 cells. They are: each of the six rings going all the way around the pie; each of the six pairs of opposite wedges; and each of the six adjacent pairs of wedges of the same color.

Contest!
Visit brainfreezepuzzles.com to find out how to submit your completed puzzle as an entry in our contest. You could win a free book!





The Never-Ending Number Story

Use the TP-CASTT worksheet to analyze Wislawa Szymborska's poem Pi.

Pi by Wislawa Szymborska

The admirable number pi:
three point one four one.
All the following digits are also just a start,
five nine two because it never ends.
It can't be grasped, six five three five, at a glance,
eight nine, by calculation,
seven nine, through imagination,
or even three two three eight in jest, or by comparison
four six to anything
two six four three in the world.
The longest snake on earth ends at thirty-odd feet.
Same goes for fairy tale snakes, though they make it a little longer.
The caravan of digits that is pi
does not stop at the edge of the page,
but runs off the table and into the air,
over the wall, a leaf, a bird's nest, the clouds, straight into the sky,
through all the bloatedness and bottomlessness.
Oh how short, all but mouse-like is the comet's tail!
How frail is a ray of starlight, bending in any old space!
Meanwhile two three fifteen three hundred nineteen
my phone number your shirt size
the year nineteen hundred and seventy-three sixth floor
number of inhabitants sixty-five cents
hip measurement two fingers a charade and a code,
in which we find how blithe the trostle sings!
and please remain calm,
and heaven and earth shall pass away,
but not pi, that won't happen,
it still has an okay five,
and quite a fine eight,
and all but final seven,
prodding and prodding a plodding eternity
to last

TP – CASTT Poetry Analysis

Title: Consider the title and make a prediction about what the poem is about

Paraphrase: Translate the poem line by line or word by word and put it into your own words. Look for complete thoughts and use a thesaurus to look up unfamiliar words.

Connotation: Examine the poem for meaning beyond the literal. Look for figurative language, imagery, and sound elements. What is being compared?

Attitude/Tone: What is the author's attitude or tone? Humor? Sarcasm? Awe?

Shift: Note any shift or changes in attitude, mood or motif. Look for key words, time change, punctuation changes.

Title: Examine the title again. Interpret what the poet feels about the subject of the poem.

Theme: Briefly state in your own words what the poem is about(subject), then what the poet is saying about the subject (theme)

"Pi" Sound Vocabulary

Each of the clues has an answer that begins with the sound *pi*.

1. Pertaining to fireworks
2. A tube
3. A large snake
4. A fruit
5. A portico
6. One who prepares the way
7. A mineral
8. A typographic unit of measure
9. Reverence
10. Musical instrument
11. An outlaw, typically at home on a ship
12. A kind of spice or pickle
13. A measure of volume
14. A guide
15. Spotted or blotched, especially of black and white
16. A square column that projects from wall
17. Objects laid on top of each other
18. A philosopher

Answer Key

1.	Pertaining to fireworks	pyrotechnic
2.	A tube	pipe
3.	A large snake	python
4.	A fruit	pineapple
5.	A portico	piazza
6.	One who prepares the way	pioneer
7.	A mineral	pyrites
8.	A typographic unit of measure	pica
9.	Reverence	piety
10.	Musical instrument	piano
11.	An outlaw, typically at home on a ship	pirate
12.	A kind of spice or pickle	pimento
13.	A measure of volume	pint
14.	A guide	pilot
15.	Spotted or blotched, especially of black and white	piebald
16.	A square column that projects from wall	pilaster
17.	Objects laid on top of each other	pile
18.	A philosopher	Pythagoras

π BOOKS

Pi Unleashed by Jorg Arndt
In the 4,000-year history of research into Pi, results have never been as prolific as present. This book describes, in easy-to-understand language, the latest and most fascinating findings of mathematicians and computer scientists in the field of Pi. Attention is focused on new methods of high-speed computation.

Why Pi? by Johnny Ball
This entertaining follow-up to DK's popular *Go Figure!, Why Pi?* presents even more mind-bending ways to think about numbers. This time, author Johnny Ball focuses on how people have used numbers to measure things through the ages, from the ways the ancient Egyptians measured the pyramids to how modern scientists measure time and space.

A History of Pi by Petr Beckman
The history of pi, says the author, though a small part of the history of mathematics, is nevertheless a mirror of the history of man. Petr Beckmann holds up this mirror, giving the background of the times when pi made progress -- and also when it did not, because science was being stifled by militarism or religious fanaticism.

The Joy of Pi by David Blatner
The Joy of Pi is a book of many parts. Breezy narratives recount the history of pi and the quirky stories of those obsessed with it. Sidebars document fascinating pi trivia (including a segment from the 0. J. Simpson trial). Dozens of snippets and factoids reveal pi's remarkable impact over the centuries. Mnemonic devices teach how to memorize pi to many hundreds of digits (or more, if you're so inclined). Pi-inspired cartoons, poems, limericks, and jokes offer delightfully "square" pi humor. And, to satisfy even the most exacting of number jocks, the first one million digits of pi appear throughout the book.

Piece of Pi by Nalia Bokhari
There are some topics or problems that have captured the interest of mathematicians for ages. Calculating pi is one of them. Although students often encounter pi in the mathematics classroom when applying various formulas, rarely do they use or explore pi in other contexts. This marvelous infinite number we know as pi shows up in many fascinating and mysterious ways. It can be found everywhere, from astronomy and probability, to the physics of sound and light. It is one of the most important numbers that exists.

Help your students discover the number that has intrigued mathematicians for centuries. Learn different ways pi has been calculated through the ages, use pi to figure your hat size, perform a variety of experiments to estimate the value of pi, or relate pi to the alphabet. These interesting and exciting activities encourage higher order thinking and offer a complete overview of this important number while giving students practice in important math skills.

This guide includes detailed lesson plans (referenced to NCTM standards) and reproducible student worksheets. Use them for Pi Day (March 14), as an enrichment or extension to your existing curriculum, or to challenge your most able math students.

Not Awake: A Dream Embodying (pi)'s Digits Fully for 10000 Decimals by David Keith & Diana Keith

Not A Wake" is a collection of poetry, short stories, a play, a movie script, crossword puzzles and other surprises, constructed according to a unique principle: counting the number of letters in successive words of the text (the first word has 3 letters, the next word has 1 letter, the next word has 4 letters, and so on) reveals the first 10,000 digits of the famous mathematical number pi (3.14159265358979...). Fans of the number pi, constrained writing (such as Georges Perec's "La Disparition"), wordplay, puzzles, or experimental prose and poetry will find much to savor in this, the first book-length work based on the pi constraint.

Pi the Great Work by Marty Leeds

Pi - The Great Work is an inspiring journey through anthropology, archaeology, alchemy, religion, spirituality, science, astrology, astronomy, numerology, linguistics, symbolism, music, riddle and rhyme. All viewed through the lens of Pi. It is an exploration of sacred number, geometry and the mathematics that rule our Universe. It is a study of oneself.

Pi in the Sky by Wendy Mass

Joss is the seventh son of the Supreme Overlord of the Universe. His older brothers help his dad rule the cosmos, but all Joss gets to do is deliver pies. That's right: pies. Of course, these pies actually hold the secrets of the universe between their buttery crusts, but they're still pies.

Joss is happy to let his older brothers shine. He has plenty to keep his hands full: attempting to improve his bowling score; listening to his best friend, Kal, try (and fail) to play the drums; and exploring his ever-changing home, The Realms. But when Earth suddenly disappears, Joss is tasked with the seemingly impossible job of bringing it back. With the help of Annika, an outspoken girl from Earth, he embarks on the adventure of a lifetime...and learns that the universe is an even stranger place than he'd imagined.

Sir Conference & the Dragon of Pi (A Math Adventure) by Cindy Neuschwander & Wayne Geehan

Sir Cumference, Lady Di of Amter, and Radius are back in their second Math Adventure! This time, a potion has changed Sir Cumference into a fire-breathing dragon. Can Radius change him back?
Join Radius on his quest through the castle to solve a riddle that will reveal the cure. It lies in discovering the magic number that is the same for all circles.

Pi: A Biography of the World's Most Mysterious Number by Alfred Posamentier

This enlightening and stimulating approach to mathematics will entertain lay readers while improving their mathematical literacy. We all learned that the ratio of the circumference of a circle to its diameter is called pi and that the value of this algebraic symbol is roughly 3.14. What we weren't told, though, is that behind this seemingly mundane fact is a world of mystery, which has fascinated mathematicians from ancient times to the present. Simply put, pi is weird. Mathematicians call it a "transcendental number" because its value cannot be calculated by any combination of addition, subtraction, multiplication, division, and square root extraction. This elusive nature has led intrepid investigators over the years to attempt ever-closer approximations.

π Movies/Videos

Pi (1998)
A paranoid mathematician searches for a key number that will unlock the universal patterns found in nature.

Life of Pi (2012)
A young man who survives a disaster at sea is hurtled into an epic journey of adventure and discovery. While cast away, he forms an unexpected connection with another survivor: a fearsome Bengal tiger.

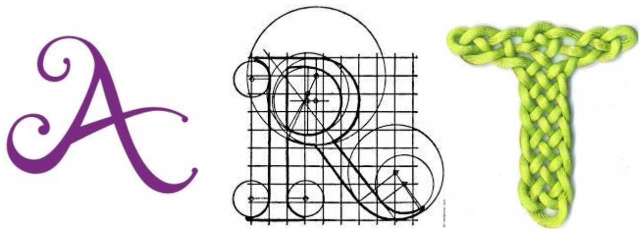
The Story of Pi http://www.projectmathematics.com/storypi.htm
The program opens with a reporter interviewing young people, asking "What can you tell me about the number pi?" Each person gives a different answer, some of which are only partially correct.
The program defines pi as the ratio of circumference to diameter of a circle, and shows how pi appears in a variety of formulas, many of which have nothing to do with circles. After discussing the early history of pi, the program invokes similarity to explain why the ratio of circumference to diameter is the same for all circles, regardless of size. This ratio, a fundamental constant of nature, is denoted by the Greek letter pi, so that 2 pi r represents the circumference of a circle of radius r.
Two animated sequences show that a circular disk of radius r can be dissected to form a rectangle of base pi r and altitude r, so the area of the disk is pi r squared, a result known to Archimedes. Animation shows the method used by Archimedes to estimate pi by comparing the circumference of a circle with the perimeters of inscribed and circumscribed polygons.
The next segment describes different rational estimates for pi obtained by various cultures, and points out that pi is irrational. After demonstrating the appearance of pi in probability problems, the program returns briefly to the reporter, who interviews the students again, asking, "Now what can you tell me about pi?" This time, each student gives a different correct statement about pi. The concluding segment explains that major achievements in estimating pi represent landmarks of important advances in the history of mathematics.

Recite Pi http://www.youtube.com/watch?v=mjuU_c3brBo&feature=youtu.be
Video of a 12-year-old boy named Meedeum from Maadi south Cairo, Egypt reciting Pi to the 120th place

Domino Pi http://www.youtube.com/watch?v=Vp9zLbIE8zo
Watch this COOL 3.14 minute video of a domino spiral creation.

Numberphile videos about the most famous ratio of all - Pi.
http://www.youtube.com/playlist?list=PL4870492ACBDC2E7C

- Calculating Pi with Pies
- Pi and the size of the Universe
- How Pi was nearly changed to 3.2
- Sounds of Pi
- Pi and Buffon's Matches
- Pi and the Bouncing Balls
- Pi
- Tau vs Pi Smackdown
- Tau Replaces Pi



1.Circle Art

Have students create pictures using only colored cut out circles.

2.Pi Paper Chains

Different colored paper strips are paired with numbers (e.g., blue for 2, red for 4). The strips are then linked in the order of π (3.1415…). The chain can be as long or as short as time and interest allow.

Materials

- Construction paper of ten different colors cut into strips
- Stapler or tape

Procedure

- Decide which color will represent which number.
- Create your paper chain by taking a strip of paper in the color you have chosen to represent the number 3 and making it into a loop. Close the loop with a stapler or piece of tape.
- Take a strip that represents the number 1 and thread it through your loop. Close the loop.
- Repeat with the strips that match the numbers in πso that you have a visual representation of π. How long can you make it? Here are the first 500 decimal places to get you started:

3.1415926535	8979323846	2643383279	5028841971	6939937510	5820974944
5923078164	0628620899	8628034825	3421170679	8214808651	3282306647
0938446095	5058223172	5359408128	4811174502	8410270193	8521105559
6446229489	5493038196	4428810975	6659334461	2847564823	3786783165
2712019091	4564856692	3460348610	4543266482	1339360726	0249141273
7245870066	0631558817	4881520920	9628292540	9171536436	7892590360
0113305305	4882046652	1384146951	9415116094	3305727036	5759591953
0921861173	8193261179	3105118548	0744623799	6274956735	1885752724
8912279381	8301194912				

3. Homemade Spirograph

Try this geometric drawing that produces mathematical roulette curves of the variety technically known as hypotrochoids and epitrochoids.

Materials

- A round cake pan (or other flat, round pan)
- Cardboard
- Scissors
- A rubber band
- A pencil
- Paper
- Tape

Procedure

1. Measure the diameter of the cake pan.
2. Draw a circle with a diameter half that of the pan. You can do this easily by making one side of the square you use to draw the circle (as described in the activity above) the length you want for the diameter.
3. Trace it on the piece of cardboard.
4. Put the rubber band around the edge of the piece of cardboard.
5. Cut out a piece of paper to fit the bottom of the pan and use tape to hold the paper in place so it doesn't move around.
6. Poke a hole in the middle of the cardboard. If you don't want to make circles, you can get weird shapes by making the hole away from the center of the circle.
7. Put the pencil in the hole and move the circle around the cake pan. Hold the edge of the pan with one hand so the pan doesn't move while you're moving the circle. The circle will guide the pencil to make cool shapes on the paper in the bottom of the pan. Try it with different color fine tip markers. The circles you're drawing are called hypotrochoids.

If you want to try this same idea on the computer, this Web site lets you try it: http://wordsmith.org/~anu/java/spirograph.html

(We need to give credit for this idea to Martin Gardner, a mathematician who wrote about cool things to do with math in Scientific American).

MUSIC

1. Try this amazing activity! It allows your students to play pi as a musical sequence! Simply pick ten notes, which are then assigned to integers, and then listen to what pi sounds like!
   http://avoision.com/experiments/pi10k

2. **Listen to Kate Bush"s song "π" from her album Aerial**

3. **Sing the song "We Wish You a Happy Pi Day" by Dianna**
   sung to the tune of We Wish You a Merry Christmas.

   We wish you a happy Pi Day
   We wish you a happy Pi Day
   We wish you a happy Pi Day
   To you and to all

   Pi numbers for you
   For you and for all
   Pi numbers in the month of March
   So three point one four

4. **Sing Happy Birthday to Albert Einstein**

5. **Listen and Watch Pi Day songs here:**
   http://www.piday.org/topics/videos/

6. **Listen to this American Pie parody "Mathematical Pi"**
   http://www.youtube.com/watch?v=_BwKZEp2K_0

7. **Sing one of the Pi Carols on the next page**

Oh, Number Pi

(to the tune of *O, Christmas Tree*)

Oh, number Pi, Oh, number Pi
You're truly transcendental.
Oh, number Pi, Oh, number Pi
You're physical and mental.
You stretch the bounds...of all we know,
And tell our circles where to go
Oh, number Pi, Oh, number Pi
Your digits are so gentle.

Oh, number Pi, Oh, number Pi
Why can't I learn you faster?
Oh, number Pi, Oh, number Pi
You're really hard to master.
Just when I think...I've got you down
I flip a 6 and 5 around
Oh, number Pi, Oh, number Pi
Numerical disaster!

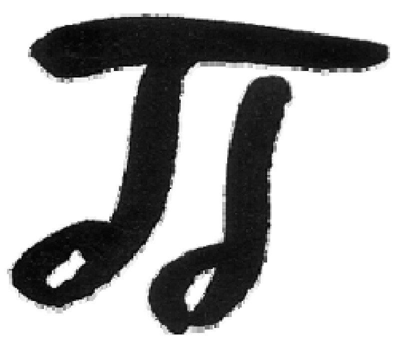
Oh, number Pi, Oh, number Pi
Why are you so specific?
Oh, number Pi, Oh, number Pi
Your digit growth's terrific.
Ten years ago, you had a Mill
And now you're at a couple Trill
Oh, number Pi, Oh, number Pi
You stretch to the Pacific!

Pi Day Time

(to the tune of *Silver Bells* , starting at "City sidewalks…")

Random digits,
Endless digits
Transcendental in style,
In the air there's a feeling of Pi Day.
Children laughing,
People graphing,
Worry-free for a while,
And in every math classroom you'll hear…

Three one four…
One five nine…
It's Pi Day Time at *(our school!)* .
Three one four…
One five nine…
Savor those numbers, today!



Ludolph The Mathematician

(to the tune of *Rudolph The Red-Nosed Reindeer*)

We know Einstein and Euclid and Sir Isaac Newton
Lifelong devotions there ain't no disputin'
But do you recall…
The most tireless one of them all?

Ludolph the Mathematician
Had a special thing for Pi
He made it his life's mission
To help the number specify

All of his fellow teachers
Never understood his plan
To unlock the number's magic
By calculating it by hand!

Then in 1599,
Ludolph set his goal...
I'll find digit 35
With geometry as my guide!

Then how the math world loved him
All his hard work helped them see
Ludolph the Mathematician
You'll go down in history!

Ring The Bells

(to the tune of *Jingle Bells*)

Basking in the glow
Of a Math Class holiday.
All we need to know
Is "Pi will lead the way!"

To circles we will sing,
The digits we'll recite
The ratio gives us everything
It's geometry's delight! Oh!

Ring the bells, Pi Day spells
Fun with 3 - 1 - 4!
It's the day to celebrate
That number we adore! Oh!

Ring the bells, Pi Day spells
Fun with 3 - 1 - 4!
First we take one slice of Pi
And then we ask for more!

Pi Jokes

Q. What is a math teacher's favorite dessert?
A. Pi!

Q: What do you get if you divide the circumference of a pumpkin by its diameter?
A: Pumpkin pi.

Q: What do you get when you take the sun and divide its circumference by its diameter?
A: Pi in the sky.

Q: How many pastry chefs does it take to make a pie?
A: 3.14.

Q: What is 1.57?
A: Half a pie

Q: What was Sir Isaac Newton's favorite dessert?
A: Apple pi

Q: What is the ideal number of pieces to cut a pie into?
A: 3.14

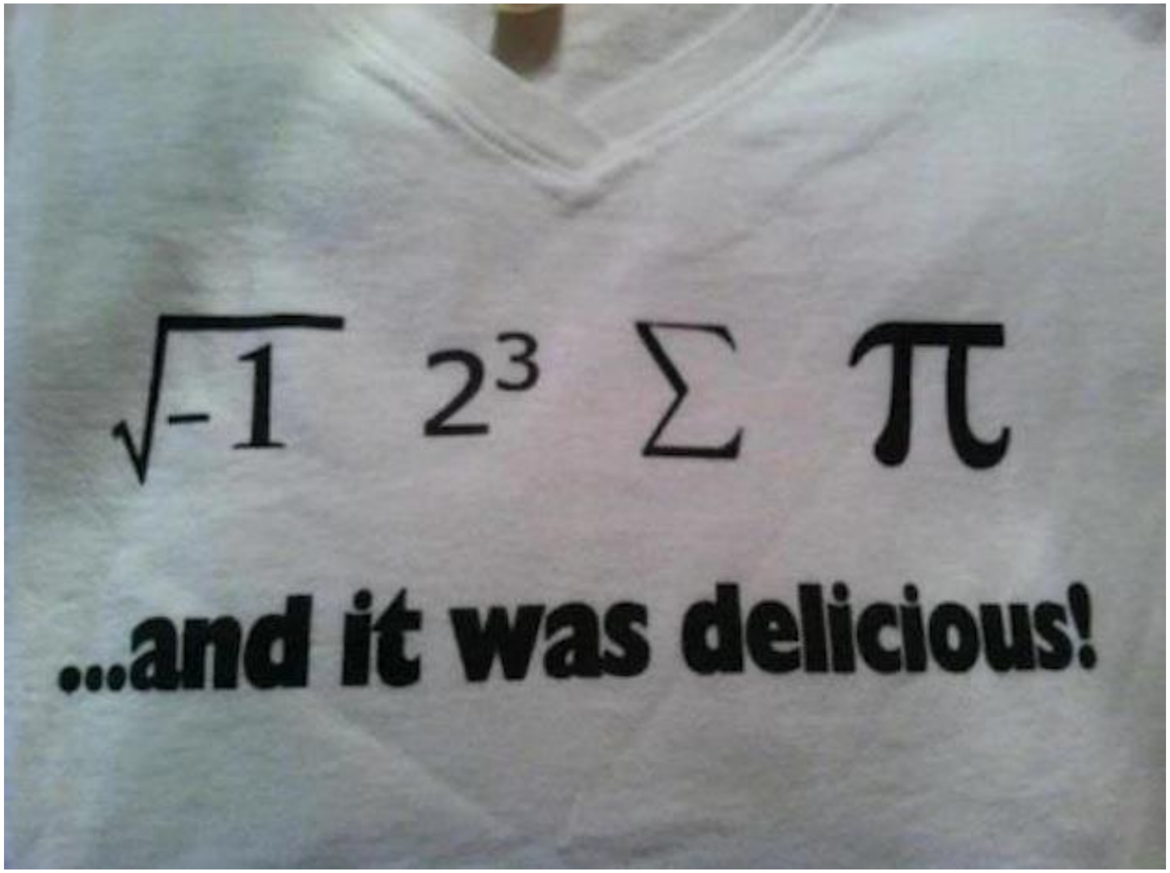
Q: What do you get when you take a bovine and divide its circumference by its diameter?
A: Cow pi.

Q: What do you get when you take green cheese and divide its circumference by its diameter?
A: Moon pi.

Q: What do you get when you take a native Alaskan and divide its circumference by its diameter?
A: Eskimo pi.

Q: What do you get if you divide the circumference of a bowl of ice cream by its diameter?

A: Pi a la mode. Mathematician: Pi R squared Baker: No! Pie are round, cakes are square!



i 8 SUM Pi


The roundest knight at Sir Arthur's table was Sir Cumference
He gained weight by eating too much Pi.
SO MUCH PUN.COM

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http://media-cache-ak0.pinimg.com/originals/d3/86/8d/d3868d3c7807b436902703ca267b5185.jpg scavenger hunt

3.1415926

535897932 3

8462643383 27950

28841971693993751058 2

0974944592307816406286208998

6280348253421170679821480865132823066

4709384460955058223172535940812848111745 0

28410270193852110555964462294895493038196442881097566593

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Nearly 1,500 digits of Pi. Chart by Susan Midlarsky, http://susanmidlarsky.com, 2011.