Mathematics Educators of Greater St. Louis

www.megsl.org

Pi Day Activities

St. Louis Community College
Forest Park Campus
3 February 2016

The Mission of Pi Day

Pi Day openly promotes the celebration of mathematics education; the collective enjoyment of mathematics; and the ageless, multicultural interest in pi. Educators, students, and parents are encouraged to join together in a variety of public activities, expressing in imaginative ways, their passion for the longstanding creative nature of mathematics. ■

The MEGSL Pi Day Committee

Chip Day, Debbie Char, Nancy English, Teresa Huether, Jenny Santee, Nevels Nevels, Tony Fressola, Shelia Hobson, and Gene Potter

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National Pi Day, March 14 … π

Since 2002, the St. Louis Science Center (SLSC) and MEGSL have worked closely together to celebrate Pi Day. The celebration will be held at the St. Louis Science Center over the weekend closest to Pi Day (March 14).

There will be a variety of activities for students in grades elementary through high school. Several activities and demonstrations have already been planned, but volunteers are still needed for the various stations.

*** Those willing to become **Pi-oneers** by volunteering for a few hours on Pi Day at the Science Center may contact Gene Potter at pottergene@msn.com. Please use "Pi" in the subject line. ■

Acknowledgements: The articles herein were compiled from various sources including MCTM, previous MEGSL Pi Day booklets, numerous Pi Day websites, *The Joy of Pi*, *Pi: A Source Book*, and contributions from Pat Kennedy and Gene Potter. Semper pi. ■

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A Teacher's Notes

Pi Day – March 14

- **Happy Birthday π**. In 1706, William Jones was to first to introduce the Greek letter π for the familiar value known as 3.141592…

- David Blatner's ***The Joy of Pi*** is a wonderful book for any mathematics teacher and school library. There are wonderful ideas for pi day at www.joyofpi.com.

- Science teachers enjoy Mole Day, October 23, celebrating Avogardro's Constant 6.02×10^{23}. Communication Skill teachers celebrate Shakespeare's birthday on April 23. Now, **MEGSL invite mathematics teachers to celebrate Pi Day, March 14.**

- Pi Day has for several years been celebrated in a non-organized fashion throughout the United States, Canada and scattered locations over the globe. Some identify Pi Day as World Pi Day; others as **National Pi Day**.

- Pi Day is also the birthdays of Albert Einstein.

- Hold a **Pi Digits Contest**. How many digits of π can you recite? Can you make the 100 Club?

- Wear a **Pi T-shirt** on Pi Day. Some sites offer discounts available for groups. Google.

- Elementary and Middle schoolers will enjoy these books: **"Sir Cumference and the First Round Table"** and "**Sir Cumference and the Dragon of Pi**." by Cindy Neuschwander. There are others.

- Excellent **Pi Day Activities for all levels** are celebrated at TeachPi.org.

- **Archimedes**, circa 250 BC, identified pi as the same constant used to calculate area and perimeter of circles, and for surface area and volume of spheres. In 1761, Johann Lambert proved that pi is irrational, and in 1882, Ferdinand von Lindemann proved that pi is a transcendental number. Explore Archimedes' Method at cut-the-knor.org.

- Math Teachers are **π-lingual.**

- $\int^{r} 2\pi x \, dx = \pi x^2 \Big|^{r} = \pi r^2$. The integral of circumference yields the area of the circle.

- If your birthday is March 14, then you are a **Pi-Baby**. How many students in your school are Pi-Babies?

- "**The Story of Pi**" (DVD 1) and "**The Early History of Mathematics**", are available from the CalTech Bookstore under Project Math. The episode of NOVA, **"The Great Math Mystery",** is available from shoppbs.org. Except for a few early scenes, **"The Life of Pi"** is not about the number known as pi. **DO NOT** waste your classroom time with the movie,"Pi". It's rated **R** for very disturbing images.

- Fundraiser: Mathletes can take orders for **(pi)eing** a friend for a local charity. Whipped cream pies?

- Archimedes demonstrated that the volume and surface of a sphere is 2/3 of its enclosing cylinder.

- Write a π poem or sing a **Pi-thagorean** Chant. Maybe over the PA?

- You can **find your birthdate** in the digits of pi. Google. Multiple sites.

- Buffon's Needle Experiment. Google. Multiple sites. mste.illinois.edu/activity/buffon/

- Compare a 8-inch square pizza with a 9-inch round pizza. Which one is greater? By how much?

- List geometric formulas involving π each day during **Pi Week**. The area of a zone of a sphere is $2\pi R \cdot h$. The surface area of a torus (ring) is $4\pi^2 rR$. The surface area of a RC cone is $\pi r \cdot$slant length.

- **Enjoy a P_π (a piece sub pie) on π day**. Small Tippin pies are sold for $3.14 on Pi Day at Dierbergs.

- Create a **Student Pi Chain** by having each student hold a digit of pi, and parade a-round your school.

- Have students work together to create a **Pi Chain** out of construction paper, assigning different colors to each digit of pi. Drape the chain down the hallway or around the cafeteria.

- **Hoola Hoops for Pi Day** ... calculate circumference and the distance of *n* rotations.

- At the 523,551,502 digit of pi, the sequence 123456789 appears for the first time. At the 763rd digit, there are six 9s, known as the Feynman region of pi.

- A **billion digits** of pi, in standard type, would stretch from New York City to the middle to Kansas.

- *Nature and History of π* by William L. Schaaf: **"Probably no symbol in mathematics has evoked as much mystery, romanticism, misconception and human interest as the number pi."**

And the winner is?

- Archimedes (c.250 BC) $\frac{22}{7}$ Tsu Chung-chih (c.480) $\frac{355}{113}$ Claudius Ptolemy (150) $\frac{377}{120}$ Fibonacci (1202) $\frac{865}{275}$ ■

Pi Day Pi-paloosa

On December 28, 2013, Alexander J. Yee, a student at Northwestern University, and Shigeru Kondo, a Japanese systems engineer, completed calculating **12.1 trillion digits of pi** in 94 days using the Chudnovsky formula. Their previous record of 5 trillion digits was set in 2010. All these decimal places are needed to test the efficiency of new supercomputers and for new encryption techniques.

From a practical point of view, how many decimal places of pi are needed? According to *Pi: A Source Book* by Lennart Berggren, Jonathan and Peter Borwein, **39 digits will do**.

> *The calculation of pi to great accuracy has had a mathematical import that goes far beyond the dictates of utility. It requires a mere 39 digits of pi in order to compute the circumference of a circle of radius (an upper bound on the distance traveled by a particle moving at the speed of light for 20 billion years, and as such an upper bound for the radius of the universe) with an error of less than 10 ^ (-12) meters (a lower bound for the radius of a hydrogen atom).* ■

Are these Digits Random?

Are the digits of pi random? Today's mathematics researchers are still trying to find a proof. Certainly statistical tests are being used. The evidence is inferential, but very strongly suggestive that they are random. Ask your students to think about the proposition. See how they might address the issue as a project.

A middle school teacher, Pat Kennedy, posed the above question to her classes. She distributed a print out of the first 1,000 digits of pi. Drawing her students into the project, her students decided to make **a frequency table**, a frequency bar graph, and then a circle graph assigning **different colors to each digit**. Her middle schoolers seemed to really enjoy working on this activity.

Other teachers have addressed this research question in another visual manner by making a string of beads using again a different color for each digit. The students are then asked to identify the patterns that they see, if any. We must realize that these activities address must larger issues, and we should bring those issues to the forefront of each activity. We are not just doing colored beads. The **beads** are visually assisting us in address the question of the randomness of the digits.

Take the issue a step forward by looking at pairs of digits (00-99) instead of single digits. Ask if they are distributed equally. Or racket it up to three digits (000-999), etc. This process is referred to as the **Normality Test of pi**. ■

U.S. Congress Recognizes Pi Day

H. Res. 224 passed the U.S. House of Representatives (391 yea to 10 nay) on March 9, 2009, designating March 14 as Pi Day. ■

Computing Pi

During the heat of August, many math teachers are sprucing up their classroom and creating a welcoming mathematics atmosphere. Geometric models hang from the lights. Puzzle posters dance around the room. A 4-inch strip of paper with the digits of pi edges all four walls. On that first day of classes as students walk into your Geometry classroom, you can sense that you have won their mind's eye for the moment.

A few weeks into the new semester, students have become bold enough to speak up. Robert, "What is your question?" "How do they calculate all those decimal places?" he remarks as he points to the string of pi digits bordering the walls.

Your response is critical to this pedagogical moment. Robert is looking for direction. You might encourage him to examine the methods of Archimedes of Syracusa, who calculated an approximation to pi using simple geometry. Archimedes was also the first to show that the constant used in finding the circumference was the same constant used in calculating the area of a circle. Furthermore, he was the first to show that his new constant could be used in calculating the surface area of a sphere as well as its volume.

The approach used by Archimedes was to pin the value of pi between an over-estimate and under-estimate, and by increase the number sides of inscribing and circumscribing regular polygons squeeze in on the value of pi (the circumference of a circle with a diameter of one unit). With a circle of diameter 1, Archimedes used the Angle Bisector Theorem to calculate the perimeters, and increased the number of sides from 6 to 96 by doubling.

The approach outlined here will focus on the areas, instead of perimeters, of inscribed and circumscribed regular polygons. Asking your students to do the constructions will be revealing. The operative word is *patience*. This construction task gives them some nice insights into the mathematics that follows. And, most of all, you are conveying the ideas of measurement, estimation, and the principle of the limit. The tactile nature of this activity may frustrate a few, but most will really enjoy the change of pace.

Consider a circle of *radius* 1. Its area is pi. Calculate the area of an inscribed regular polygon with 4 sides, then 8, then 16, and finally 32 sides. Make a table of the areas of these inscribed polygons. The first inscribed area, a square, is 2. If a student's mathematical mature prevents him from using trigonometry, one may broach the task with a careful construction and then make a few measures.

Do the same with circumscribed regular polygons. The first circumscribed area, a square, is 4. If your students know some right-triangle trigonometry (sine and tangent ratios), then the task of finding the areas becomes much easier as students will then use their calculators. For the advanced classes, you may ask them for a generalized statement regarding the areas in terms of *n*, the number of sides. ■

Experimenting with Toothpicks

(Commonly known as Buffon's Needle Experiment)

In 1777, Georges Leclerc Comte de Buffon, discover of the binomial theorem, proposed dropping a needle on lined paper and asking for the probability of the needle crossing one of the lines**. The answer surprisingly is related to pi.**

With your students in teams, make 300 drops of a toothpick (one unit length) onto paper with several parallel lines one unit apart, same length as the toothpick. Count the number of times the toothpick crosses a line. This is a hit. The ratio of hits to 300 approaches $\mathbf{2/\pi}$. (hits):(total drops) approaches 2:pi.

$$\frac{hits}{total\ drops} \approx \frac{2}{\pi}$$

Pi is approximated as 2 times the number of drops divided by the number of hits. Let your students vary the needle length (L) and the distance (D) between the lines to see if your students can propose a general formula involving L and D. For **an excellent online simulation**, visit *mste.illinois.edu*. A proof can be found in *A History of Pi* by Peter Beckman. ■

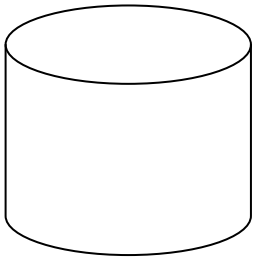
The Pi Trivia Game

Upper level students may enjoy a contest regarding the history of pi. Team your students up and encourage them to study the history of pi. Best score wins. There is a fine interactive website that quizzes students in a multiple choice format and provides results with the correct answers. This game site randomizes the questions upon replaying *The Pi Trivia Game*. Students will enjoy this challenging game. Google *The Pi Trivia Game*. ■

Surprising Results with Cylinders

Excerpt from MCTM – Pi Day 2002

Bring a collection of cylindrical objects to class (e.g., various size spools, cups or cans).



Ask students to examine (by looking only) the base and height of each object. Make a guess regarding which is larger – the circumference of the base or the height of the cylinder? To demonstrate the answer, use masking tape to trace around the base of the first cylinder. Cut the masking tape to fit just around the base. Now remove the masking tape and put it up the side of the cylinder. Which is larger? Students are often surprised to find that for most cylinders the circumference of the base is longer than the height. This helps illustrate the significance of pi and its relationship to the diameter of a circle. As a follow-up you might have students use a piece of construction paper to build a cylinder which is taller than the base of its circumference or one that has the same height as the cylinder. How common are cylinders with this characteristic? ■

An Interdisciplinary Approach to Pi Day

Pi Day can be an all-subject, all-school day festival. As you explore activities for Pi Day, you begin to see that pi touches upon many subject areas and many cultures.

Science students might enjoy celebrating Albert Einstein's birthday on Pi Day. It's also, Waclaw Sierpinski's birthday. Sierpinski is famous for his work with lacey fractal designs of triangles nested within triangles, now known as Sierpinski Gasket.

The history of Archimedes on the isle of Sicily fighting off the mighty Roman Legions with his inventions should appeal to students World History. The final scene is that of a Roman soldier killing Archimedes.

Students with an interest in architecture might appreciate the fact that the ratio of the perimeter to the height of the Great Pyramid at Giza is 2π (almost). They may even enjoy creating a scale model?

A student considering law might take interest in the O. J. Simpson Trial on July 26, 1995, when defense attorney Blasier questioned Special Agent Martz:

Q: Can you calculate the area of a circle with a five-millimeter diameter?
A: I mean I could. I don't …math I don't…I don't know right now what it is.
Q: Well, what is the formula for the area of a circle?
A: Pi R squared.
Q: What is pi?
A: Boy, you are really testing me. 2.12.
Judge Ito: How about 3.1214?
Q: Isn't pi kind of essential to being a scientist knowing what it is?

For the musically inclined, assign notes to the digits of pi. Have a pi symphony. Check youtube.

Students of poetry might enjoy reading Michael Keith's poem, *Poe E. Near A Raven*, created after Edgar Allen Poe's poem *The Raven.* Keith encoded 740 digits of pi by counting the letters of each word. " {see p. 18}

Poe E. Near A Raven (3.1415)
Midnight so dreary, tired and weary. (926535)
Silently pondering volumes extolling all by-now obsolete lore. (89793584)
During my rather long nap – the weirdest tap! (62643383) …

How many words can students spell beginning with 'pi'? Here are a few: *pioneer, pirate, pilot, pill, pin, pine, pint, pipe, Pisa, pizza, pizzazz, pinochle, pillow, pig, Picasso, piano, picture, piccolo, pickle, …*

Computer Science students may wish to show that the probability of two random numbers being relatively prime (no common factor) is $6/pi^2$.

Of course, Home Arts students may wish to make some creative Pi Cookies. ■

Pi is Everywhere!

Discovering Pi - Grades 4-6

Excerpt from MCTM – Pi Day 2002

Hold up to the class a large round object. Use a string to show the diameter of the object then ask students to estimate the number of times they think the diameter will fit around the edge (circumference) of the round object. Will two diameters go around the circumference? Will three? How about four? Take all estimates, recording them on the board. Tell students you'd like them to collect some data to get a better estimate. Organize students groups of 2-4. Each group needs a piece of string (about 10 ft. long). Ask each group to locate a circular object in the classroom or around the school (trashcan, clock face, cup, playground carousel, top of the key on a basketball court, etc.). Outline the circumference of the circular shape with the string, marking the total length on the string. Next, use the string to trace the diameter of the circular object. Mark this measurement on the string. Go back to your desk and work together to get a measurement (in centimeters) of the two lengths you've marked. Use a meter stick or ruler to measure the circumference and diameter of the circular object. Record your results on a class chart (see sample below).

Once all groups have their measures on the class chart, ask them to see if they want to revise the estimates they gave earlier. Ask students to calculate C ÷ d and record this ratio in the 3rd column. Depending on how accurate students were able to measure C and d, the ratio should be about 3.14 (pi!). Draw student's attention to the fact that even though they all measured different sized objects, it appears to take about 3 diameters to fit around a circumference. In fact it takes π diameters to make a circumference where π is a little more than 3 or 3.14159… ■

C	d	C÷d

The Prime Number Function ... $\pi(n)$

Have students make a table of integers circling all the prime numbers. Go to 100. Mathematicians use pi as a function $\pi(n)$, the **prime number function,** to count the primes less than or equal to n. $\pi(10) = 4$ since there are only 4 primes less than or equal to 10. $\pi(100)=25$. $\pi(n)$, n=1,2,3,4,5,6,7,8,9,...yields 0,1,2,2,3,3,4,4,4, ...

The Prime Number Theorem

Karl Gauss at the **age of 15** conjectured the famous **Prime Number Theorem** which was later proven by de la Vallee Poussin in 1896. It states that the ratio of the number primes which are $\leq n$ to $n / \ln(n)$ approaches 1 as n increases.

$$\lim_{n \to \infty} \frac{\pi(n)}{(n / \ln n)} = 1$$

■

Rolling Along - Grades 7-8

Excerpt from MCTM – Pi Day 2002

To explore the ratio of circumference to diameter, have students develop a graph of this relationship, with diameter as the x-coordinate and circumference as the y-coordinate.

Have students collect circular objects (cups, cans, CDs, etc.) of various sizes. **Tape a large sheet of graph paper to the board**. Ask each student to plot the diameter versus the circumference of his or her circular object on the graph paper. To do this, line up the left side of the can on the origin and mark the right side of the can (diameter) along the x-axis (bottom of the graph). Then take the can and mark a starting point on the can, lining up the starting point with the x-axis. Roll the can up one revolution (1 complete roll) and mark the end point. Repeat for all of the circular objects.

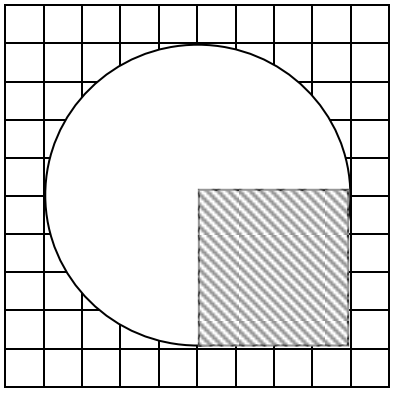
What does the graph look like? Does it have a constant slope? What is the slope? π? ■

Squaring a Circle

Excerpt from MCTM – Pi Day 2002

The diagram shows a circle with a shaded square. The side of the square is the same as the radius of the circle. A square such as this is called a "radius-square."

Use centimeter graph paper to make your own circle (of any size). Make 4-5 copies of a radius-square for your circle using another sheet of centimeter graph paper. Estimate how many radius-squares it takes to **fill in** the area of the circle (cut the radius-squares into parts and fit them into the circle). Repeat this activity using several different sized circles (or have other members of the class each do the activity with a different sized circle). What did you find? About how many radius-squares does it take to cover the area of a circle? Students will find that it takes a little more than 3 radius-squares to fill the circle. In fact, the area of a circle equals π radius-squares or $\pi r^{2.}$ ■



Pi r round; cornbread r square!

Frequency Charts for the Digits of Pi

Using grid paper, students are asked to create a frequency chart for the ten digits in the value of pi. A teacher may select the first 100 or 200 digits of pi for the chart. Student should then write a paragraph stating their conclusions regarding which digit occur most frequently. Are the ten digits equally likely to occur? ■

Pi Day Resources

Pi Day Activities and related links can be found by visiting the website of the Mathematics Educators of Greater St. Louis (MEGSL), **www.megsl.org**. Select the *Pi Day* tab.

Teachers who believe in promoting enthusiasm for mathematics may wish to visit **TeachPi.org** or **piday.org**.

Also, google topics like: Digits of Pi, Einstein birthday, History of Pi, School Activities on Pi Day, Advanced Pi, Happy Pi Day Cards, Pi Day attire, Joy of Pi, Fine Arts of Pi, Pi Humor, Pi Day Fundraiser, Find your birthday in the digits of Pi, Books about Pi, and DVDs about Pi. ■

Product Notation ... A Capital π

$$\prod_{i=1}^{6} i^2 = (1)(4)(9)(16)(25)(36)$$

Taken from the Illinois State University website *math.illinoisstate.edu*. ■

Reflect 3.14 in a Mirror

Try it.

3.14 ‖ ←Put a mirror here. ■

"Understanding Pi means to explore the universe." David Chudnovsky

The First Use of π

G. Potter

Did you ever have a student ask, "Where did π come from?" I often answered with a little history of the Babylonians or Egyptians or Greeks. But another spin to that question might be: Who first used the symbol π for the all-familiar value of pi?

Asking math students to do a little historical research can easily result in more than a few moans. You can motivate their interest by playing *The Pi Trivia Game* by Eve Anderson or *The Pi Trivia Quiz* to create a competitive classroom challenge. Your students will find that these trivia games challenge their knowledge of pi. Those students that know their pi history will undoubtedly have the edge. You will certainly want to add *The Pi Trivia Game* to your activities on Pi Day.

William Jones

The sixteenth letter of the Greek alphabet, π, was first used for the familiar value 3.1415… in the publication, "Synopsis Palmariorium Mathesios", authored by **William Jones in 1706**. "Synopsis Palmariorium Mathesios" was a text that included some lessons related to Newton's fluxions among several other mathematical topics. Jones associated the word 'periphery' with the value pi and in parentheses shows the Greek letter π. He provides no explanation for the selection or use. It is believed by many that the Greek word 'perimetron, *περιμετρον*' derived from 'peri' (around) and 'metrein' (to measure) is the desired reference with π being the first letter of the Greek spelling. ***However, the popularization of the symbol π is often credited to the prolific writings of Leonard Euler (1707-1783).***

William Jones was born on a small farm in Wales in 1675. Little is known of his formal education. However, it is known that he taught mathematics on a British ship in the Indies, and later tutored the future President of the Royal Society, Thomas Parker.

Jones also published "Newton's De Analysis" (an analysis of Newton's work), "A New Compendium of the Whole Art of Navigation", and "Introduction to the Mathematics." He was **a friend of Newton**, and it is believed that he reviewed and edited some of Newton's manuscripts. After being elected Vice-president of the Royal Society, he was instrumental in settling the dispute between Sir Isaac Newton and Baron Gottfried von Leibnitz regarding the propriety claims to the authorship of calculus.

Today, many schools around the globe celebrate **Pi Day**. It's a wonderful opportunity for us to see our students in a rich light as we move beyond the formality of curriculum with our joy of mathematics. I invite you to celebrate **Pi Day** in as many creative pedagogical venues as possible.

References

Van Helden, Albert. "Jones, William." http://es.rice.edu/ES/humsoc/Galileo/Catalog/Files/jones.html. 2001.
Berggren, Lennart, Jonathan Borwein, and Peter Borwein. *Pi: A Source Book*. New York: Springer, 2000.
(Printed in the Missouri Council of Teachers of Mathematics *Bulletin*, the Mathematics Educators of Greater St. Louis *Newsletter*, January 2002, and the Ontario Association for Mathematics Education *Ontario Mathematics Gazette*, December, 2004) ■

Digits of Pi

(groups of 10; 100 per line)

Pi ≈ 3. and then

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

(500 Digits)

9833673362 4406566430 8602139494 6395224737 1907021798 6094370277 0539217176 2931767523 8467481846 7669405132

0005681271 4526356082 7785771342 7577896091 7363717872 1468440901 2249534301 4654958537 1050792279 6892589235

4201995611 2129021960 8640344181 5981362977 4771309960 5187072113 4999999837 2978049951 0597317328 1609631859

5024459455 3469083026 4252230825 3344685035 2619311881 7101000313 7838752886 5875332083 8142061717 7669147303

5982534904 2875546873 1159562863 8823537875 9375195778 1857780532 1712268066 1300192787 6611195909 2164201989

(1,000 Digits)

A Contest Reciting the Digits of Pi

G. Potter

If you decide to conduct a Pi Digits Contest, you might be surprised at the results - as was a friend of mine in San Jose, California. This is his Pi Digits Contest story. He offered a huge, very huge, stuffed cloth bear as a prize to any student in his first-year algebra classes who could accurately recite the most digits of pi.

The lull of winter had taken its toll and Pi Day was an excellent chance to re-energize the class. He announced the contest and offered the prize. It worked, the class snapped into a frenzy of excitement. Pi Day came; the contest began. No one in the class, nor in the school, and certainly not the teacher could believe who won – **the most difficult student in the school** – straight Fs, straight zeros, and absolutely no cooperation.

The presence of this young man walking to the front of the room uncomfortably quelled the class. He cautiously began reciting the digits of pi. They were transfixed with each digit; no one dared break his concentration. After missing on the 221st digit, there was a very brief moment of silence, and then the class stood, cheered and applauded. He knew he had changed.

Imagine the sight of your school's tough guy reciting 220 digits of pi and clutching an over-sized stuffed teddy bear. *What a transformation!*

Now, let me share with you how Elaine Harke, former Mathematics Department Chair at Hazelwood West High School (Missouri), conducted her Pi Digits Contest. She announced that the contest would take place during 6th period on Pi Day. A few weeks before the eventful day, she distributed a sheet with 1,000 digits of pi.

On Pi Day, students went to the Wildcat Cafe, signed in, and were called before a panel of four students to recite. The panel checked the accuracy of the digits and recorded results. Each student was given two attempts.

At the end of the period, a trophy, a Pi Day T-shirt, Pi cologne, and McDonald's Apple Pies were awarded to the top students. The first place trophy went to a student who recited 314 digits. He stated that he knew more digits, but thought it would be *cool to stop at 314*. Everyone had some fun and gained a little more respect for each other. ***What's your school record?*** ■

RECORDS

Incidentally, the world record for reciting digits of pi was set in 1995 by Hiroyuki Goto of Japan. Hiroyuki recited 42,195 digits of pi. Rajan Mahadevan set the record for India with 31,811 digits in 1981. In 2004, Daniel Tammet set a new record for Great Britain reciting 22,514 digits. The long standing record for the United States was set by David Fiores (age 18) in 1979 when he recited 10,625 digits of pi. Sweden is closing in on the US record. In 1999, Daniel Stridsman of Sweden recited 10,000 digits; and in 2005, Mats Bergsten recited 9,778 digits while juggling three balls. Registration forms and other details can be found at http://pi-world-ranking-list.com.

Pi Day Fundraiser
for St. Jude Children's Hospital

Patricia Kennedy, a math teacher at Kirby Middle School, fundraised over $100 on Pi Day for St. Jude Children's Research Hospital. During lunch, several teachers volunteered to be targets for shaving-cream pieings by students. Students paid 25 cents to pie a teacher. I'll bet she could have charged substantially more. Teachers placed their faces through openings in a sheet of protective cardboard, and wore goggles and shower caps. Another lunchtime venue sported a pie-eating contest with students paying $3.14 to enter the contest. S

During Pi Day a human pi chain was formed outside the school with each student holding up a digit of pi and, of course, the decimal point. Previously, a raffled was held to see who would get to be the first digit, the "3", and who would be the runner-up, the "decimal point." ■

Slicing Up Pi Day

Jane Turley, Woodstock High School, reports that she serves pi for Pi Day. She uses cupcake liners as the pans, vanilla wafers as the crust, assorted fillings, and a little cool whip. {She's one very brave woman.}

After putting their pies together, she challenges her students with a classic math problem. **What is the largest number of pieces that one can get with exactly six straight cuts of a pie?** The pieces need not be equal. Students might be asked to make a table of the number of cuts verses the number of pieces. She encourages her students to make a graph. Then, they are asked to carefully write a method for getting a solution if they were to make seven cuts. She concludes the lesson with a little algebraic-thinking by asking them to generalize the solution if they were making *n* cuts. Hint: *n cuts,* pieces $f(n)=(n^2 + n + 2)/2$; pieces{2, 4, 7, 11, 16, 22}. ■

The Pi Symphony

The Pi Symphony is an orchestral work whose melodic content is derived from the number pi. Lars Erickson has scored the Pi Symphony by assigning notes to the digits of pi for various instruments. If you don't happen to have an orchestra handy, visit www.youtube.com and search *Explanation of the Pi Symphony*. For a copy of his CD or a copy of the master score go to www.pisymphony.com. ■

π π π π π π π π {an octopi}

Biblical Pi

Upon reading the scriptures of 1 Kings, Chapter 7, one may reach the conclusion that the builders of the Solomon's Temple didn't have a reasonable approximation for pi.

The key verse is 1 Kings 7:23. "And he made a Molten Sea, ten cubits from brim to the other: it was round about, and its height was five cubits; and a line of thirty cubits did compass it round about." That verse assumedly provides the circumference and diameter of a large basin, known as the Molten Sea, outside the Temple. In the days of King Solomon, before entering the Temple one must stop at the large basin to clean one's hands and feet. After reading verse 23, one typically concludes that the builders must have understood pi to be equal to three.

King Solomon hired Hiram of Tyre to construct the Molten Sea basin in brass. We read in verse 14: "… and he was filled with wisdom, and understanding, and cunning to work in brass. …" This raises the question: Should Hiram have known that the circumference of a circle was more that three times its diameter? I would like to think that a smart man like Hiram knew that the circumference of a circle was more than three times the diameter.

The Molten Sea basin had a brim which flared out from the basin. Verse 24 describes the brim: "And under the brim of it round about there were knops compassing it…"

Verse 26 provides additional details on the brim: "And it was a hand breadth thick, and the brim thereof was wrought like the brim of a cup, like a lily blossom …"

It is reasonable to believe that the "ten cubits from brim to the other" was the outer diameter of the brim, whereas the "thirty cubits did compass it round about" refers to the inner measurement of the circular brim (outer circumference of the basin). If that be the case, and a cubit taken to be 18 inches, and a hands breadth taken to be 4 inches, then the mathematics related to the circular brim follows:

Circumference C = 30 cubits = 30(18 inches) = 540 inches.
Diameter D = 10 cubits – 2 hands breadth
D = 10(18 inches) – 2(4 inches)
D = 180-8 inches
D = 172 inches.

C / D = 540 / 172 ≈ 3.139.

Therefore, our Biblical Pi can be taken to be approximately 3.14 and not 3. ■

$\sqrt{(-1)} \quad 2^3 \quad \Sigma \quad \pi$ and it was good.

Pi-oneers

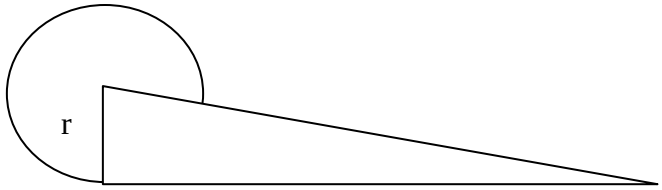
- **Before pi**, mathematicians would write:
  "the quality which, when the diameter is multiplied by it, yields the circumference"
  The Joy of Pi by David Blatner

- In Germany, pi is sometimes referred to as **the Ludolfian number** in honor of Ludolf van Ceulen who spent his life calculating pi.

- The most famous formula relating the five most frequent constants in mathematics is **Euler's Formula**,

$$e^{\pi \cdot i} + 1 = 0$$

- **Archimedes** (c.250 BC) proved that the area of a circle with radius r was equal to the area of this right triangle.



$2 \pi r$

- In 1655, John **Wallis** proves:

$$\frac{\pi}{2} = \frac{2 \cdot 2 \cdot 4 \cdot 4 \cdot 6 \cdot 6 \cdot 8 \cdot 8 \cdots}{1 \cdot 3 \cdot 3 \cdot 5 \cdot 5 \cdot 7 \cdot 7 \cdot 9 \cdots}$$

- In 1579, Francois Viete proves using Archimedes method that

$$\frac{2}{\pi} = \sqrt{\frac{1}{2}} \cdot \sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2}}} \cdot \sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2} + \frac{1}{2}\sqrt{\frac{1}{2}}}} \cdots$$

- In 1675, James **Gregory** proves $\frac{\pi}{4} = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \frac{1}{9} - \frac{1}{11} + \cdots$

- In 1761, Johann **Lambert** proves that pi is irrational by first proving that if tan (x) is rational that x must be irrational. Thus, since tan ($\pi/4$)=1 then π must be irrational.

- In 1811, Karl **Gauss** introduces a capital pi **TT** for product notation.

$$\prod_{n=3}^{5} n = 3 \cdot 4 \cdot 5 = 60$$

- Using the Taylor expansion for sin x, Leonard **Euler**, in 1736, gave us a remarkable proof for:

$$\frac{\pi^2}{6} = \frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2} + \cdots$$

- He then proves: $$\frac{\pi^4}{90} = \frac{1}{1^4} + \frac{1}{2^4} + \frac{1}{3^4} + \frac{1}{4^4} + \cdots$$

- The probability that two randomly selected integers are relatively prime is $\frac{6}{\pi^2}$

- The probability that two randomly selected points on a lattice are directly connected, without any other points between them, is $\frac{6}{\pi^2}$.

- Around 1670, Isaac **Newton** calculates pi to 16 decimal places based on the binomial expansion of $(1-x)^{1/2}$

$$\sqrt{1-x} = 1 - \frac{1}{2}x - \frac{1}{8}x^2 - \frac{1}{16}x^3 - \frac{5}{128}x^4 - \cdots$$

- John **Machin** (c.1750) proves $\frac{\pi}{4} = \arctan(1/2) + \arctan(1/3)$

- In 1914, Srinivasa **Ramanujan** proves $$\frac{1}{\pi} = \sum_{n=0}^{\infty} \binom{2n}{n}^3 \frac{42n+5}{2^{12n+4}}$$

- In 1996, David Bailey, Peter Borwein and Simon Plouffe prove:

$$\pi = \sum_{i=0}^{\infty} \frac{1}{16^i}\left(\frac{4}{8i+1} - \frac{2}{8i+4} - \frac{1}{8i+5} - \frac{1}{8i+6}\right)$$

- **Bell Curve** – Normal Curve - Gaussian Probability Distribution of a standardized random variable

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}x^2}$$

- 1996, Michael Keith created a poem making the word length a mnemonic for pi. His poem encodes the first 740 digits of pi, beginning with 'Poe' (3). A word with 10 letters represents the digit 0. Words with more than 10 letters (99 or less) represent two digits.

Poe, E. - Near A Raven (3.1415)

{Count the letters in each word}

Midnights so dreary, tired and weary. (926535)
Silently pondering volumes extolling all by-now obsolete lore.
During my rather long nap – the weirdest tap!
An ominous vibrating sound disturbing my chamber's antedoor.
"This", I whispered quietly, "I ignore".

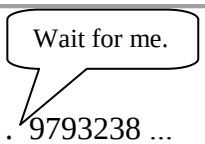
Perfectly, the intellect remembers: the ghostly fires, a glittering ember.
Inflamed by lightning's outburst, windows cast penumbras upon this floor.
Sorrowful, as one mistreated, unhappy thoughts I heeded:
That inimitable lesson in elegance – Lenore –
Is delighting, exciting…nevermore.

Ominously, curtain parted (my serenity outsmarted),
And fear overcame my being – the fear of "forevermore".
Fearful foreboding abided, selfish sentiment confided,
As I said, "Methinks mysterious traveler knocks afore.
A man is visiting, of age threescore."

Taking little time, briskly addressing something: "Sirs," (robustly)
"Tell what source originates clamorous noise afore?
Disturbing sleep unkindly, is it you a-tapping, so slyly?
Why, devil incarnate! --" Here completely unveiled I my antedoor;
Just darkness, I ascertained – nothing more.

The remainder of the poem can be found in Pi: A Source Book, pp. 659-662. ■

The Pi'd Piper



π ,,, ,,,,, 3 „ 1 „ 4 , 1 5 9 2 6 5 3 5 8 . 9793238 ... ■

Ideas and Activities

Pat Kennedy

This is a list of various activities that students can complete with their mathematics teachers on Pi Day and during Pi Week:

1. Have students write the digits of pi on adding-machine paper to 1000 decimal places. Then display the non-terminating digits around the classroom or on the hallway outside the classroom.

2. **Paper Chain** – used 2-inch wide strips of construction paper approximately 18 inches long color-coded to represent the digits of pi. Each digit is represented by a different color including the decimal point. The color coding system should be displayed somewhere near the beginning of the pi chain. Students could construct 10-digit sections to be later connected in the classroom and hung in the classroom or a nearby hallway.

3. **Pi Quilt** – using the same color-code as the paper chain, place colored squares on grid paper spiraling to match the digits of pi. The digit "3", on a 2-by-2 square, is placed at the center and then the decimal point and the remaining digits of pi, on single squares, spiraled around the center.

4. **Pi Bee** – How many digits can you remember? Hold daily competitions, and then on Pi Day hold the final competition.

5. **Pie-Eating Contest** – cost $3.14 per student to participate and the money was donated to the St. Jude Children's Hospital (students were participating in the St. Jude Math-a-Thon fund-raiser at the same time).

6. **"Pi" (Pie) in the face** – students were given the opportunity to throw a whip-cream pie at volunteering teachers. This was done outside and the teachers were behind comic plywood cutouts wearing protective clothing. If it is a windy day, then the pies do not "throw" very easily.

7. Students held placards with the digits of pi to make a **"human" pi chain** across a field. Students paid $1.00 for each chance in a drawing to hold the leading "3" placard and also to hold the decimal-point placard.

8. **"Pi" Key Chains** – beads are used to make the key chains using the color code. Ten decimal places were used. Students could make a bracelet or necklace depending on how many beads are available. A large bead could be used to represent the leading "3", a gold bead for the decimal point, and then smaller colored beads for each following digit matching the color code.

9. Students could research the rich multicultural history of pi from Egypt to China to India to France to England to Germany to the United States.

10. Students made a **Bar Graph and Circle Graph** of the frequency of the first 200 digits of pi. Also, one could include a frequency table as part of the activity. Students used a color code to shade in each bar or central angle.

11. Students made posters about pi. These were hung in the hallways throughout the school in advance of Pi Day. Posters included facts about pi, including the fact that Pi Day is also the birthday of Einstein and Sierpinski.

12. **Pi Day Badges** – die-cut circles were labeled with "Pi Day March 14" by students as part of an after-school activity session. A straight pin was attached to the badges. On Pi Day, all of the staff members wore their Pi Day Badges!

13. **Pi Day Cookies** – Cafeteria staff made chocolate chip cookies with the pi symbol in green icing. Cookies were sold at lunch time as part of the menu for Pi Day.

14. Students wrote letters to the principal or to their parents explaining how pi is used. Their letters included some historical facts, as well, about pi. Students may need to do some research. For a collaborative effort, you should include the English teacher on your team.

15. **Cooperative Learning Activity** – Students worked in groups to estimate the value of pi. Each group measured the circumference and diameter of 10 circular items and found the ratio of the two measurements. As various groups share their averages, be sure to discuss the accuracy of measurements, and how many of the digits in the averages have meaning. You may also want to find the class average.

16. **Poems, Rap Songs or Jokes** – Students could create their own poems or songs about pi after doing some research in the library and/or over the internet.

17. **Pi Project** – Determine which pizza size - small, medium, or large – is the best buy for your money. Use a local pizza ad for prices and sizes. First, measure the radius of your pizza to find the area. Next, divide the cost of your pizza by the area in square inches. This will yield the price per square inch of your pizza. You should do this for the small, medium, and large pizza sizes. Compare the cost per square inch for each size, and you will be able to determine the best value for your money.

18. Students will enjoy reading the *Sir Cumference and the First Round Table*, *Sir Cumference and the Dragon of Pi*, *Sir Cumference and the Great Knight of Angleland*, or *Sir Cumference and the Sword in the Cone* each by Cindy Neuschwander.

■