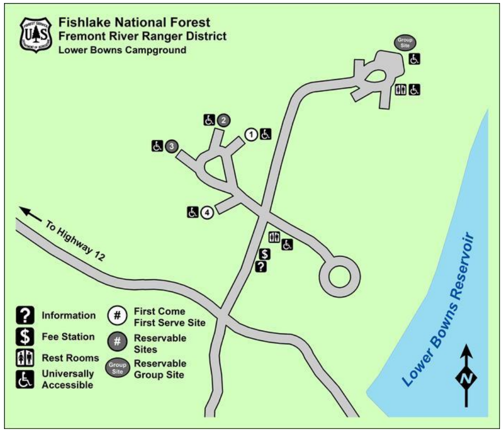
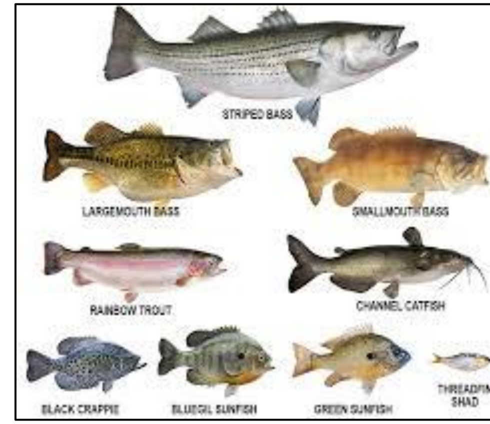


Science Camp #2024.15
Theme: Math



08-11 June 2024 @ Teasdale Jewell,
Capitol Reef, and Surrounding Area

Advisors:

H. Roice Nelson, Jr., Andrea S. Nelson,
Paul & Kate Nelson, Melanie Wright, Sara Ellen & Bobby Beckmann.

Attendees:

Grant Matthew Nelson, Dallin Spencer Nelson, Avalyn Ashby Wright,
Quinton Miles Nelson, Kendall Joyce Wright, Chloe Grace Nelson,
Karson Nelson, Ashlyn Nelson, Madison Nelson

Guest: Sage Beckmann

Technical Support: Uncle Roice & Colby Wright

Past Science Camp Themes & Sites Visited

1. Nelson Cabin, Fishing, Condensation, Water Coloring, and Music
    1. Nelson Cabin
    2. Panquich Lake
    3. Swimming at Cedar City Aquatics Center
2. Mining Range, Frisco, Silver Reef, Iron Town, Astronomy at Frisco Peak, Archery
    1. Nelson Cabin, Kolob Reservoir, Silver Reef, Snow Canyon, Volcano
    2. Parowan Gap, Rack Range Mines, Frisco, Frisco UU Telescope
    3. Iron Mine, Iron Town
3. Geocaching, Mammoth Cave, Cascade Falls, and Cedar City Cemetery
    1. Nelson Farm, Fiddler's Canyon,
    2. Boys to Mammoth Cave, Cascade Falls and Girls to St. George and Pottery Making
    3. Cedar City Cemetery
4. Volcanoes, Classy Closets, Maps, Surveying, Sand Painting, and Genealogy
    1. Condo, Snow Canyon Volcanoes, Classy Closets, Fiddler's Canyon
    2. Nelson Farm to survey, Nelson Cabin
    3. Cedar City 24th of July Parade
5. Patterns, Horse Riding, Internet, Be-a-man-campout
    1. Dust Devil Ranch, InfoWest, Fiddler's Canyon
    2. Nelson Cabin
    3. Cedar City July 4th Parade
6. Music & Spoken Word, SilencerCo, Indian Tribes & Archaeology, Solar Astronomy
    1. Family Discovery Center, Sophie & Dallin's Baptism, SilencerCo, Music & Spoken Word, UU Science Museum
    2. Freemont Indian Museum, Boulder Anasazi Ruins, Escalante Petrified Forest, Bryce Canyon
    3. Parowan Gap, Solar Astronomy, Nelson Cabin, Uncle Des' & Aunt Sara's, Swimming
7. Rock Cutting, SUU Museum, Computer Hardware and Software, Cabin
    1. 1st Annual Fun Run / Walk, rock collection Bloody Ridge, rock cutting and polishing
    2. HTML at SUU, and Lego Robots at Nelson Cabin
    3. Astronomy at Nelson Cabin, Bottle Rockets, and having a good time
8. 8G: Geography, Genetics, Genealogy, Grandma, Grandpa, Geology, Geophysics, & Guitar
    1. Watered garden, 2nd Annual Fun Run / Walk, Iron Springs, Iron Town, Genetics, Cabin, Guitar
    2. Zion, Angels Landing & Emerald Pools, Geophysical Slides
    3. Bottle Rockets, swimming, and having a good time
9. Garden of the Gods, Drones, Intercontinental Divide, Teepee, Salida Hot Springs, University Mountains
    1. Bow & Arrows, Drone, Intercontinental Divide
    2. Guitar and Buena Vista 4th of July Parade
    3. Mount Antero, Hot Springs at Salida, Teepee
10. Eisenhower Park, Guadalupe River, i-Fly, Cave Without a Name, Alamo, San Antonio
    1. Hike to overlook San Antonio, i-Fly, swimming Guadalupe River State Park
    2. Cave without a Name, Singing, Rob Nelson on Sound and Music
    3. Alamo, Wax Museum, San Antonio Riverwalk
11. Engines, Ghost Towns and Kilns, Nelson Cabin, Al Matheson's Place, Iron Springs Resort
    1. Fisco, Kiln Springs, Nelson Cabin
    2. Teepees at Nelson Cabin, water races, Dutch Oven
    3. Matheson Engines, 4-wheelers, Iron Springs statues, Bottle Rockets, Ride in a Tesla
12. Warner Cabin, Gravity, Zip Lines, & Experiments
    1. Warmer Cabin and Panquich Lake
    2. Marysville Zip Line & Lazy River
    3. Bryce Canyon and Gravity Experiments
13. Nelson Cabin, Light, Distance, Physics, Lasers
    1. Green Show & All's Well That Ends Well
    2. James Webb Telescope, Stargazing
    3. Cascade Falls, Water Rockets
14. Nelson Cabin, Water
    1. Kolob Reservoir: fishing & swimming
    2. Water Games and Water Rockets
    3. Romeo & Juliet
15. Teasdale Jewell
    1. Math
    2. Fishing, Swimming, Boating, Water Rockets
    3. Natural Bridges & Arches

15th Annual Nelson Grandkids' Summer Science Camp; Theme: Math

Itinerary

Monday:
5:00 Arrive Teasdale Jewell
6:00 Pizza Dinner
8:00 Bobby Arrives (cold pizza)
Tuesday:
8:00 Eggs and Bacon Breakfast.
10:00 Fishing and Swimming at ? Reservoir.
1:00 Lunch at ? Reservoir.
3:00 Swimming, Boating, Fishing, bottle rockets.
7:00 Melanie Dinner.
8:00 Math Introduction
Wednesday:
8:00 Waffles.
9:00 Hickman Bridge.
12:00 Lunch Slackers.
12:30 Ice Cream Creamery
2:00 Cassidy Arch.
3:00 Grand Gulch
5:00 Petrified Wood
6:00 Sara Dinner
7:00 Math Details.
Thursday:
8:00 Breakfast Grab & Go.
10:00 Melanie to Provo
Paul to Logan
Sara to Cedar City

Good Times!

Photos + slides to be posted at:
http://www.walden3d.com/photos/Grandkids_Science_Camps/240608-11_Science_Camp

Safety

- **Never go anyplace alone, preferably 3+**.
- Exception is if one of you is hurt, then:
  - One of you stay and help the person hurt.
  - The other one run and get help.
- If you get lost, stay put, we will find you.
- If you hear a rattlesnake do not move quickly, just slowly move away from the sound.
- Do not run with a knife open. Use knife safety.
- If you cut yourself, apply pressure to the wound to stop bleeding, and send for help.
- Never point an arrow in a cocked bow or a gun at any person.
- Drink lots and lots and lots of water.
- Do not go swimming unless an adult is with you.
- Do not start branches on fire and swing them around where others can be hurt.
- Have fun, use common sense, and **think before you act**.

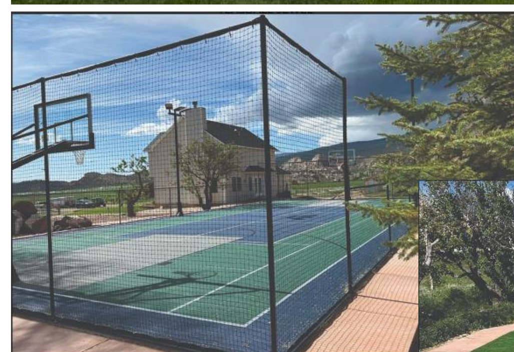
Everybody picks up their own dishes!

Everyone cheerfully does what asked to do by Grandpa, Grandma, Uncle Paul, Aunt Kate, Aunt Melanie, Aunt Sara, Uncle Bobby, or other adults.

Job Chart

Monday	Tuesday	Wednesday	Thursday
Paul, Melanie, & Sara to meet at noon at a grocery store in Provo	Breakfast (Paul): - Eggs & Bacon - Helpers: ?	Breakfast (Paul): - Waffles - Helpers: ?	Breakfast (Kate): - Homemade Bread - Helpers: ?
Bobby arrives Monday evening	Lunch (?): - Picnic fixed at house - Helpers ?	Lunch: (changed because closer to Natural Bridges) - Slackers Burger Joint & Color Ridge Farm & Creamery	Melanie leave at 10:30. Paul & Kate, Logan Grandpa, Grandma, Bobby, Sara & Sage, Boulder for museum and lunch?
Dinner: - Curry Pizza	Dinner (Melanie): - Chimi Congas	Dinner (Sara):	Then to Cedar City

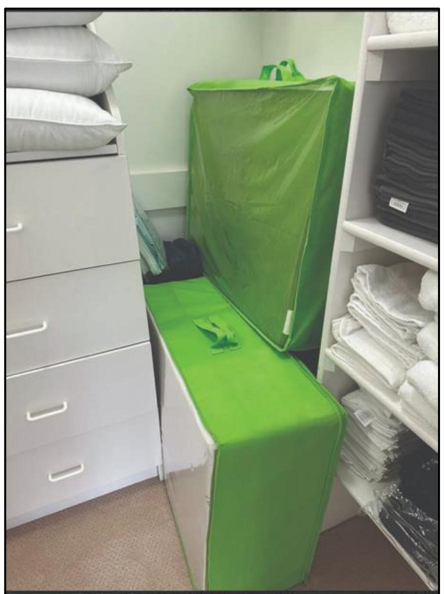
Location: Teasdale Jewell, Eric Krueger



Accommodations Downstairs

Aunt Melanie

Avalyn & Kendell (& Chloe & Pad?)



Pad

Dallin & Quinton

Accommodations Upstairs

Grandpa & Grandma

Aunt Sara & Uncle Bobbie & Sage

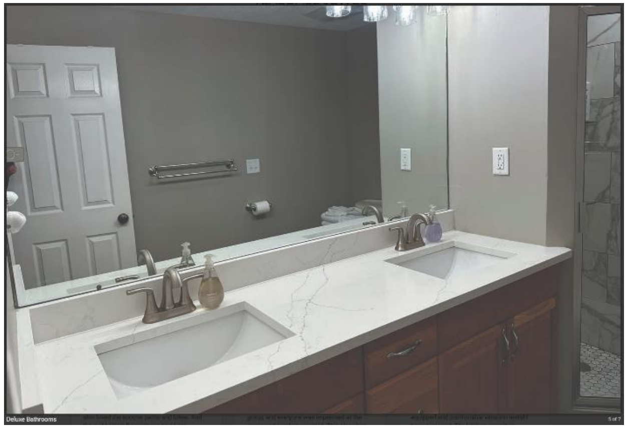
Pad

Uncle Paul & Aunt Kate (& Chloe on Pad?)

Eating & Utilities


Updated Kitchen - Equipped with everything you might need. 1 of 7


Table Settings for 10 2 of 7

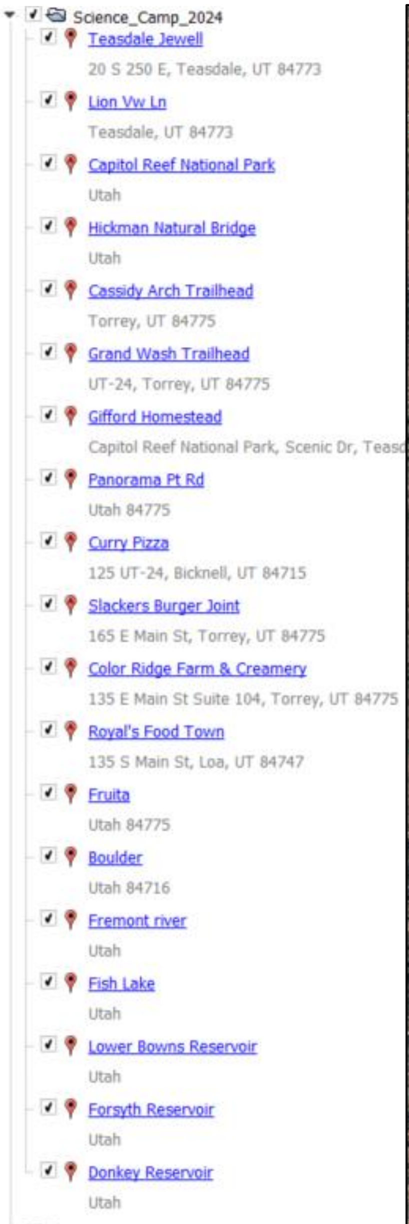

Deluxe Bathrooms


Deluxe Jetted Tub

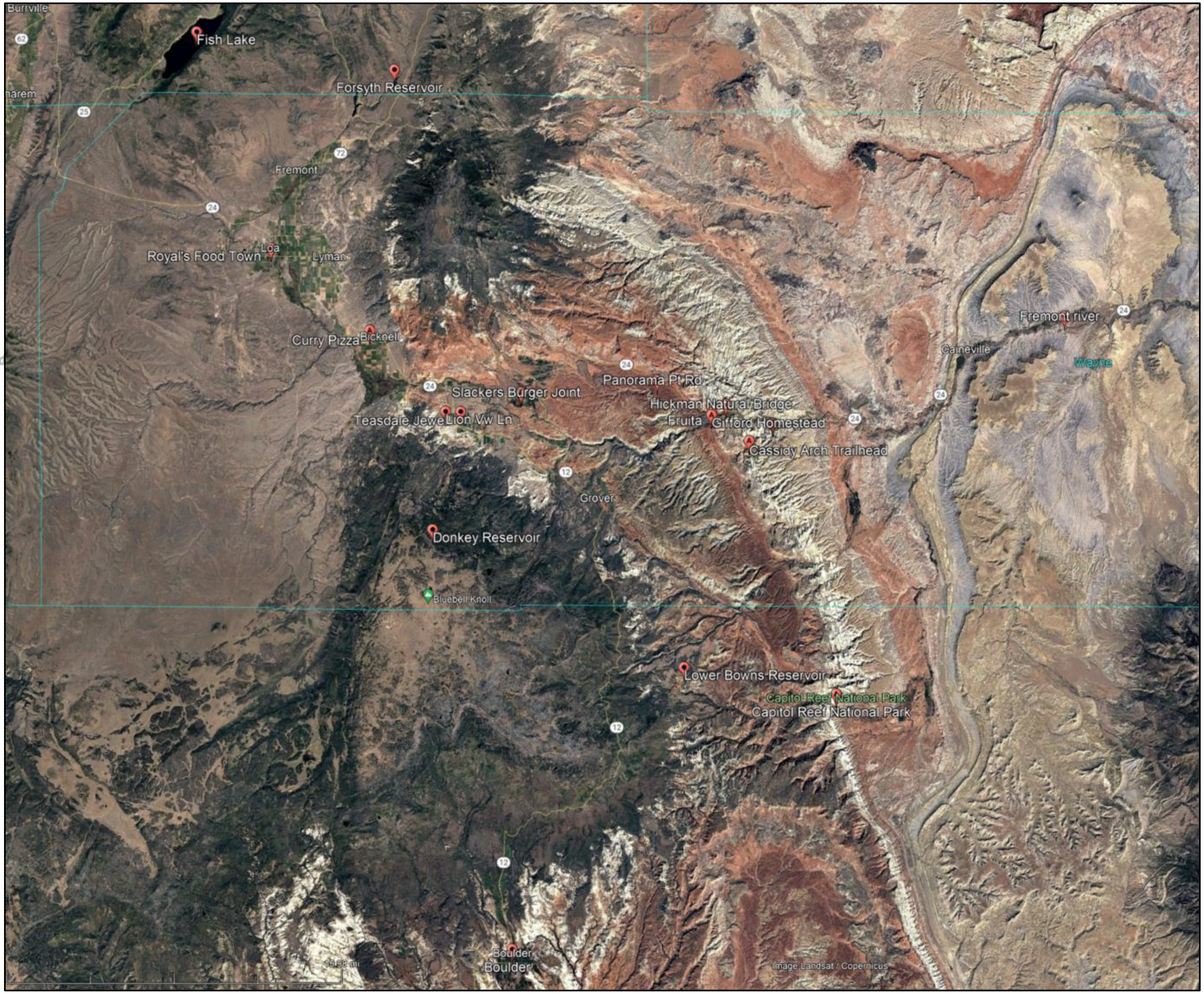

Table Settings for 6 - Folding Chairs Available

Main Floor & Basement Couches / Beds

Activities

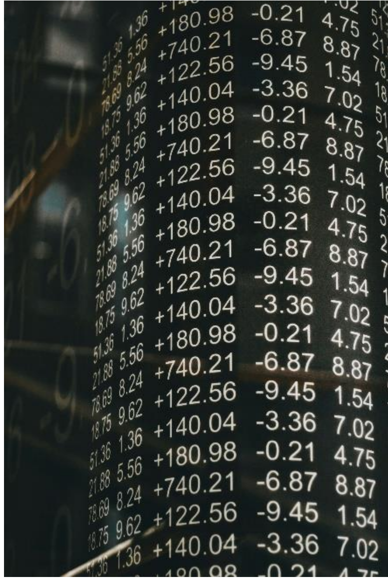


Science_Camp_2024
Teasdale Jewell
20 S 250 E, Teasdale, UT 84773
Lion Vw Ln
Teasdale, UT 84773
Capitol Reef National Park
Utah
Hickman Natural Bridge
Utah
Cassidy Arch Trailhead
Torrey, UT 84775
Grand Wash Trailhead
UT-24, Torrey, UT 84775
Gifford Homestead
Capitol Reef National Park, Scenic Dr, Teasd
Panorama Pt Rd
Utah 84775
Curry Pizza
125 UT-24, Bicknell, UT 84715
Slackers Burger Joint
165 E Main St, Torrey, UT 84775
Color Ridge Farm & Creamery
135 E Main St Suite 104, Torrey, UT 84775
Royal's Food Town
135 S Main St, Loa, UT 84747
Fruita
Utah 84775
Boulder
Utah 84716
Fremont river
Utah
Fish Lake
Utah
Lower Bowns Reservoir
Utah
Forsyth Reservoir
Utah
Donkey Reservoir
Utah



Fish Lake
Forsyth Reservoir
Fremont
Royal's Food Town
Loa
Lyman
Curry Pizza
Bicknell
Slackers Burger Joint
Panorama Pt Rd
Hickman Natural Bridge
Fruita
Gifford Homestead
Teasdale Jewe
Lion Vw Ln
Cassidy Arch Trailhead
Grover
Donkey Reservoir
Bluebell Knoll
Lower Bowns Reservoir
Capitol Reef National Park
Capitol Reef National Park
Fremont river
Caineville
Wayne
Boulder
Boulder
Image Landsat / Copernicus

Letters vs. Numbers, Mathematics, or Math, Definition

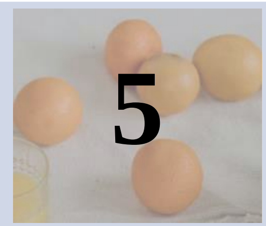


- Math is the study of numbers, and how they are related to each other and to the real world.
- Math is as important as language and is a language with numbers instead of an alphabet.
- There are many branches of mathematics, including: arithmetic, algebra, geometry, trigonometry, calculus, statistics, and probability.

Math Operations

NAME	1^{st} Number	SYMBOL	2^{nd} Number	RESULT
Addition		+		
Subtraction		−		
Multiplication		×		
Division		÷		

Arithmetic Operations

NAME	1st Number	SYMBOL	2nd Number	RESULT
Addition	 2	+	 3	 5
Subtraction	 3	−	 2	 1
Multiplication	 4	×	 5	 20
Division	 10	÷	 2	 5

What is a Square Root? $\sqrt{}$

A number, which is the value that, when multiplied by itself, gives the original number:

For example, $\sqrt{16} = 4$,

and $\sqrt{9} = 3$,

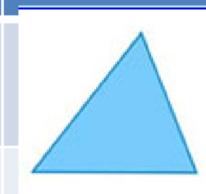
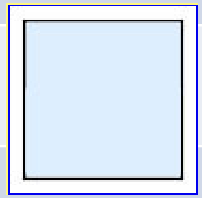
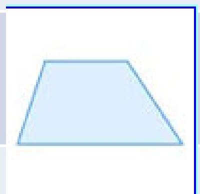
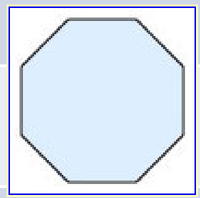
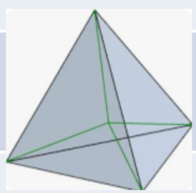
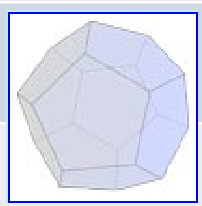
and $\sqrt{100} = 10$,

and $\sqrt{676} = 26$.

Math Numbers

NAME	SYMBOL	PROPERTIES	SET/EXAMPLES
Integers	Z	All positive and negative whole numbers.	$\{\dots -1, -2, 0, 1, 2, \dots\}$
Natural	N	Numbers used for counting (all *positive integers*).	$0, 1, 2, \dots$
Prime	P	A whole number greater than 1, with exactly two factors, 1 and the number itself, any two prime numbers are always co-prime to each other. Every number can be expressed as the product of prime numbers	First 25: 2, 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97.
Real	R	Includes all numbers on the number line.	$\frac{1}{5}, \sqrt{\frac{1}{5}}, 0, -2$
Rational	Q	All real numbers which can be expressed as a fraction, $\frac{p}{q}$ where p and q are integers and q≠0. All integers are rational numbers as 1 is a non-zero integer.	$\frac{1}{5}, \frac{5}{1}(=5), \frac{2}{3}, \frac{3}{2}, \frac{0}{3}(=0)$
Irrational	I	All real numbers which can't be expressed as a fraction whose numerator and denominator are integers (i.e., all real numbers which aren't rational).	$\pi, \sqrt{2}, \sqrt{3}$
Imaginary	NA	Numbers which are the product of a real number and the imaginary unit i (where $i = \sqrt{-1}$).	$3i = \sqrt{-9}, -5i = -\sqrt{-25}$
Complex	C	All numbers which can be expressed in the form $a+bi$ where a and b are real numbers and $i = \sqrt{-1}$. Each complex number is a combination of a real number (a) and an imaginary number (bi).	$1 + 2i, 1, i, -3i, 0, -5 + i.$

Math Shapes

NAME	SHAPE	(SURFACE) AREA	VOLUME
Triangles		A = ½ Base * Perpendicular Height	No Volume
Squares		A = Length * Length	No Volume
Quadrilaterals		Turn to 2 Triangles, A=1/2*D*(H1+H2)	No Volume
2D Polyhedron Shapes		Turn to N Triangles, A=1/2*D1*H1+1/2*DN*HN	No Volume
Tetrahedranes		TSA= $\sqrt{3}$ * a^2	V= $(A^3 * \sqrt{2}) / 12$
Cubes		TSA – 6*a^2	V = A^3
Spheres		A = 4 * π * r^2	V = 4/3 * π * r^3
3D Polyhedron Shapes		A = sum of areas of each surface	V = sum of volumes of sub-volumes

How to hang a triangle tree tent hammock

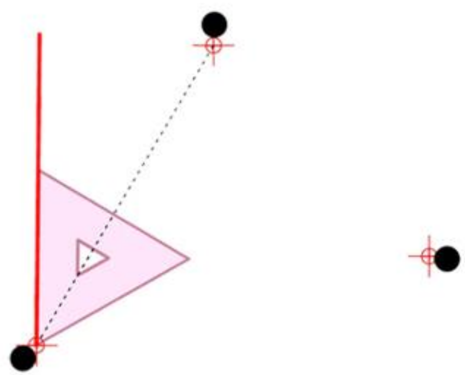
between any three given trees in a various triangle shapes?

STEP 1

Find 3 trees in a triangle (it doesn't have to be an perfect/equilateral triangle) and wrap the straps around the tree at the same height in the positions shown by the red crosshairs.

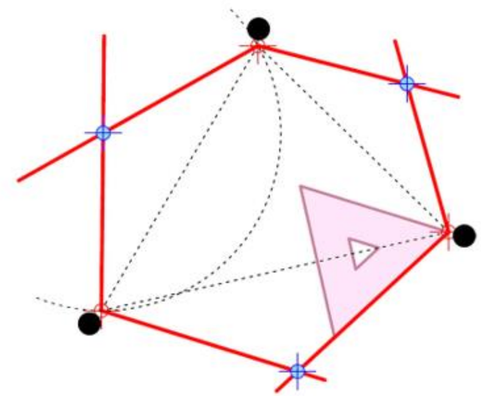
STEP 2

Lay the front of the tent at the edge of 1 of the trees and then draw a straight line along the triangle.



STEP 3

Repeat this 5 times with all corners and you will find 3 points when all the lines intersect.

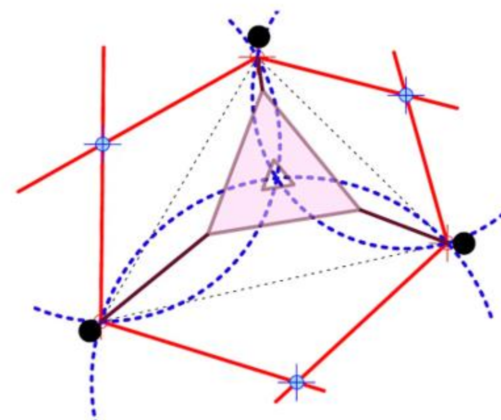


STEP 4

The intersecting points are the centerpoints of the corners. Use a rope as a compass to make the circles.

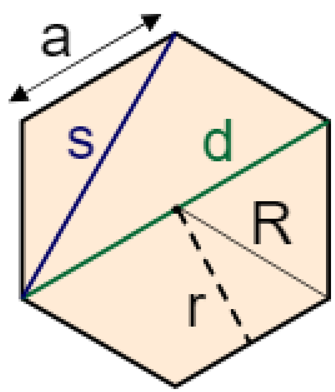
These circles will intersect at a single point.

For perfect force balance, the centre of your tree shoulds sit over this point.



Real World Problem (Dallin)

I have a hexagon sandbox 48" in length (side a below) on one side that I need to fill up with sand (it has gotten low over time due to kids playing, flooding the sandbox, etc.). The sand is 3" low, how much sand do I need to get at Home Depot to top it off? Sandbox sand at Home Depot comes in .5 cubic foot bags.



Use this calculator to get the area: https://www.omnicalculator.com/math/hexagon = 41.57 ft squared.

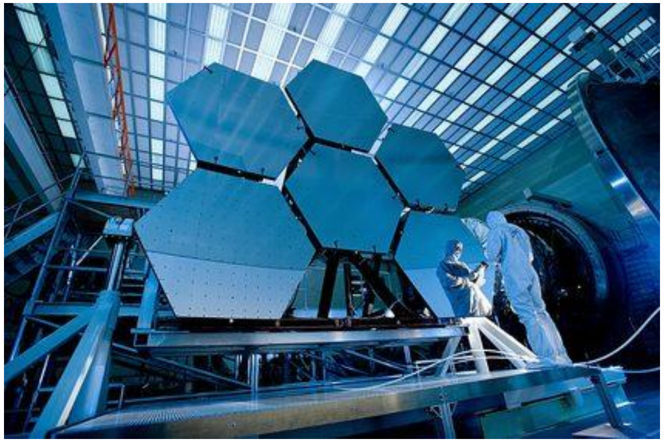
3"/12" = .25 foot deep * 41.57 = 10.4 cubic feet / .5 cubic foot bags = ~21 bags.

Each bag weighs 50 lbs. or 1050lbs. Hitch cargo carrier holds 500 lbs. How many bags should I put in the cargo carrier and how many should go into the middle of the Ford Explorer?

Additional explanations on hexagon math: https://m.youtube.com/watch?v=9jBT5izfGnU

How many sides does a hexagon have?

It should be no surprise that the hexagon (also known as the *"6-sided polygon"*) has precisely six sides. This fact is true for all hexagons since it is their defining feature. The length of the sides can vary even within the same hexagon, except when it comes to the **regular hexagon, in which all sides must have equal length**.



One of the most valuable uses of hexagons in the modern era is in **astronomy**. Thanks to regular hexagons, we can see better, further, and more clearly than we could have ever done with only one-piece lenses or mirrors.

The honeycomb pattern is composed of **regular hexagons arranged side by side**. They completely fill the entire surface they span, so there aren't any holes in between them. The honeycomb is so popular that one could say it is the default shape when conflicting forces are at play and spheres are not possible due to the nature of the problem.

Math Questions

- **What is the apothem in a hexagon?**
  – In a hexagon, the ***apothem*** is the distance between the **midpoint of any side and the center** of the hexagon. When you imagine a hexagon as six equilateral triangles that all share a vertex at the hexagon's center, the apothem is the height of each of these triangles.

- **How do I find the area of a hexagon given perimeter?**

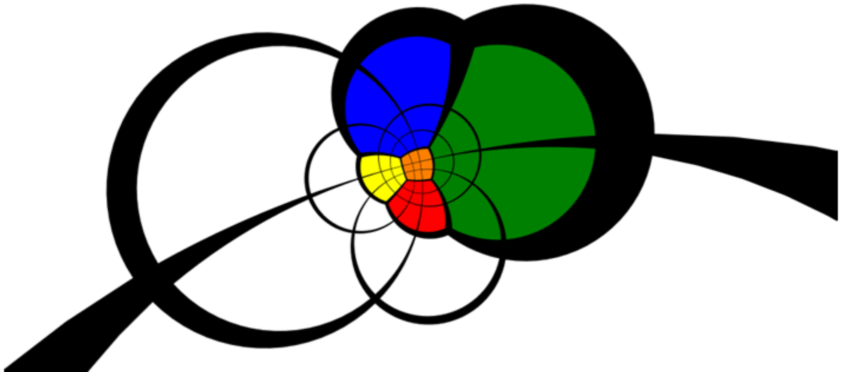
  To determine the area of a hexagon with perimeter P:

  1. Divide P by 6 to get the **side length** a.
  2. Find the **square** of the side length: a^2.
  3. **Multiply** a^2 by $3\sqrt{3} / 2$.
  4. **The result is the area of your hexagon!**
  5. You could also **go directly from P to the area** by using the formula $\text{area} = \sqrt{3} P^2 / 24$.

- **How many sides does a circle have?**
  – Zero
  – One
  – Infinity

- **How many corners does an N-dimensional cube have?**
  – Given an n-dimensional cube, corners of the cube look like $(x_1, x_2, \ldots, x_n)$. For ever x_i there are 2 possibilities: $x_i=0$ or $x_i=1$. So, this cube has 2^n corners.

Abstracting Rubik's Cube pages 1-2



Abstracting Rubik's Cube

Roice Nelson

> "The art of doing mathematics consists in finding that special case that contains all the germs of generality" - David Hilbert

Over the past few decades, a growing group of "hypercubists" have been discovering analogues of Rubik's cube, traversing a wide range of mathematical ground. Solving puzzles is a core pastime, but this group is about much more. The explorations have been a microcosm of mathematical progress. Finding and studying natural analogues provides a rich way to approach varied topics in mathematics: geometry (higher-dimensional, non-Euclidean, projective), group theory, combinatorics, algorithms, topology, polytopes, tilings, honeycombs, and more. Elegance is a core principle in the quest.

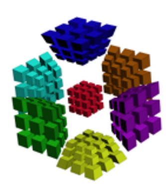
(a) "Megaminx" uses a dodecahedral shape rather than a cube.

(b) The "Helicopter Cube" twists around edges instead of faces.

Figure 1: We begin abstracting Rubik's cube as soon as we change some property.

Those exposed to the twisty puzzle community know there are many properties of the classic *3x3x3* Rubik's Cube we can change to make new and interesting puzzles, for example by altering the shape or the twist centers as in Figure 1. The hypercubing group began by changing a more abstract property, namely the dimension. Don Hatch and Melinda Green wrote an exquisite working 4-dimensional *3x3x3x3* (or 3^4) analogue, which they called MagicCube4D. Using *dimensional analogy*, every property of this puzzle is upped a dimension. Faces, stickers, and twisting are 3D rather than 2D. Using a central $4D \rightarrow 3D$ projection, we see the hyperpuzzle as if you are looking into a box, with the nearest face hidden. Figure 2 puts the 3D and 4D puzzles side-by-side to emphasize the analogy.

(a) The 3^3, projected so a 2-dimensional "flatlander" sees 5 of the 6 cube faces.



(b) The 3^4, projected so a 3-dimensional being sees 7 of the 8 hypercube faces.

Figure 2: Dimensional analogy and projection tricks can help us understand higher dimensional Rubik's Cubes.

The 3^3 Rubik's Cube has $6 \times 3^2 = 54$ stickers that can live in a mind-boggling 4.325×10^{19} possible states. The hypercubical 3^4 has $8 \times 3^3 = 216$ stickers and the number of possible puzzle positions explodes to an incomprehensible 1.756×10^{120}. Calculating this number is a challenge that will test your group theory mettle!

> "In that blessed region of Four Dimensions, shall we linger on the threshold of the Fifth, and not enter therein?" - Edwin Abbott, Flatland

The group didn't stop there. In 2006, a working 5-dimensional puzzle materialized with $10 \times 3^4 = 810$ hypercubical stickers and 7.017×10^{560} states, pushing the boundaries of visualization. The picture on the screen is effectively a shadow of a shadow of a shadow of the 5D object. Nonetheless, as of mid 2017, around seventy individuals have solved this puzzle. In June 2010, Andrey Astrelin stunned the group by using a creative visual approach to represent a 7-dimensional Rubik's Cube. Yes, it has been solved. Can you calculate the number of stickers on the 3^7? You may also enjoy using dimensional analogy to work out the properties of a 2-dimensional Rubik's Cube. What dimension are the stickers?

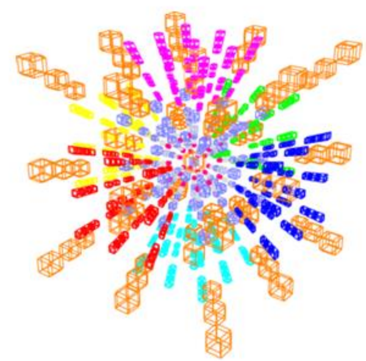


Figure 3: A shadow of a shadow of a shadow of the 3^5. Stickers are little hypercubes.

Of course we can play the same game of changing the shape in higher dimensions to yield a panoply of additional puzzles. There are 5 Platonic solids in 3 dimensions, but 6 perfectly regular shapes a dimension up, and you can attempt to solve twisty puzzle versions of all of them! Figure 4 shows one of the most beautiful in its pristine state.

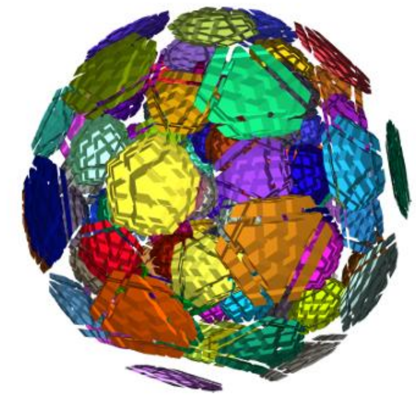


Figure 4: Magic120Cell, or the "4D Megaminx" has 120 dodecahedral faces. It derives from the *120-Cell*, one of 6 Platonic shapes in 4 dimensions.

Shapes in arbitrary dimensions are called *polytopes*, or *polychora* in 4 dimensions. In addition to the regular polychora, there are many *uniform* polychora and quite a few have been turned into twisty puzzles. Uniform polychora can break regularity in various ways. They may have multiple kinds of 3D faces or the faces may be composed of uniform (a.k.a. *Archimedean*) polyhedra.

> "For God's sake, I beseech you, give it up. Fear it no less than sensual passions because it too may take all your time and deprive you of your health, peace of mind and happiness in life."

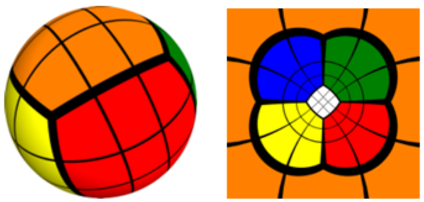
No, these were not desperate pleas to a hypercubist about excessive puzzling adventures. Such were the words of Farkas Bolyai to his son János, discouraging him from investigating Euclid's fifth postulate. János continued nonetheless, which led him into the wonderful world of hyperbolic geometry. We also did not heed the advice.

Let's use topology to abstract away a different property of Rubik's Cube - its cubeness. To do this,

Abstracting Rubik’s Cube pages 3-4

we project the cube faces radially outward onto a sphere. Mathematicians label the sphere S^2 because they consider it a 2-dimensional surface rather than a 3-dimensional object. Notice in Figure 5a that although the familiar cubeness is gone, all of the important combinatorial properties remain. Furthermore, what were 2-dimensional planar slices of the Rubik’s cube are now 1-dimensional circles on the spherical surface. A twist simply rotates the portion of the surface inside one of these “twisting” circles.

In short, we are considering the Rubik’s cube as a 2-dimensional tiling of the sphere by squares, sliced up by circles on the surface. Why? Because we can then consider other colored regular tilings and a huge number of new twisty puzzles become possible, some living in the world of hyperbolic geometry!



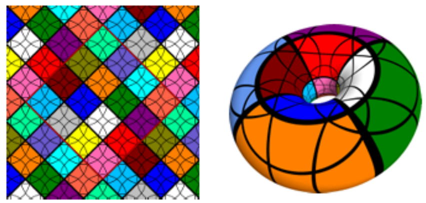
(a) Radially projected to the sphere, S^2.

(b) *Stereographically* projected from the sphere to the complex plane.

Figure 5: The Rubik’s cube viewed as a 2-dimensional tiling on a surface.

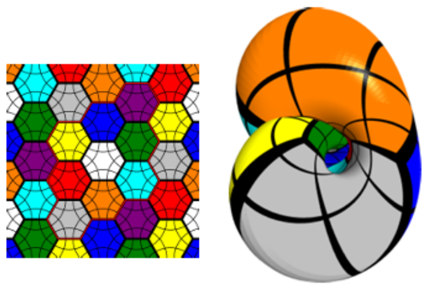
In 2 dimensions, there are three geometries with constant curvature: spherical, Euclidean, and hyperbolic, and each can be tiled with regular polygons. These geometries correspond to whether the interior angles of a triangle sum to greater than, equal to, or less than 180 degrees, respectively. The *Schläfli symbol* efficiently encodes regular 2-dimensional tilings in all of these geometries with just two numbers, $\{p, q\}$. This denotes a tiling of p-gons in which q such polygons meet at each vertex. For example, $\{4, 3\}$ denotes the tiling of squares with three arranged around each vertex, i.e. the cube. The value of $(p-2)(q-2)$ determines the geometry: Euclidean when equal to 4, spherical when less, and hyperbolic when greater.

Euclidean geometry is the only one of the three that can live on the plane without any distortion. A lovely way to represent the others on the plane is via *conformal*, or angle preserving, maps. *Stereographic* projection is a conformal map for spherical geometry. Its analogue for hyperbolic geometry is the *Poincaré disk*, which squashes the infinite expanse of the hyperbolic plane into a unit disk. These models have many beautiful properties and the *isometries* (transformations which preserve length) of all 3 models can be described via a simple mathematical expression that



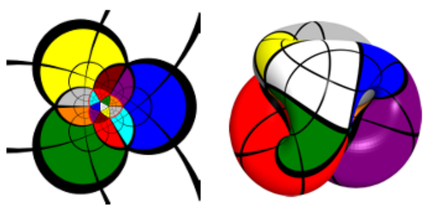
(a) Torus Rubik’s cube on the Euclidean universal cover.

(b) Torus Rubik’s cube mapped to the *Clifford* torus.



(c) Klein bottle Rubik’s cube on the Euclidean universal cover.

(d) Klein bottle Rubik’s cube mapped to a *Lawson* Klein bottle.



(e) Hemi-icosahedron (or real projective plane) Rubik’s cube on the spherical universal cover.

(f) Hemi-icosahedron Rubik’s cube mapped to the *Bryant–Kusner parametrization* of Boy’s surface.

Figure 6: Example tiling analogues. Note that there are other tilings that can also map to the surfaces on the right.

acts on the complex plane: the *Möbius* transformations.

$$f(z) = \frac{az+b}{cz+d}$$

You may have noticed that we have with another problem to make puzzle analogues workable for Euclidean and hyperbolic tilings. Spherical tilings are finite, but tilings of the other two geometries go on forever. To overcome this final hurdle, we take a fundamental set of tiles and identify edges to be glued up into a *quotient* surface. This serves to make the infinite tilings into finite puzzles. Figure 6 show but a few examples. We can even glue up a subset of tiles on the sphere, as in Figure 6e.

One of the crown jewels of this abstraction is the *Klein Quartic* Rubik’s cube, composed of 24 heptagons, three meeting at each vertex. It has “center”, “edge”, and “corner” pieces just like Rubik’s cube. The *universal cover* is the $\{7, 3\}$ hyperbolic tiling, and the quotient surface it is living on turns out to be a 3 holed torus. This results in some solution surprises; if you solve layer-by-layer as is common on the Rubik’s cube, you’ll find yourself left with **two** unsolved faces at the end instead of one.

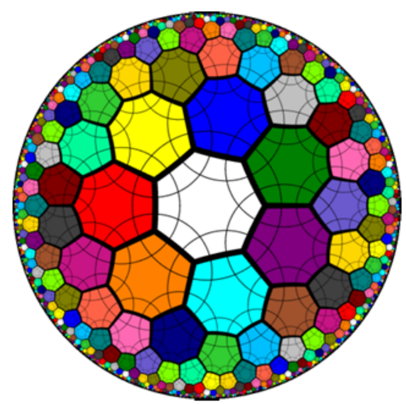


Figure 7: Klein Quartic Rubik’s cube on the hyperbolic universal cover. The quotient surface is a 3 holed torus.

All of these puzzles and more are implemented in program called MagicTile. The puzzle count recently exceeded a thousand, with literally an infinite number of possibilities remaining.

“We live on an island surrounded by a sea of ignorance. As our island of knowledge grows, so does the shore of our ignorance.” - John Archibald Wheeler

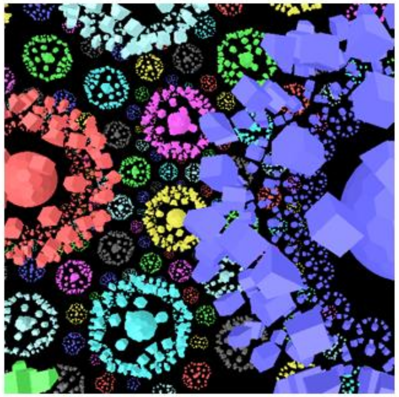
There are quite a few intriguing analogues that I have not been able to describe here. Let me just mention two of my favorite abstractions, shown in Figure 8. The first is another astonishing set of puzzles by Andrey are based on the $\{6, 3, 3\}$ *honeycomb* in 3-dimensional hyperbolic space, $\mathbb{H}^3$. The faces are hexagonal $\{6, 3\}$ tilings, with 3 faces meeting at each edge. Gluing via identifications serve to make the underlying honeycomb finite in two senses: the number of faces and the number of facets per face. If we take a step back and consider where we started, this puzzle has altered the dimension, the geometry, and the shape compared to the original Rubik’s cube!

The second is a puzzle written by Nan Ma based on the 11-cell, an *abstract regular polytope* composed of eleven hemi-icosahedral cells. You might consider this a higher dimensional cousin of the Boy’s surface puzzle we met earlier. The 11-cell can only live geometrically unwarped in ten dimensions, but Nan was able to preserve the combinatorics in his depiction.

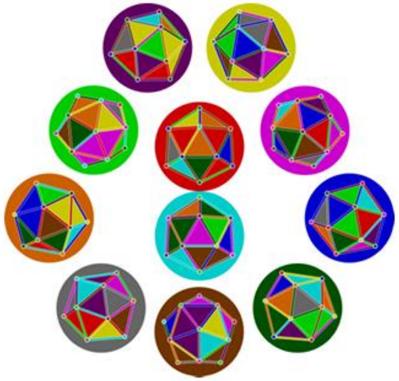
With so many puzzles having been uncovered, one could be forgiven for suspecting there is not much more to do. On the contrary, there are arguably more avenues to approach new puzzles now than ten years ago. For example, there are no working puzzles in $\mathbb{H}^3$ composed of finite polyhedra. There are not yet puzzles for uniform tilings of euclidean or hyperbolic geometry, in 2 or 3 dimensions. Uniform tilings are not even completely classified, so further mathematics is required before some puzzles can be realized. Melinda has been developing a physical puzzle that is combinatorially equivalent to the 2^4. The idea of *fractal* puzzles have come up, but no one has yet been able to find a good analogue.

In addition to the search for puzzles, countless mathematical questions have been asked or are ripe for investigation. How many permutations do the various puzzles have? What checkerboard patterns are possible? Which n^d puzzles have the same number of stickers as pieces? How many ways can you color the faces of the 120-Cell puzzle? What is the nature of *God’s number* for higher dimensional Rubik’s cubes? The avenues seem limited only by our curiosity.

Abstracting Rubik's Cube page 5



(a) Magic Hyperbolic Tile $\{6, 3, 3\}$. This is an in-space view of the puzzle in 3-dimensional hyperbolic space.



(b) Magic 11-Cell. Here we see the puzzle scrambled.

Figure 8: Two extremely exotic Rubik's cube abstractions.

Furthur Exploration

MagicCube4D website
Contains links to all the puzzles in this article and the hypercubing mailing list.

Burkard Polster (Mathologer) produced wonderful introductory videos to MagicCube4D and MagicTile.
Cracking the 4D Rubik's Cube with simple 3D tricks
Can you solve THE Klein Bottle Rubik's cube?

The following papers are freely available online:

Kamack, H. J., and T. R. Keane. "The Rubik Tesseract." (1982).

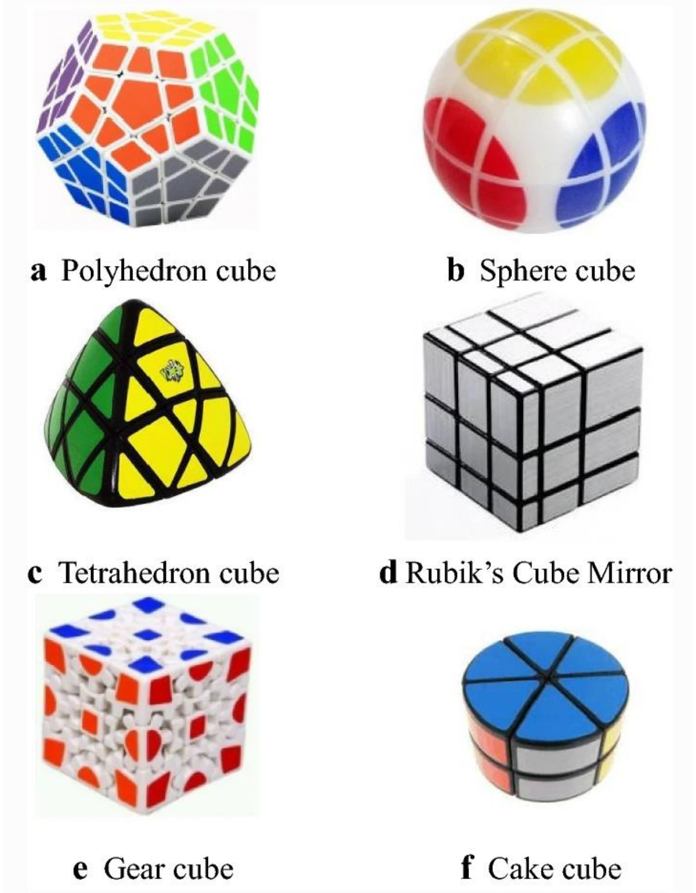
Stillwell, John. "The Story of the 120-cell." Notices of the AMS 48.1 (2001).

Séquin, Carlo H., Jaron Lanier, and UC CET. "Hyperseeing the regular Hendecachoron." Proc ISAMA (2007): 159-166.

Roice is a software developer with a passion for exploring mathematics through visualization. He enjoys spending time with his soul-mate Sarah and their three cats, and prefers traveling on two or fewer wheels.

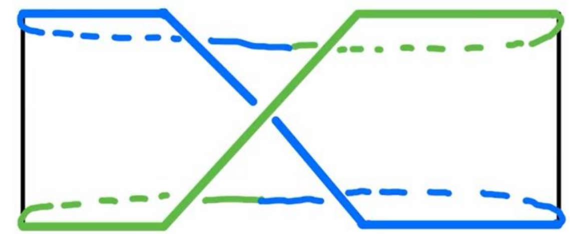
This is a preprint of an article published by Taylor & Francis Group in Math Horizons on March 7, 2018, available online: Abstracting the Rubik's Cube.

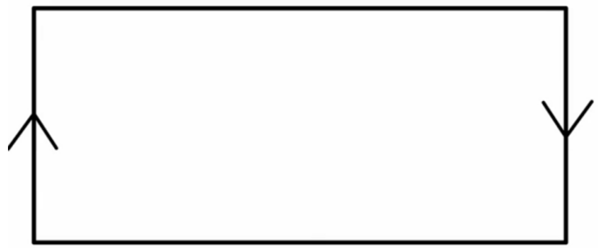
http://roice3.org/papers/abstracting_rubiks_cube.pdf

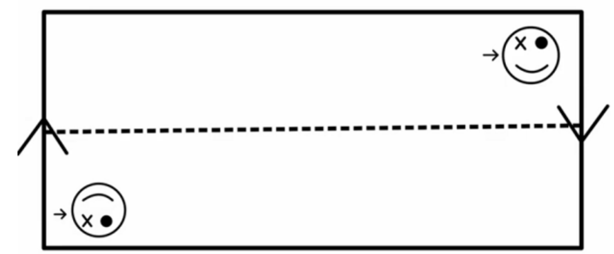


https://cjme.springeropen.com/articles/10.1186/s10033-018-0269-7

Möbius Strip







Next, Twist Strip 2 Half-Turns,
then cut down the middle.

https://www.youtube.com/watch?v=Qy0FSfEPBic

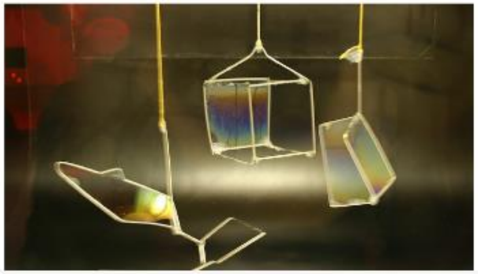
Math Bubbles

Why is the soap bubble spherical instead of another shape, such as a long and skinny ellipsoid with the same radius as the circular wand? Try using the following soap formula to blow your own bubbles.

Ingredients:

- 6 parts water
- 1 part dishwashing liquid
- For longer lasting bubbles, add 1/3 part glycerin or corn syrup.

Experiment with different types of wands, such as pipe cleaners, metal coat hangers, or flexible wire bent into shapes such as polygons, spirals, or stacked circles.



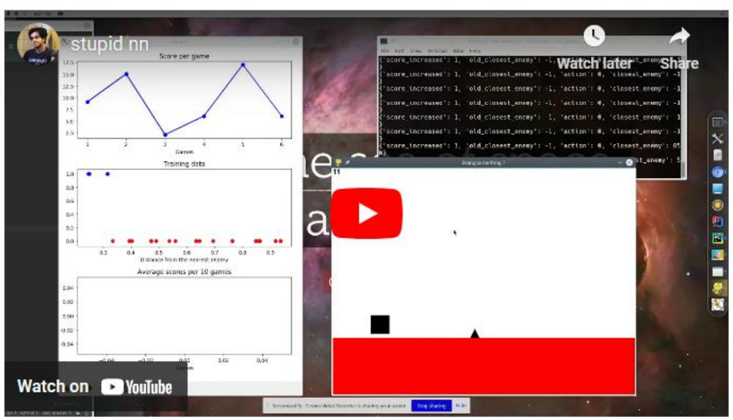
https://brilliant.org/wiki/math-of-soap-bubbles-and-honeycombs/

Math Algebra

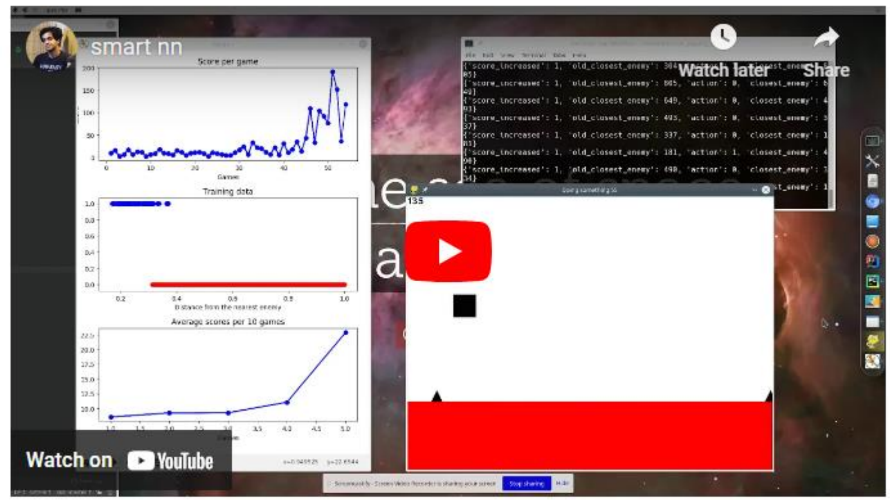
A simple neural network that like learns how to play a game or something like that. That would be engaging. Like an ai learns and “evolves” over generations to get better at a game. it’s all linear algebra and it’s simple to explain the basic concept. Colby Wright

The player is the black box and the enemies are the black triangles. The only control is spacebar to jump over them. Initially the game is extremely simple and easy but I am going to make it more complex and difficult as I create the neural network. For now, this will do. Here is a video of me playing the game to give you a sense of how it works.

Now, here is a video of the neural network first playing the game (Look at the score on the top left)



And here is one after it has learnt to play the game



It is pretty clear that the neural network is learning from playing the game on its own slowly. On this particular run, I think the neural network scored more than 300 points. And in one run, I have gotten it to achieve a score in thousands! That is clearly impressive as the difference between the two videos is just of a few minutes.

https://medium.com/@sanilkhurana7/building-a-neural-network-that-learns-to-play-a-game-part-1-e408ae7106d0

Hyperbolic Crochet

https://www.youtube.com/watch?v=1ahCk2dD6EI

Discover more with Omni's hexagon quilt calculator!

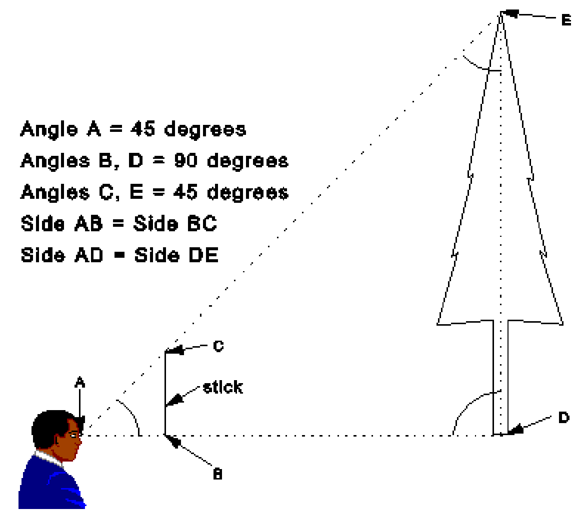
https://www.omnicalculator.com/everyday-life/hexagon-quilt#the-hexagon-quilt-calculator

Math Trigonometry: Tree Height Measurement

You can measure heights of very tall objects such as trees by projecting a right triangle (one that includes a 90 degree angle) using your arm, a stick, and your line-of sight.

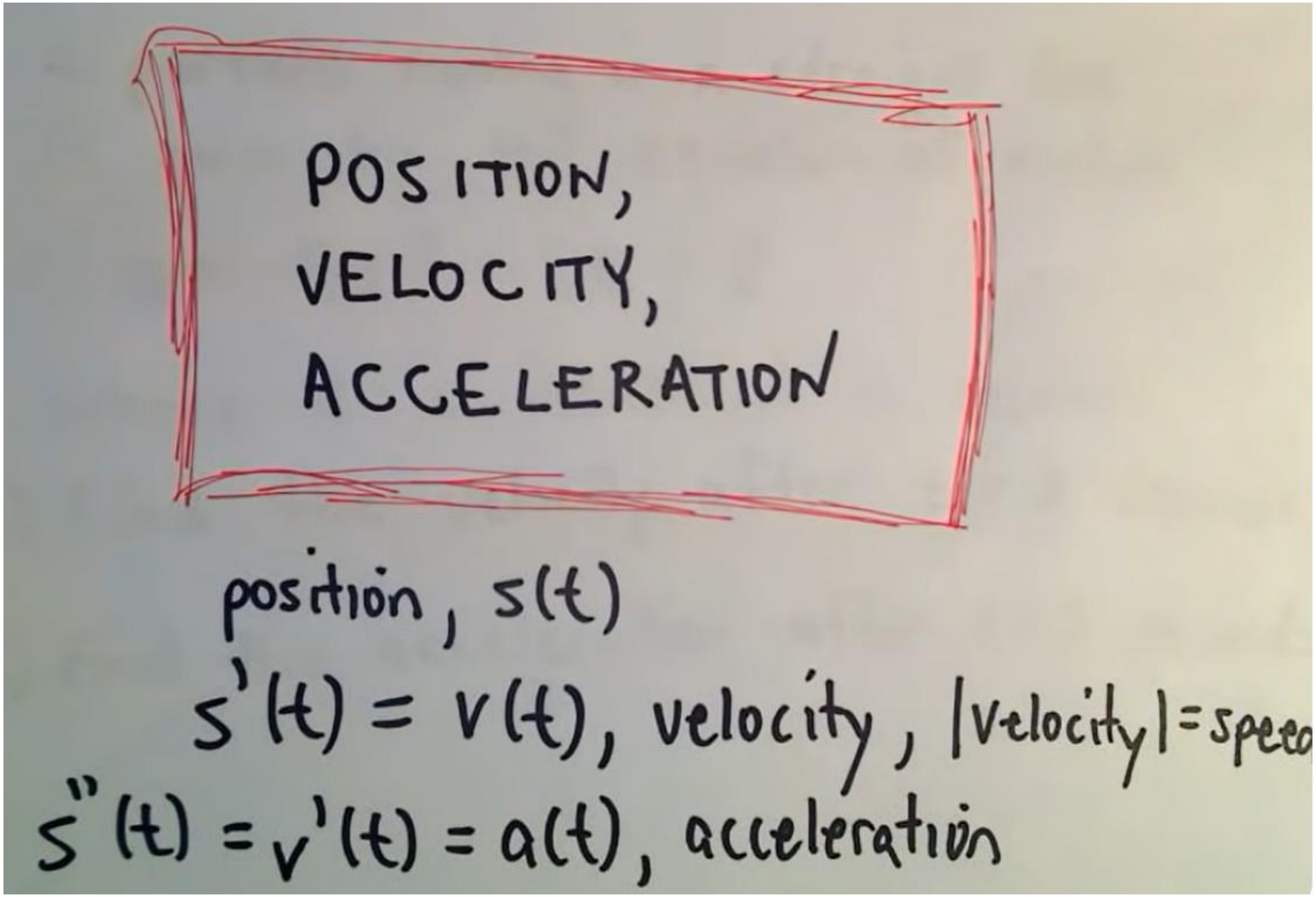
Procedure:

1. Get a stick that is equal in length to the distance from your eye (cheekbone) to your fingers when your arm is fully extended in front of your face. Break off part of the stick or mark it at the correct length if you don't find one that is exactly right.
2. Grasp the stick by the tips of the thumb and index finger and hold it out in front of you with your arm fully extended. The stick must be held vertical.
3. Walk toward or away from the tree until the tip of the stick is visually lined up with the top of the tree and the bottom of the stick is lined up with the bottom of the tree. Your line of sight to the tree base should be as close as possible to horizontal. In sighting to the top and bottom of the stick rotate your eye rather than your head.
4. The distance from your eye to the base of the tree is equal to the height of the tree. Measure this distance with a measuring tape. If no long-distance measuring device is available, calibrate your step (the walking distance between your two feet--walk normal, don't stretch) or pace (walking distance for two steps) over a known distance (say 50 feet). Then measure the distance A-D in paces or steps and convert to feet, meters, etc.



https://extension.usu.edu/forestry/resources/kids-and-teachers/tree-height

Math Calculus

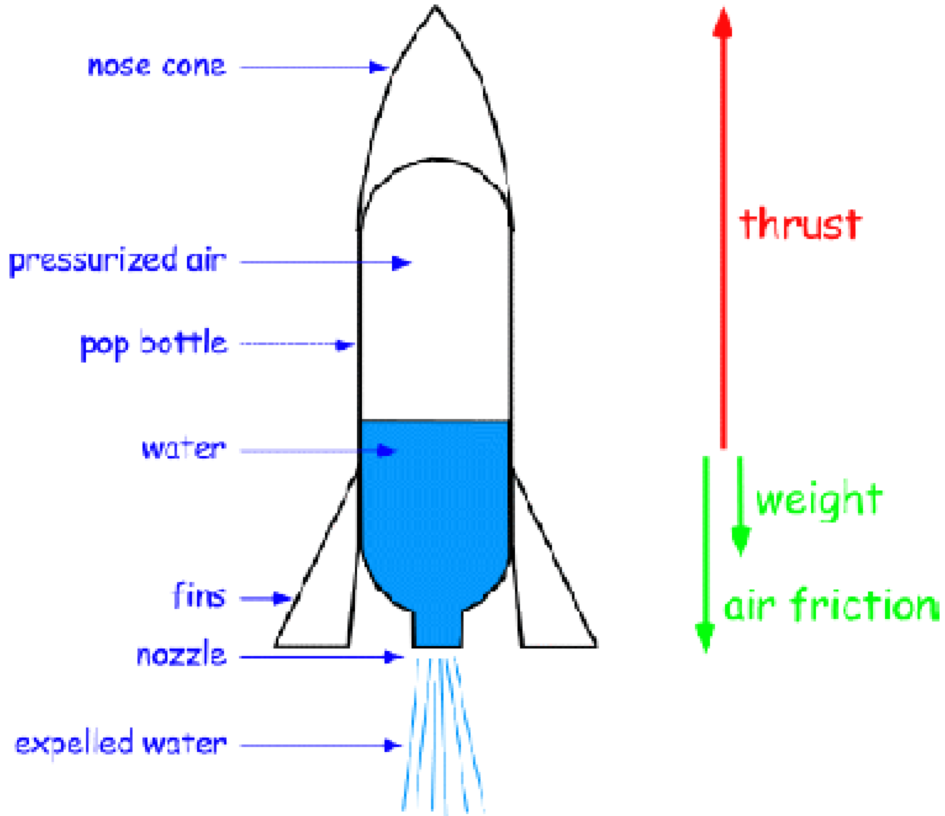


https://www.youtube.com/watch?v=pFeuGMMiZWw

Water Bottle Rockets

2-Liter Water Bottle Rockets Overview

Great detailed website: http://www.et.byu.edu/~wheeler/benchtop/flight.php



The equation for thrust, caused by water exiting the nozzle, is:

$$T = (P_{in} - P_{out}) \cdot A_n$$

where P_{in}-P_{out} is the difference between pressure within the rocket and atmospheric pressure, and A_n is the cross-sectional area of the nozzle opening. Thrust is dependent on pressure, nozzle diameter. The amount of water dictates how long the thrust force will be applied, and therefore contribute to the rocket's total kinetic energy.

Water Bottle Rockets continued

The following values are the optimal values for maximum height at 90 psi:

- Air/Water ratio = 0.5 liters
- Dry Weight = 220 grams
- Stabilizer Length = 3.5 inches
- Maximum Height = 350 ft (impact pressure = 120 mph baseball pitch)

Water Bottles with thicker plastic (cord strength) can be pressurized greater; many European bottles have much stronger cord strengths than U.S. plastic bottles.

The following mathematical expression yields ~apogee height for a given total flight time:

$$h_{ap} = (g/8)(t_{end})2 - 3.5 \text{ meters}$$

Water rockets, requiring a largish capacity for air and water, are usually large in diameter, this causing a large amount of drag and limiting the height achieved. However, the impulse rating for even a 2 liter water rocket is normally E - four times the impulse of a pyro motor that can be bought over the counter in a high street toy shop.

Motor Impulse Classes	
Impulse /Ns	**Class**
I <= 0.625	¼A
0.625 < I <= 1.25	½A
1.25 < I <= 2.5	A
2.5 < I <= 5	B
5 < I <= 10	C
10 < I <= 20	D
20 < I <= 40	E
40 < I <= 80	F
80 < I <= 160	G
160 < I <= 320	H
320 < I <= 640	I
640 < I <= 1280	J
1280 < I <= 2560	K
2560 < I <= 5120	L
5120 < I	>L

Electronic Laser Double Elliptical Pendulum Harmonograph

https://www.instagram.com/reel/C7hUXxFpKlI/?igsh=c3I0NGhzaGZmeGNu

Speaker in a bowl:

Fabric and Mirror:

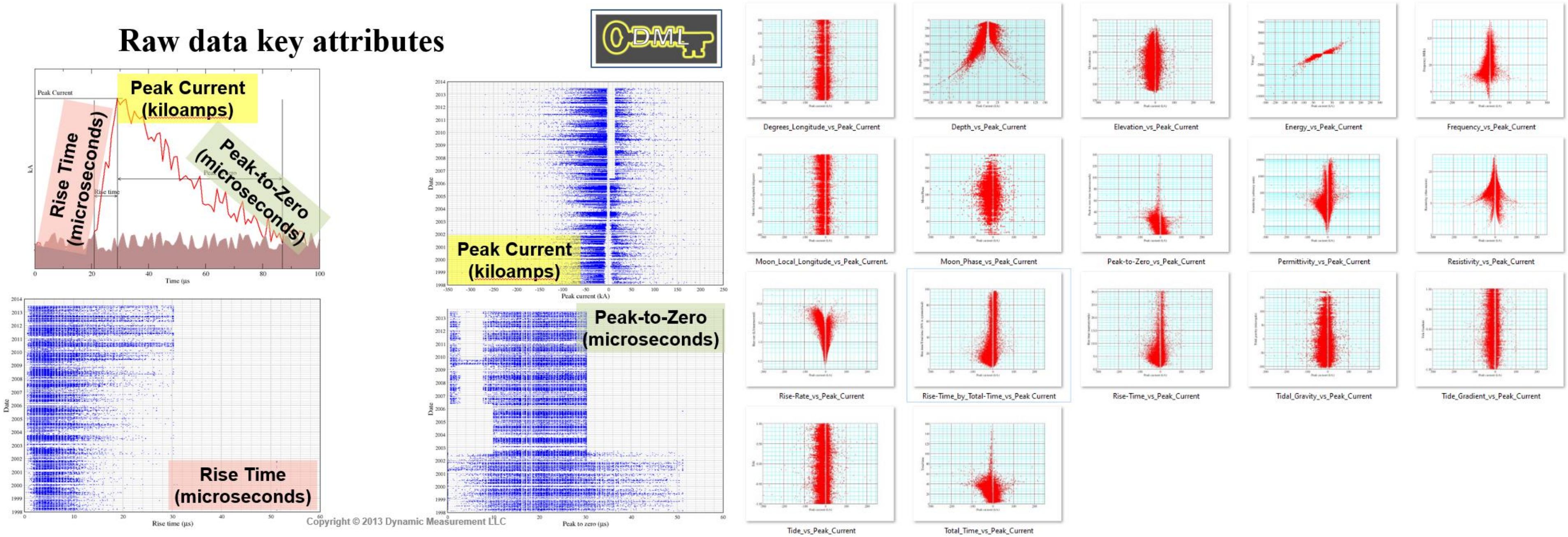
Laser on Mirror:

One Frequency:

Two Frequencies:

Math Statistics

Mathematical statistics, or statistics, is the study of collecting, organizing, analyzing, interpreting, and presenting data. It uses mathematical techniques like linear algebra, differential equations, mathematical analysis, and probability theories. Statistics can be applied to scientific, industrial, or social problems.

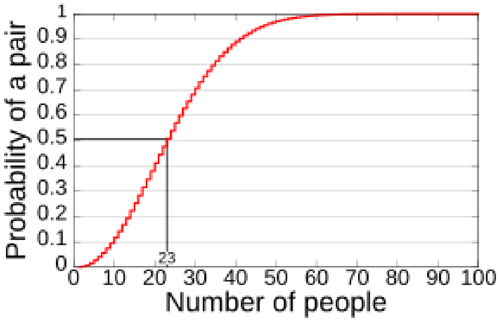


Lightning Analysis statistics and cross-plots

Math Probability

In probability theory, the **birthday problem** asks for the probability that, in a set of n randomly chosen people, at least two will share a birthday. The **birthday paradox** refers to the counterintuitive fact that only 23 people are needed for that probability to exceed 50%.

The birthday paradox is a veridical paradox: it seems wrong at first glance but is, in fact, true. While it may seem surprising that only 23 individuals are required to reach a 50% probability of a shared birthday, this result is made more intuitive by considering that the birthday comparisons will be made between every possible pair of individuals. With 23 individuals, there are $\frac{23 \times 22}{2} = 253$ pairs to consider, far more than half the number of days in a year.



The computed probability of at least two people sharing a birthday versus the number of people

Real-world applications for the birthday problem include a cryptographic attack called the birthday attack, which uses this probabilistic model to reduce the complexity of finding a collision for a hash function, as well as calculating the approximate risk of a hash collision existing within the hashes of a given size of population.

The problem is generally attributed to Harold Davenport in about 1927, though he did not publish it at the time. Davenport did not claim to be its discoverer "because he could not believe that it had not been stated earlier".[1][2] The first publication of a version of the birthday problem was by Richard von Mises in 1939.[3]

https://en.m.wikipedia.org/wiki/Birthday_problem

Notes

Notes

2024 Science Camp

- **What was best about 2024 Science Camp?**
  - ___
  - ___
  - ___
  - ___
- **What would be your ideal 2025 Science Camp Theme?**
  - ___
  - ___
  - ___
  - ___
- **Remember, Grandpa & Grandma plan to be serving a mission for The Church of Jesus Christ of Latter-Day Saints in 2025-2026. Uncle Rob stated he wants to visit, maybe you and your family want to visit too.**