Natural Philosophy from Stonehenge to Gamma Rays

John Michael Preston

The Almost No Math Physics Course

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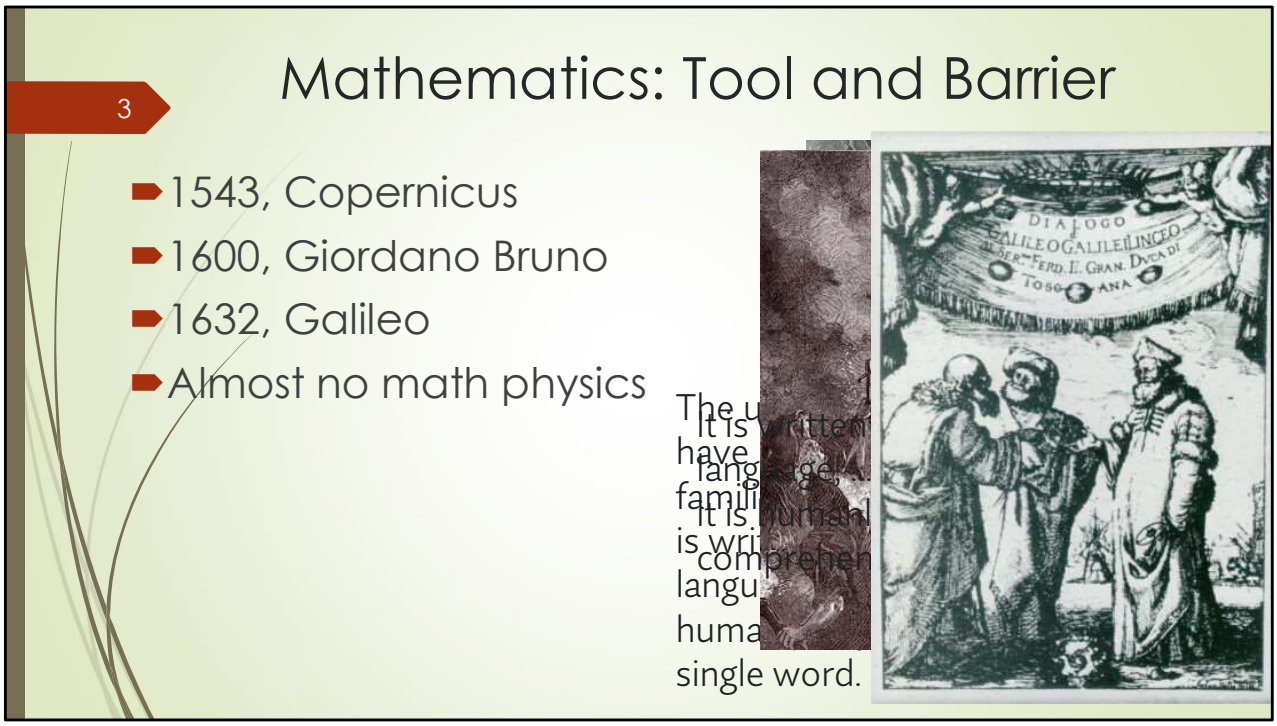
Welcome to the “almost no math” physics course. In this session, we will explore the origins of physics as a form of philosophy and how philosophy influenced the discoveries of the laws of nature that have dominated western thought for two thousand years.



*Galileo once wrote that mathematics was necessary to understand a single word about the laws of nature. There is more to this story.
*In 1543, Nicolas Copernicus wrote a book named *On the Revolutions* in which he argued that the earth revolved daily and rotated around the sun annually. The Spanish Inquisition ruled that this idea was heresy because it contradicted stories in the bible and banned the book.
*In 1600, Giordano Bruno taught this idea in spite of the ban and he was burned at the stake by the Inquisition.
*About thirty years later, Galileo was working on a book that also argued in favor of the Copernican system. He submitted a draft copy for approval by the Inquisition but included this statement. His statement was probably intended to keep them from reading any of the book before he got to publish it. His trick apparently worked, and they waited until it came out to read it. *The book is titled *Dialogue Concerning the Two Chief World Systems*. When they saw that it was written as a dialog between three men with no mathematics where the character that voiced the church's views was named Simplicio, they immediately banned the book, but it was too late, it was already being distributed. (Show a copy of the book.)
*It is unfortunate that this view of the relationship of physics and mathematics has dominated the teaching of physics. Many people who don't have several years of mathematics training have been deprived of this fundamental knowledge. As Galileo

demonstrated, big ideas in physics can be learned without complex mathematics. In my personal experience, a few simple tools of mathematics are sufficient to understand most of the concepts in physics. I'll take a few minutes in this class to show you a few of these tools and how they relate to natural laws. When additional mathematical tools they are needed in future classes, I will take a few minutes to review them for you.

Physics and Metaphysics

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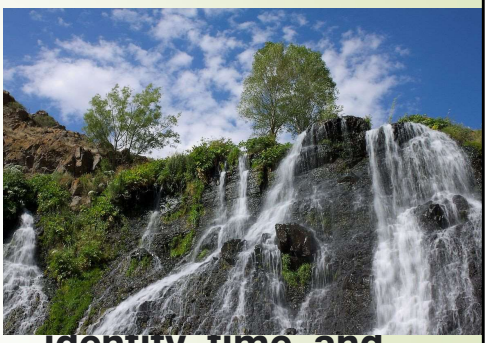
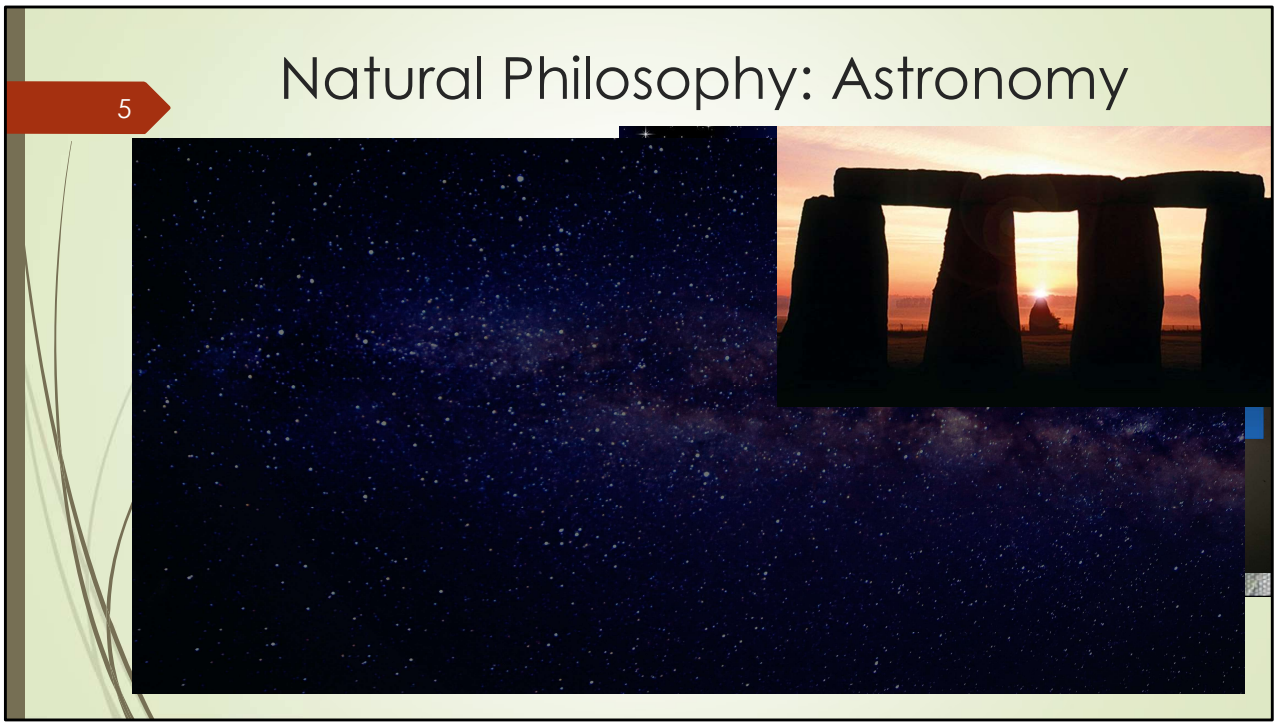
- Natural Philosophy (physics)
- Metaphysics
- Laws of nature
- Interaction



Identity, time, and space

*The early Greeks divided philosophy into the study of the physical world, called Natural Philosophy or physics, *and the larger questions of cause, being, identity, time, and space called metaphysics.
*Natural philosophers sought to reveal fundamental laws of nature that were repeatable and agreed closely with observations. *Biographers of Aristotle organized his writings starting with natural philosophy followed by metaphysics, implying a linear progression and that metaphysics was something one studied after mastering physics. However, history shows that the two influence each other and have done so from the beginning of Greek thought through today.



The earliest natural philosophy that predated the Greeks was astronomy. It had several of the key elements of modern physics: *Careful observation and *record keeping, *looking for patterns*, and *using those patterns to predict future events like eclipses. The earliest mathematics tool was simply counting.

Pythagoras and Triangles

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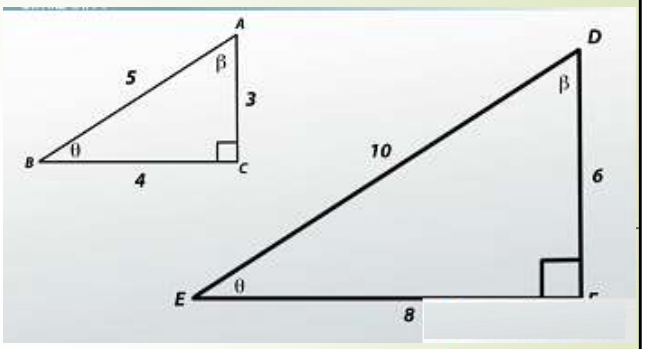
- Pythagoras, sums and ratios
- Interior angles add up to a straight line
- Ratios; 2:1 and 4:2 are the same ratio
- **Similar** triangles



*Pythagoras was a Greek who lived around 500 BCE. He sought answers to metaphysical questions through the study of geometric shapes, ratios of whole numbers, and musical intervals. He inspired a cult of followers who were devoted to his methods. Two tools of mathematics that he used were **sums** and **ratios**.

*The Pythagoreans were fascinated by triangles. They demonstrated that the sum of the interior angles of any triangle add up to a straight line. A statement that can be generalized is an example of a law of nature.

*When we say that one thing is twice as big as another, that is a ratio. A long sentence can be represented by a few numbers and symbols, e.g. 2:1. Pairs of numbers that have the same proportion to each other have the same ratio.

*If two triangles have the same size interior angles, the sides of those triangles have the same ratios. Triangles with the same angles and proportional sides are called **similar** triangles.

Area and Volume

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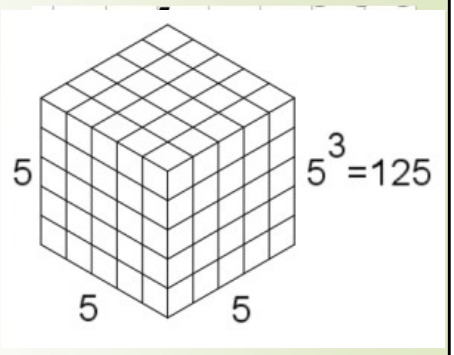
- Area = 25 square units
- Any number multiplied by itself is "squared"
- The notation is a small, superscript 2, e.g. 5^2
- Area is proportional to the square of the length of a side
- Any number multiplied by itself three times is "cubed", 5^3
- Volume is proportional to the cube of a side



The Pythagoreans discovered a fundamental law of nature about triangles and areas. We will need the mathematical tools of area and volume. *If the length of one side of a square is measured, it may be divided into an array of small squares, each of which is one measurement unit in length and the number of small squares or the "area" of the square, may be found by multiplying the lengths of two sides together. In this illustration, a square that is five units on a side will contain 25 small squares whose sides are one unit long, and we say its area is 25 square units.

*In general, whenever a number is multiplied by itself, we say it is squared and *write it with a superscript of *2. *We can say that the area of a square is proportional to the square of one of its sides.

*A cube may be divided into small cubes that are one unit length on a side. The volume of the cube is the number of small cubes one unit long on each side that fit within the larger cube which may be found by multiplying the three sides together. *Any number multiplied by itself three times is cubed and is noted by a raised 3.

*The volume of a cube is proportional to the cube of the length of its sides. Several laws of nature that were discovered later observe that the size of something is directly or inversely proportional to the square or cube of another.

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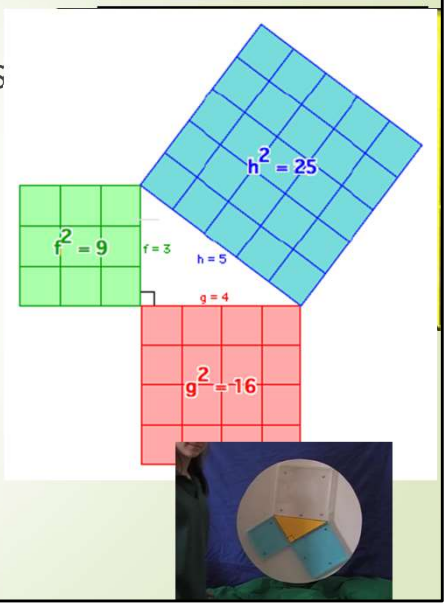
Right Triangles

- Triangle: shape with three angles and three sides
- Right Triangle: Triangle with one square corner
- Egyptians
- Pythagoras: sum of the two smaller squares always equals the area of the larger square
- General law of right triangles



*A triangle has three angles and three sides. *A shape that seemed to have metaphysical properties was the “right” triangle. A right triangle is any three-sided shape that has one square corner. *The Egyptians discovered that they could reliably produce a right triangle if the three sides were 3,4, and 5 units long.
*Pythagoras recognized that if he constructed a square on each of the three sides of a 3,4,5 right triangle, that the sum of the areas of the two smaller squares added up to the area of the large square. *Further exploration showed that this was true for all right triangles. He had discovered a law of nature and it is called the Pythagorean Theorem.*

Pythagoras and Music

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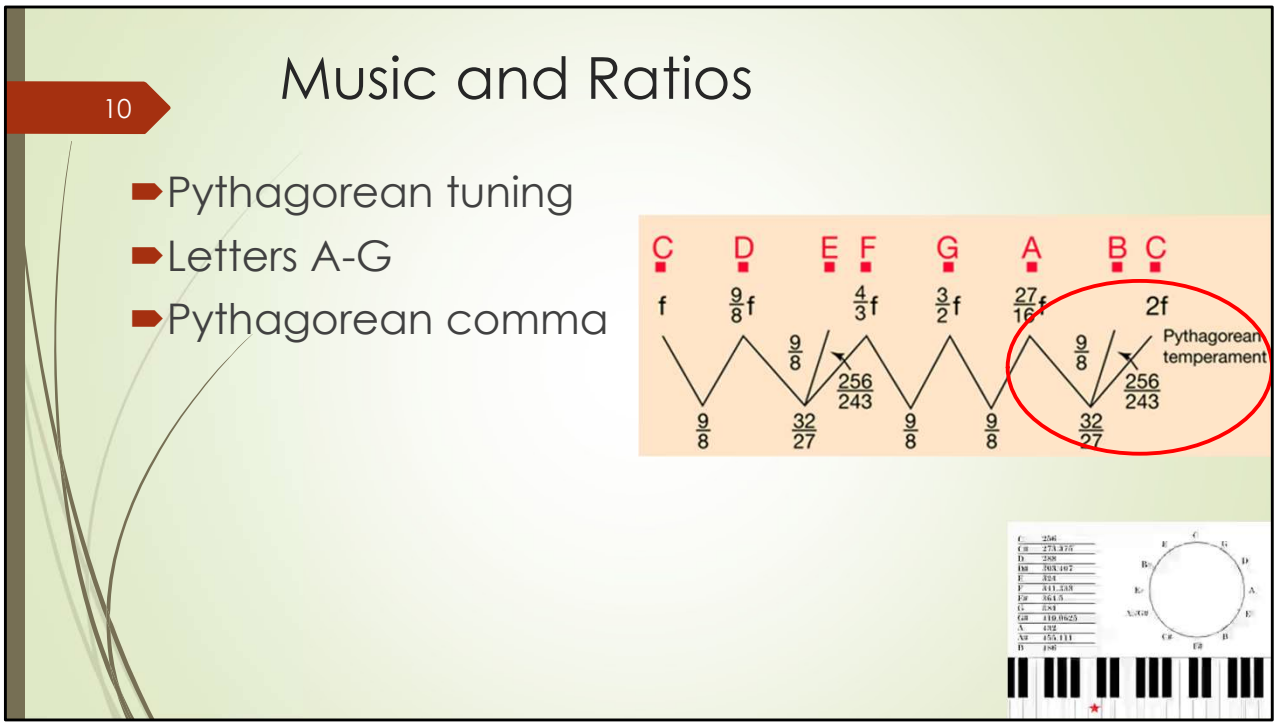
- Musical tones related to the size or length of the vibrating object
- Ratios of sizes or string lengths
  - 2:1 (octave)
  - 3:2 (fifth)
- Ratios of whole numbers

*Pythagoras recognized a special musical relationship between objects where the sizes were ratios of whole numbers.
*He experimented with different size objects and discovered that two of the ratios where particularly pleasing. They are: *2:1 and *3:2. *
*He believed that ratios of whole numbers were the key to understanding the natural world, so he proceeded to construct a scale using multiples of these two ratios.



*Pythagoras experimented with different combinations of octaves and fifths to create a sequence of twelve notes, that were all based on ratios of whole numbers, including the two notes at either end that had a 2:1 ratio. This set of intervals is known as Pythagorean tuning.

*The Letters A through G were added a thousand years later by the Romans.

Pythagoras discovered a natural law related to the two ratios of 2:1 and 3:2 but when he tried to force his metaphysical idea of perfect ratios on the system, it didn't quite work. The last interval did not result in a note that was twice the pitch of the first note. The interval had to be adjusted to fit and is called the Pythagorean comma.

The Pythagorean tuning system, based on ratios, was used for almost two thousand years in Europe during which time musicians typically *avoided the wolf fifth. We will revisit these two pitch ratios when we examine wave behavior in a future session. We will find that there are several examples in the history of physics where someone thought they had discovered a natural law, but it didn't quite fit the physical reality.

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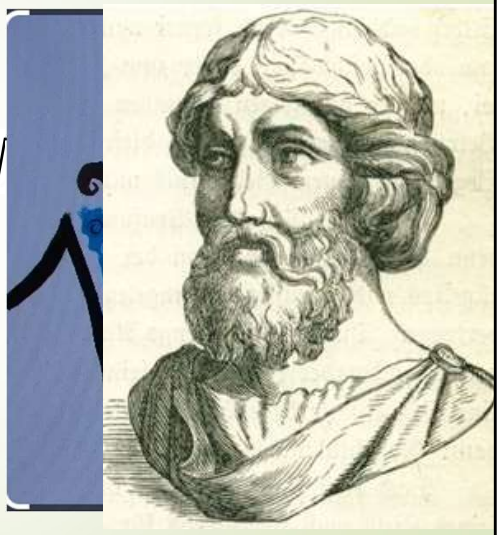
Irrational Numbers

- Rational numbers (ratios)
- Hippasus
- Irrational (not ratio) numbers $\sqrt{}$
- "the number, that when multiplied by itself is"
- Square root ~ 1.414…
- Similar roots; $\sqrt[3]{}$ $\sqrt[4]{}$
- Hippasus killed



*Pythagoras taught his followers that all things could be described with numbers that were ratios of "whole" numbers, similar to his musical scale. These types of numbers are called "rational" numbers

*One of Pythagoras' students, Hippasus, demonstrated that his teacher was wrong, and he used Pythagoras' own theorem to do so. *He observed that if a right triangle had two short sides of 1 unit length each, then squares based on those sides would each be 1 square unit. According to the Pythagorean theorem, the area of the square on the longest side must be the sum of these or 2 square units and the length of the longest side must be some number that, when multiplied by itself equaled 2. *However, no such rational number existed! The answer is called an "irrational" number; not because it doesn't make sense, but because it cannot be expressed as a ratio of whole numbers. *Today, we represent this type of number with a special symbol that stands for the phrase *"the number, that when multiplied by itself is" and we call the irrational number the *square root. The square root of 2 is about 1.414.

*This notation can be extended by adding a small number. To indicate the number that when multiplied by itself three times, aka *the cube root we use a 3. *Similarly, the fourth root is indicated with a four and so on.

*This concept was heresy to the Pythagorean cult, and according to legend, they threw Hippasus into the sea where he drowned. This is a cautionary tale for those whose study of natural philosophy contradicts metaphysical beliefs. The Pythagorean tuning system, based

on ratios of whole numbers, was used for almost two thousand years in Europe during which time musicians typically avoided the wolf fifth and avoided irrational numbers.

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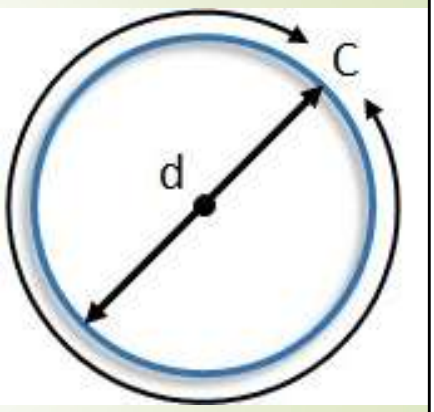
Circles and Spheres

- Ratio is a constant
- C/d ~ 22/7 or 3.14159…
- Ratio named **π** from **π**ερίμετρος
- Predictions
- A sphere is a three-dimensional circle



Another irrational number involves a circle. *Many early cultures recognized that the distance across a circle is directly proportional to the distance around the circle regardless of the size of the circle and that *the ratio of the two is always the same. It is close to 22/7 but no ratio of whole numbers is quite right. *The ratio was given its own name, π, which is the first Greek letter in the word perimeter.

*The power of knowing such a law of nature is that it can be used to make predictions. For example, if you know the distance across a circle, you can accurately predict that the distance around it is a bit more than three times as much.

*A sphere is a three-dimensional circle and the ratio of its circumference to its diameter is also Pi

Metaphysics of the Circle and Sphere

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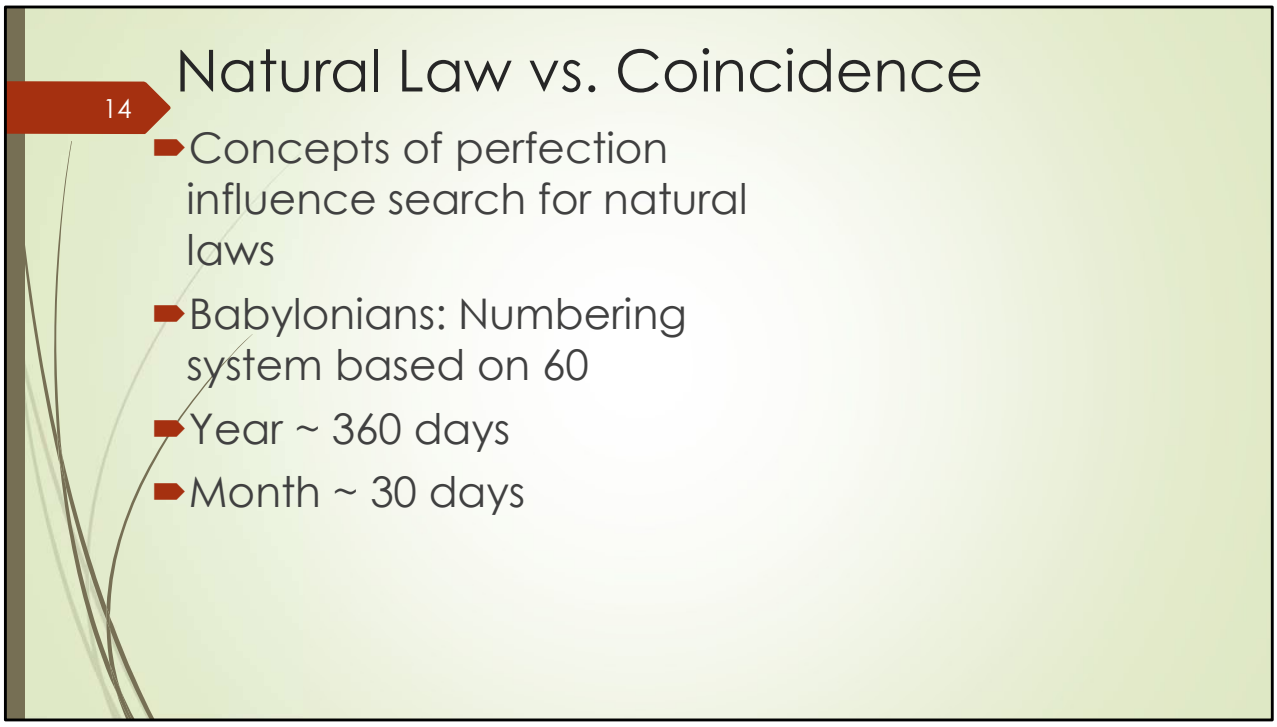
- Shape of the moon
- Path of the Moon
- Path of the Sun
- Paths of the stars
- Metaphysics of circ spheres

*Observation over the course of a month showed that the moon is a sphere, illuminated by the sun, and its apparent phases are due to the direction of the sun's light. *The moon also appears to cross the sky each day in a circular path at an incline. *The daily path of the sun through the sky appears to be part of a circle whose plane moves with the seasons. *The night sky appears to be the inside of a great sphere that rotates about an axis that is close to the north star.

*Because these heavenly objects were associated with circles and spheres, the circle and sphere were thought to be heavenly too. The circle and sphere were metaphysical examples of perfection and therefor the natural shape path for motion of heavenly bodies.



Natural laws like the Pythagorean theorem or the ratio designated by pi retain their proportionality when the measurements involved are increasingly accurate while coincidences like the relationship between musical notes and Pythagorean ratios don't fit well when examined more closely. *Sometimes, metaphysical considerations influence the search for natural laws and embed themselves in our culture even when they are known to be incorrect. *For example, the Babylonians based their numbering system on sixty because of the metaphysical nature of the number 60 which could be divided by 2,3,4,5,6,10,12,15, and 30 as well as 1 and 60. *It was also an interesting coincidence that a year appeared to have 360 days (60x6), and a *lunar month had about 30 days (60/2).

Natural Law vs. Coincidence

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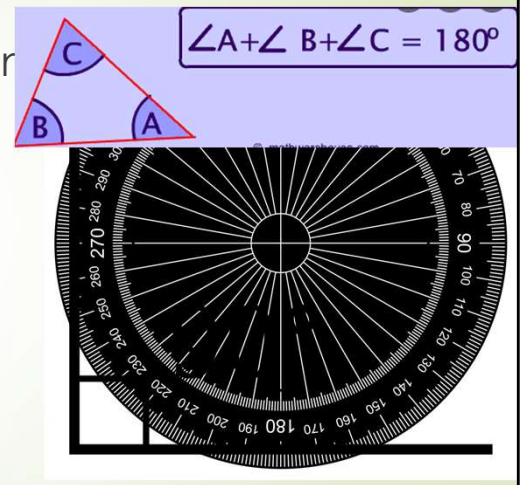
- Circle divided into 360 degrees. Angles measured in degrees.
- Right angle is 90 degrees
- Sum of interior angles is 180 degrees

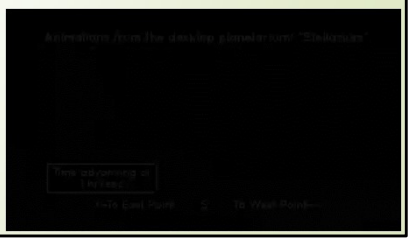


*The Babylonians assumed that a perfect shape like a circle should be divided into a perfect number of equal angles and chose to measure angles by dividing a circle into 360 equal parts or degrees.
Closer observations shows that there are about 365 ¼ days per year and about 29.5 days in a lunar month and the relationship to 60 is just a coincidence, rather than a natural law, but this method of measuring angles is still with us. *Consequently, a right angle is ¼ of 360 so we say it is a 90-degree angle and *the sum of the interior angles of a triangle is half a circle or180 degrees.

Motion of the Planets

16

- Planet means "wanderer"
- Named after Greek and then Roman gods
- Mercury and Venus always near the sun
- Mars, Jupiter, and Saturn can appear opposite the sun or near it
- Retrograde motion
- Changes in speed

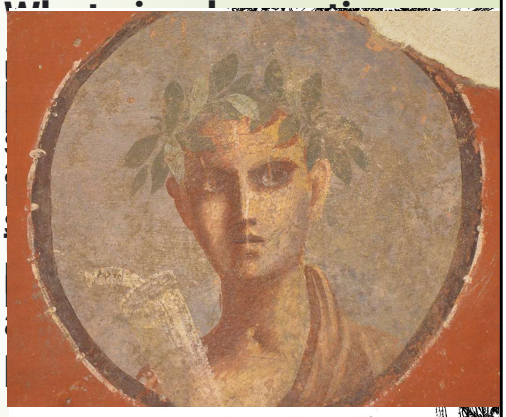


*Observers of the heavens noticed that the position of stars remained fixed relative to each other while they circled the night sky with the exception of five of them that wandered amongst the stars. These were called the wanderers or "planetes" in Greek.
*The Greeks did not think of them as large bodies that were like the earth. They were just wandering stars. Greek and Roman mythology associated them with gods like Mercury, Venus, Mars, Jupiter, and Saturn.
*Mercury and Venus are always near the sun and may be seen before dawn and after sunset. Venus is the third brightest object in the sky after the sun and moon.
*Mars, Jupiter and Saturn can appear anywhere along the sun's apparent path across the sky, even at midnight.
All of the planets exhibited an odd behavior called retrograde motion.
*Careful observation also showed that the planets did not progress at a constant speed.
*Apparent backward or retrograde motion and changing speed did not seem to fit the idea that heavenly objects all followed circular paths at a constant speed. It raised doubt about the idea that heavenly objects moved in perfect circles.

17

Socrates and Plato

- Socratic method (420 BCE)
- Plato (380 BCE) student of Socrates
- Writings were in dialog format



The Greeks made several important additions to the practice of natural philosophy.
*Socrates was a famous teacher who asked the question "Why?" He responded to questions with questions that were intended to cause a student to examine his assumptions, especially to determine if some of them were wrong. He was unpopular in Athens because he often made officials look foolish and he opposed democracy. He was put on trial for impiety and corruption of the youth of the city. Rather than take a lesser penalty like banishment, he chose the death penalty. He administered a lethal dose of hemlock to himself.
*One of Socrates' students, Plato, who we may assume was one of the youths Socrates corrupted, wrote mostly about government but his philosophy regarding the relationship between perception, reality, and truth influenced natural philosophy. *Plato wrote; "to understand our perceptions of reality by somehow transforming it into what we know to be true without violating any known principles. (Father of alternative facts?). *He challenged his students to find out how to explain the appearance of retrograde motion while still using perfect circles which is known as "Plato's Problem"
*The ideas of these teachers were often written in the form of a dialog between two or three people to provide both sides of an argument.

Aristotle

18

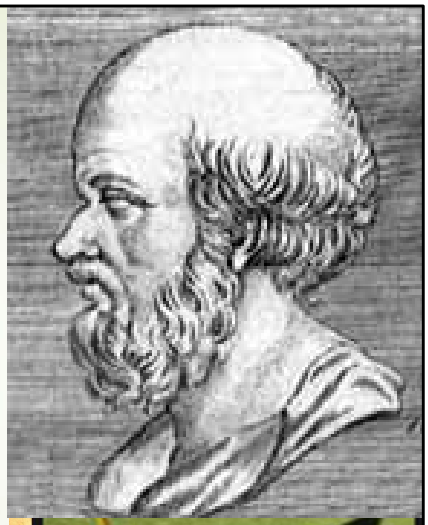
- Aristotle (~350 BCE)
- Observation
- Heavy objects fall faster
- Meteorology
- Comets
- Theories must agree with observations

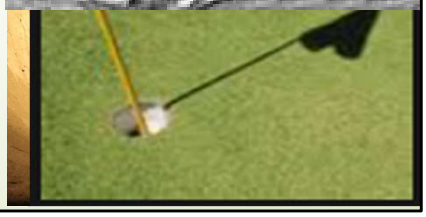
*Aristotle was a star student of Plato's and he felt that *natural philosophy is the highest calling. *He observed nature and wrote extensively about animals, plants, and the behavior of physical objects. His theories that explained the behavior of objects made sense such as the observation that *heavy objects fall faster than lighter ones.
*He literally wrote the book on Meteorology in which he explained that the heat from the sun caused vapors to rise from the ocean and earth and when they met with the spheres of air and fire they caused clouds, lightning, and rain. He coined the term **meteorology** where meteor means to rise up. *He also thought that comets were located near earth and were an example of the dry vapors from the earth catching fire at high altitude. *He developed rules of logic that helped test the validity of theories and was willing to discard a theory if it didn't agree with observation. *

Size of the Earth

19

- Alexandria
- Eratosthenes ~200 BC
- Sun directly overhead at Aswan
- Flagpole at Alexandria cast a short shadow, about 7 degrees from vertical





*While Alexander was busy conquering most of the middle and far east, he designed a port city in Egypt that was named after him. It became the center of Greek culture and thought, even though it was in Egypt.
*About 150 years after Aristotle, Eratosthenes used observations, logic, and proportions to measure the size of the earth. *Because he was in Egypt where the sun is higher in the sky than in Greece, he was aware that the sun would shine all the way to the bottom of a well once a year in the city of Syene, about 500 miles south of Alexandria. *On that same day, the sun made a 7-degree angle with a vertical flagpole at Alexandria .

Size of the Earth

20

- Alternate interior angles between parallel lines are equal
- 7 degrees is to 360 as 500 is to the circumference; 7/360 = 500/circumference
- Circumference = 25,700 miles (24,900 miles actual)

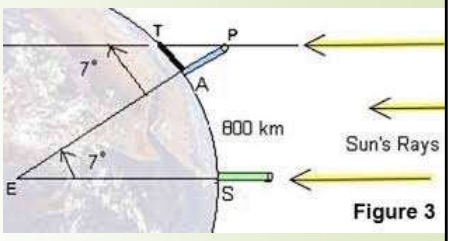


Figure 3

*Eratosthenes reasoned that the well and the flagpole were extensions of vertical lines that intersected at the center of the earth. He also assumed that the rays of sunlight were parallel and then applied a geometry rule (interior angles between parallel lines are equal) to deduce that the angle between the two lines at the center of the earth was also 7 degrees. *He then deduced that a ratio of seven degrees to 360 degrees must equal the ratio of 500 miles to the circumference of the earth. *This technique yielded a measurement that is very close to today's value.

21

Similar Right Triangles

- Hipparchus ~150 BCE
- Ratios of all right triangles
- Table of ratios for every right triangle
- Father of Tri-gon-ometry

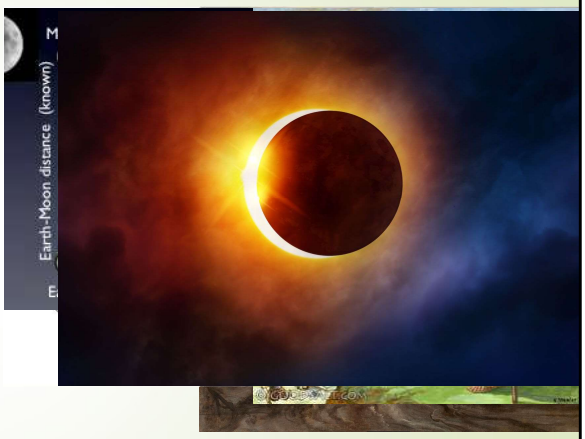
x			sin(x)	cos(x)	tan(x)	cot(x)	csc(x)	sec(x)
deg	rad							
0	0		0.0000	1.0000	0.0000			1.0000
1	0.0175		0.0175	0.9998	0.0175	57.2900	57.2987	1.0002
2	0.0349		0.0349	0.9994	0.0349	28.6363	28.6537	1.0006
3	0.0524		0.0523	0.9986	0.0524	19.0811	19.1073	1.0014
4	0.0698		0.0698	0.9976	0.0699	14.3007	14.3356	1.0024
5	0.0873		0.0872	0.9962	0.0875	11.4301	11.4737	1.0038
6	0.1047		0.1045	0.9945	0.1051	9.5144	9.5668	1.0055
7	0.1222		0.1219	0.9925	0.1228	8.1443	8.2055	1.0075
8	0.1396		0.1392	0.9903	0.1405	7.1154	7.1853	1.0098
9	0.1571		0.1564	0.9877	0.1584	6.3138	6.3925	1.0125
10	0.1745		0.1736	0.9848	0.1763	5.6713	5.7588	1.0154
11	0.192		0.1908	0.9816	0.1944	5.1446	5.2408	1.0187
12	0.2094		0.2079	0.9781	0.2126	4.7046	4.8097	1.0223
13	0.2269		0.2250	0.9744	0.2309	4.3315	4.4454	1.0263
14	0.2443		0.2419	0.9703	0.2493	4.0108	4.1336	1.0306
15	0.2618		0.2588	0.9659	0.2679	3.7321	3.8637	1.0353
16	0.2793		0.2756	0.9613	0.2867	3.4874	3.6280	1.0403
17	0.2967		0.2924	0.9563	0.3057	3.2709	3.4203	1.0457
18	0.3142		0.3090	0.9511	0.3249	3.0777	3.2361	1.0515
19	0.3316		0.3256	0.9455	0.3443	2.9042	3.0716	1.0576
20	0.3491		0.3420	0.9397	0.3640	2.7475	2.9238	1.0642
21	0.3665		0.3584	0.9336	0.3839	2.6051	2.7904	1.0711
22	0.384		0.3746	0.9272	0.4040	2.4751	2.6695	1.0785
23	0.4014		0.3907	0.9205	0.4245	2.3559	2.5593	1.0864
24	0.4189		0.4067	0.9135	0.4452	2.2460	2.4586	1.0946
25	0.4363		0.4226	0.9063	0.4663	2.1445	2.3662	1.1034
26	0.4538		0.4384	0.8988	0.4877	2.0503	2.2812	1.1126
27	0.4712		0.4540	0.8910	0.5095	1.9626	2.2027	1.1223
28	0.4887		0.4695	0.8829	0.5317	1.8807	2.1301	1.1326
29	0.5061		0.4848	0.8746	0.5543	1.8040	2.0627	1.1434
30	0.5236		0.5000	0.8660	0.5774	1.7321	2.0000	1.1547
31	0.5411		0.5150	0.8572	0.6009	1.6643	1.9416	1.1666
32	0.5585		0.5299	0.8480	0.6249	1.6003	1.8871	1.1792
33	0.576		0.5446	0.8387	0.6494	1.5399	1.8361	1.1924
34	0.5934		0.5592	0.8290	0.6745	1.4826	1.7883	1.2062
35	0.6109		0.5736	0.8192	0.7002	1.4281	1.7434	1.2208
36	0.6283		0.5878	0.8090	0.7265	1.3764	1.7013	1.2361
37	0.6458		0.6018	0.7986	0.7536	1.3270	1.6616	1.2521
38	0.6632		0.6157	0.7880	0.7813	1.2799	1.6243	1.2690
39	0.6807		0.6293	0.7771	0.8098	1.2349	1.5890	1.2868
40	0.6981		0.6428	0.7660	0.8391	1.1918	1.5557	1.3054
41	0.7156		0.6561	0.7547	0.8693	1.1504	1.5243	1.3250
42	0.733		0.6691	0.7431	0.9004	1.1106	1.4945	1.3456
43	0.7505		0.6820	0.7314	0.9325	1.0724	1.4663	1.3673
44	0.7679		0.6947	0.7193	0.9657	1.0355	1.4396	1.3902
45	0.7854		0.7071	0.7071	1.0000	1.0000	1.4142	1.4142

Recall that Pythagoras studied the ratios of sides of similar triangles and the special properties of right triangles (triangles with one square corner).
*A Greek named Hipparchus who did his work about 150 BCE, followed up on the work of Pythagoras and Hippasus and determined the ratios of the sides for each shape of right triangle. *For example, if a right triangle also had an angle of 45 degrees, the two short sides are always equal and have a ratio of 1:1 and a ratio of the either side to longest side is 1 to the square root of 2. This is true for all right triangles that also have a 45 degree angle.
*The sides of each triangle have three unique ratios. Hipparchus started with an extremely thin right triangle and constructed a table of the three ratios for each shape of right triangle as the corner angle increased. This table was very useful because an unknown side at a distance could be calculated if you knew the nearest angle and the length of one of the sides.
*Hipparchus is considered to be the best of the ancient Greek astronomers and he is also thought to be the father of a branch of mathematics called trigonometry.

Distance to the Moon and Sun

22

- Distance to the moon, 239 thousand miles
- Distance to the sun, 93 million miles
- Appear to be the same size
- Affect on world view

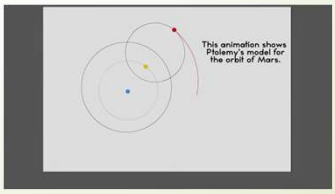


*Hipparchus combined his knowledge of triangle ratios with the size of the earth found by Eratosthenes to calculate the distance to the moon. Although the moon appears to be just a few miles above us, he discovered that it is about a quarter of a million miles away and that it is about ¼ the diameter of the earth.
*Using the new knowledge about the distance to the moon, Hipparchus could estimate the distance to the sun. He assumed that when the moon was half-full the light from the sun made a right angle with a line of sight from earth. Recall that Eratosthenes assumed that light from the sun was parallel between Alexandria and Seyene which were 500 miles apart. Hipparchus observed that by using the much greater distance between the earth and moon as the base of a right triangle, the light from the sun wasn't quite parallel which implied a distance to the sun of about 400 times greater than the distance to the moon.
*Since the sun appears to be the same size as the moon, this implies that it is about 400 times bigger. This is another coincidence.
*The discovery by Hipparchus challenged the world view of many people. Instead of being a few miles above us, the moon and sun were very far away and the sun was much bigger than the earth. Stories about flying too close to the sun and commanding the sun to stop in the sky seemed much less likely to be literally true.

Explaining Apparent Motion of Planets

23

- Plato's problem; 400 BCE
- Ptolemy's Solution (150 CE)
- Epicycles (small circles)



*Plato posed his famous challenge to Greek astronomers around 400 BCE to explain retrograde motion using circles with the earth at the center. It took the best minds in ancient Greece more than 500 years to come up with an answer. *About 150 CE, an Egyptian Greek named Ptolemy who lived in Alexandria provided a compromise explanation that utilized a smaller circle, *called an epicycle, to explain retrograde motion. *

Ptolemy's explanation was accepted for the next fourteen centuries.

Library at Alexandria

24

- Alexander designs a new city
- Rich trade center
- World's largest library
- Burned during civil and religious wars

While Aristotle's student, Alexander, was busy conquering the Middle and Far East, he took time to design a new port city in Egypt that was named Alexandria that *boasted the largest lighthouse in the world. *The Egyptians and Babylonians had already constructed a canal linking the Nile with the Red Sea, so Alexandria was in a great location to connect trade routes between Europe and the Far East. Before Alexander died, he appointed one of his generals, Ptolemy I, soter, to rule the area. Ptolemy founded the last line of Egyptian pharaohs that ended with Cleopatra. As Alexandria's prosperity grew, the center of Greek culture shifted from Athens to Alexandria.

*The best paper for books and scrolls was made with papyrus which grew well along the Nile. The city had a practice of requiring all ships that came there to turn over any books they might have which were taken to the library. If the library didn't have a copy, they kept the original and provided a copy to the owner. The library at Alexandria had the largest collection of papyrus scrolls in the world; between 40,000 and 400,000.

*The library was burned and/or partially destroyed during a Roman civil war and in subsequent religious wars. It is likely that the original works of ancient Greek scholars were destroyed in these fires. Aristotle wrote about 200 works but none of them survive in finished form. We have lecture notes, draft manuscripts and quotations from contemporary writers. About 30 of his works survive in this form. Scholars fled Alexandria seeking safer places to study.

Library at Cordoba

25

- Moorish conquest of Iberia, 720 CE
- Library at Cordoba
- 400,000 books
- Recaptured by Christians, 1236 CE
- Works of ancient Greeks spread through Europe

With the fall of Rome about 400 CE, much of the knowledge from the ancient Greeks was lost in Europe. About 200 years later, Islam was founded on the teachings of the Prophet Muhammad and his followers *conquered the middle east, North Africa, and the Iberian peninsula. Islamic rulers vied for importance by demonstrating their commitment to culture such as amassing libraries. *One of the largest was in the city of Cordoba,* which had over four hundred thousand books including what remained of the works of the Greeks. At this time, the library at the Sorbonne in France had about two thousand. *Iberia was recaptured by Christians in 1236, including the library. *The works of the Ancient Greeks were spread through Europe

26

Thomas Aquinas 1250 A.D.

- Blended Aristotelian teachings with Ptolemy and Christian theology
- Chain of Being
- Maintained order and the authority of kings
- Disagreeing with Ptolemy or Aristotle meant disagreeing with the church

*Twelve years after the recapture of the library at Cordoba, a catholic theologian, Thomas Aquinas, synthesized Christian theology with Plato's idealism and Aristotelian physics. He applied the natural, vertical order of the elements to the natural vertical order of God, Angels, Church, King, commoners, and animals called the **Chain of Being.* By blending Greek philosophy and church doctrine, one could argue that *kings were naturally above the common people who could no more rule themselves than a rock could fly. *An unfortunate byproduct of this synthesis was that if you disagreed with Aristotle's science, you were challenging the infallibility of the church. Aquinas' teachings were widely accepted and taught in Europe for another 300 years.

Summary

27

- Pythagoras: Triangle, rational numbers, scale
- Hippasus: Irrational numbers $\sqrt{2}$
- Circles: Pi is an irrational number a little larger than 3
- Plato: Ideal shapes, Planets, Plato's Problem
- Aristotle: Observations, theories, common sense
- Distances to the moon and sun far greater
- Ptolemy: Explained retrograde motion with circles
- Thomas Aquinas 1250: synthesis of Christianity, Ptolemy, and Aristotle

28

What experiences and insights can you share with us?

References

- History of Logic (link)
- Pythagorean tuning (Link)
- Equal temperament in Chinese music (Link)