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RESEARCH ARTICLE

PLATO'S TRIANGLES AND GENERAL RELATIVITY

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I think [Plato's] account of the creation as bringing order out of chaos is to be taken quite seriously; so also is the proportion between the four elements, and their relation to the regular solids and their constituent triangles.

—Bertrand Russell

Modern science declares that atoms are the ultimate stuff of the universe. All material objects consist of individual elements, such as gold, or combinations of elements, such carbon-based lifeforms.

Plato, on the other hand, argued that triangles are the ultimate stuff of the universe – in particular, right triangles. How do we make sense of this?

Backstory

Thales, widely regarded as the first philosopher, predicted an eclipse in 585 B.C., made money speculating on olive presses, and fell into a hole while pondering the universe, but he is most famous for his claim that water was the ultimate stuff of the universe.

The Pre-Socratics focused on cosmology, with various theories about the ultimate stuff. Anaximenes said it was air, and Heraclitus said fire. Anaximander said it was infinite, eternal, and ageless, a neutral base that takes the form of the four elements. Pythagoras said it was number, and Anaxagoras said mind.

Much of the debate focused on the problem of permanence versus change. The world around us is constantly changing, with new things emerging and old things fading away. However, this raised a question about knowledge. If knowledge is possible, must it be of something that persists through time?

Parmenides opted for the primacy of permanence by claiming all change was an illusion. The ultimate stuff was The One, an indestructible substance. This gave rise to the famous paradoxes of Zeno, such as the Tortoise and Achilles.

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Empedocles was the first philosopher to postulate fire, air, water, and earth as the four elements. He said the elements were everlasting, thus providing a foundation for knowledge, but mysteriously mixed in different proportions by Love and Strife.

The Atomists, to include Leucippus and Democritus, presciently claimed the universe consists of an infinite number of indestructible atoms. This raises questions about why the atoms exist or what sets them in motion – a persistent challenge for the mechanistic view of the universe – but these anecdotes highlight the brilliance of the Greek mind.

Enter Plato

By Plato's time the four elements were the accepted paradigm. All objects in the universe were one of the elements or a combination – a less sophisticated version of our modern table of elements.

However, as Plato noted, the four elements were grasped by perception, not reason, and were therefore subject to change. For example, a burning log transforms into cool ashes. We experience fire as hot and not solid, but what is the unchanging, eternal nature of fire? Not to mention, were the four elements ontologically distinct or merely four manifestations of the same underlying substance?

In *Timaeus*, Plato offers a creation story, which restates the core issue.

"What is *that which always is* and has no beginning, and what is *that which becomes* but never is? The former is grasped by understanding, which involves a reasoned account. It is unchanging. The latter is grasped by opinion, which involves unreasoning sense perception".

We can perceive the elements, but we can we grasp their true nature? As Kant might ask, can reason penetrate the phenomenal world to behold the noumenal world?

Plato devises a new starting point. In addition to the two options – first, a changeless, intelligible model, and second, a visible imitation – he proposes a third.

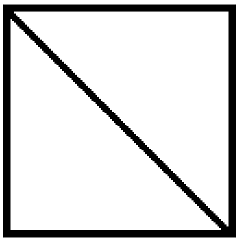
"Now, however, it appears that our account compels us to attempt to illuminate in words a kind that is difficult and vague.

What must we suppose it to do and to be? This above all: it is a receptacle of all becoming".

Plato uses the example of a neutral base for a fragrant ointment to make his point. If your goal is to create an ointment that smells like violets, the base liquid should be as odorless as possible. The same goes for the receptables of all becoming. "That is why the thing that is to receive in itself all the elemental kinds must be totally devoid of any characteristics."

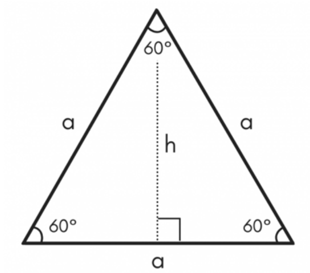
Plato shifts to a discussion of triangles, noting that any surface bounded by straight lines can be reduced to triangles. In other words, we should think of the eternal receptacles of all becoming as geometric shapes. For example, if you draw the diagonal of a square, you are left with two triangles.

Each triangle that is not a right triangle consists of two right triangles, which is done by drawing a line from the base to the



height, such as the below equilateral triangle.

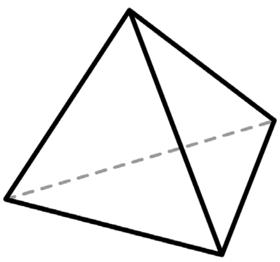
With this established, Plato highlights two types of right triangles. The first is the isosceles right triangle (see above



square with diagonal), in which the two shorter sides are the same length. Proportionally, all isosceles right triangles are the same. For the second, although there are infinitely many scalene right triangles, the best is one half of an equilateral triangle (see above equilateral triangle). As far as why this is the case, Plato offers the following.

"Why this is so is too long a story to tell now. But if anyone puts this claim to the test and discovers that it isn't so, his be the prize, with our congratulations".

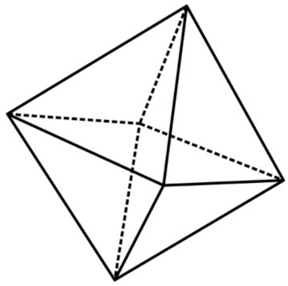
Not Plato's best explanation, but he proceeds to associate the most basic regular solid (tetrahedron) with fire, which consists



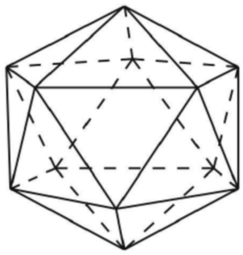
of four sides with equilateral triangles (eight scalene right triangles).

Plato associates the second regular solid (octahedron) with air, which consists of eight sides with equilateral triangles (16 scalene right triangles).

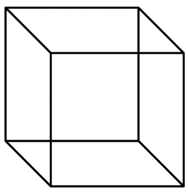
Plato associates the third regular solid (icosahedron) with water, which consists of twenty sides with equilateral triangles (40 scalene right triangles).



Finally, Plato associates the fourth regular solid (cube) with earth, which consists of six sides with squares (12 isosceles right triangles).

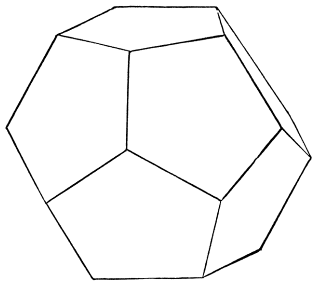


Of interest, Plato doesn't include the fifth regular solid (dodecahedron) in his schema, with the following explanation: "One other construction, a fifth, still remained, and this one the



god used for the whole universe, embroidering figures on it."

Plato's universe is spherical, so perhaps the god (demiurge) used the dodecahedron as a model for the universe, as opposed



to a model for the contents of the universe, or because the pentagon (pentagram) has religious connotations.

The five regular solids are not arbitrary abstractions. For example, the cube is associated with earth because it is, “the most immobile and the most pliable – which is what the solid whose faces are the most secure must of necessity turn out to be, more so than the others.” Likewise, Plato assigns the most mobile and sharpest solid to fire, the second to air, and the third to water.

This is where Plato’s insight shines. Not only has he provided an eternal receptable for the elements, which allows for eternity to coexist with change (many elements are, for all practical purposes, eternal), but he uses the geometrical structure of the regular solids to explain how the elements combine or transform into one another.

For example, fire is the fundamental element, not capable of reduction, like the tetrahedron. This allows fire to “cut” air, resulting in two corpuscles of fire (the eight sides of one octahedron are reduced to two four-sided tetrahedrons), or it allows fire to “cut” water, resulting in one corpuscle of fire and two of air, or five of fire. Fire can cut air and water and air can cut water because they all have equilateral triangles for sides. Likewise, water can be reduced to fire or air, and air can be reduced to fire, all based on the geometric properties of the regular solids.

What about earth? Fire can cut earth, but earth never into another form because the sides of the cube are squares, not equilateral triangles. Earth fragments will drift about until the parts meet again, refit themselves together, and become earth again.

This model aligns with modern chemistry. Consider the combining of two hydrogen atoms with one oxygen atom to form water (H_2O). We use atomic diagrams to show how they “fit” together. Granted, the driving force of chemistry is the tendency of atoms to achieve stable electron configurations, but we can use atomic diagrams with electron orbits to anticipate how atoms will interact or combine, prior to empirical observation. We can even analyze the table of elements to find gaps where we should expect to find new elements. This led to the discovery of gallium, helium, neon, and argon.

The Geometry of General Relativity

The question now remains as to how this relates to general relativity. Plato’s triangles, the regular solids, and the four elements clearly have an analogy to chemistry, but general relativity relates to the space-time continuum.

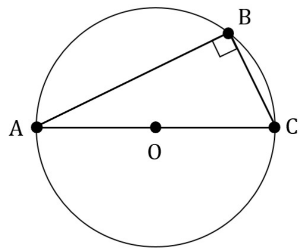
According to general relativity, for an outside observer, there is a predictable relationship between the observed freefall velocity of an object and the rate at which an atomic clock appears to tick. For example, imagine an astronaut with an atomic clock inside a spaceship that is free falling toward a black hole. For the astronaut, the passage of time feels the same (i.e., the atomic clock does not appear to slow down), even as the spaceship approaches the speed of light at the event horizon of the black hole. However, to an outside observer, the atomic clock appears to stop when the spaceship reaches the speed of light at the event horizon of the black hole.

To simplify our example, we will normalize the two key variables (free fall velocity and atomic clock tick rate) to a range of 0 to 1. For velocity, when the spaceship is not moving before freefall begins, the value is 0. When it reaches the speed of light (c), the value is 1. For the atomic clock tick rate, when time stops, the value is 0. When it is ticking at the fastest rate possible (i.e., when the atomic clock is sufficiently removed from the gravitational field of the black hole), the value is 1. Let’s assume that the spaceship begins sufficiently removed from the black hole and ends at the event horizon of the black hole.

	Start	End
Atomic Clock	1 (fastest rate)	0 (time stops)
Velocity	0 (at rest)	1 (speed of light)

What is the mathematical relationship between the atomic clock tick rate (as it goes from 1 to 0) and freefall velocity (as it goes from 0 to 1)? We can see from the formulas for gravitational time dilation and free fall velocity that the relationship is not linear (both include the square root operation), which means that we would not expect the atomic clock tick rate to decrease to ½ when the velocity reaches ½ the speed of light. Rather, because the formulas include the square root, we find that $((1 – 2GM/R))^2 + ((2GM/R))^2 = 1 – 2GM/R + 2GM/R = 1$, for all values of G, M, and R.

According to the Pythagorean Theorem, for all right triangles, all of which can be inscribed inside a half circle, the length



of the two shorter sides squared equals the length of the hypotenuse squared. Therefore, if we normalize our variables, such that AC = 1, then if AB = atomic clock tick rate from 1 to 0 and BC = freefall velocity from 0 to 1, the relationship between the two always forms a right triangle. The spaceship freefalls along a straight line toward the black hole, but the tradeoff between the decreasing atomic clock tick rate and the increasing freefall velocity can be represented by the circular perimeter (starting at A and passing through B before reaching C).

The fact that general relativity can be partially understood in terms of right triangles has interesting implications for philosophy and science. Perhaps this right triangle could be combined with other right triangles that model other forces or quantum phenomena to achieve a unified theory or find “gaps” that could point us in the right direction for new discoveries.

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