

# Philosophy of space and time

**Philosophy of space and time** is the branch of [philosophy](#) concerned with the issues surrounding the [ontology](#) and [epistemology](#) of [space](#) and [time](#). While such ideas have been central to philosophy from its inception, the philosophy of space and time was both an inspiration for and a central aspect of early [analytic philosophy](#). The subject focuses on a number of basic issues, including whether time and space exist independently of the mind, whether they exist independently of one another, what accounts for time's apparently unidirectional flow, whether times other than the present moment exist, and questions about the nature of identity (particularly the nature of identity over time).

## Ancient and medieval views

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The earliest recorded philosophy of [time](#) was expounded by the [ancient Egyptian](#) thinker [Ptahhotep](#) (c. 2650–2600 BC) who said:

Follow your desire as long as you live, and do not perform more than is ordered, do not lessen the time of the following desire, for the wasting of time is an abomination to the spirit...

—11th *maxim* of [Ptahhotep](#) <sup>[1]</sup>

The [Vedas](#), the earliest texts on [Indian philosophy](#) and [Hindu philosophy](#), dating back to the late [2nd millennium BC](#), describe ancient [Hindu cosmology](#), in which the [universe](#) goes through repeated cycles of creation, destruction, and rebirth, with each cycle lasting 4,320,000,000 years.<sup>[2]</sup> [Ancient Greek philosophers](#), including [Parmenides](#) and [Heraclitus](#), wrote essays on the nature of time.<sup>[3]</sup>

[Incas](#) regarded space and time as a single concept, named **pacha** ([Quechua](#): *pacha*, [Aymara](#): *pacha*).<sup>[4][5][6]</sup>

[Plato](#), in the [Timaeus](#), identified time with the period of motion of the heavenly bodies, and space as that in which things come to be. [Aristotle](#), in Book IV of his [Physics](#), defined time as the number of changes with respect to before and after, and the place of an object as the innermost motionless boundary of that which surrounds it.

In Book 11 of [St. Augustine's Confessions](#), he reflects on the nature of time, asking, "What then is time? If no one asks me, I know: if I wish to explain it to one who asks, I know not." He goes on to comment on the difficulty of thinking about time, pointing out the inaccuracy of common speech:

"For but few things are there of which we speak properly; of most things we speak improperly, still, the things intended are understood."<sup>[7]</sup> But Augustine presented the first philosophical argument for the reality of Creation (against Aristotle) in the context of his discussion of time, saying that knowledge of time depends on the knowledge of the movement of things, and therefore time cannot be where there are no creatures to measure its passing (*Confessions* Book XI ¶30; *City of God* Book XI ch.6).

In contrast to ancient Greek philosophers who believed that the universe had an infinite past with no beginning, [medieval philosophers](#) and [theologians](#) developed the concept of the universe having a finite past with a beginning, now known as [temporal finitism](#). The [Christian philosopher John Philoponus](#) presented early arguments, adopted by later Christian philosophers and theologians of the form "argument from the impossibility of the existence of an actual infinite", which states:<sup>[8]</sup>

"An actual infinite cannot exist."

"An infinite temporal regress of events is an actual infinite."

"∴ An infinite temporal regress of events cannot exist."

In the early 11th century, the [Muslim physicist Ibn al-Haytham](#) (Alhacen or Alhazen) discussed [space perception](#) and its [epistemological](#) implications in his *Book of Optics* (1021). He also rejected Aristotle's definition of *topos* (*Physics* IV) by way of geometric demonstrations and defined place as a mathematical spatial extension.<sup>[9]</sup> His [experimental](#) disproof of the extramission<sup>[10]</sup> hypothesis of vision led to changes in the understanding of the [visual perception](#) of space, contrary to the previous [emission theory of vision](#) supported by [Euclid](#) and [Ptolemy](#). In "tying the visual perception of space to prior bodily experience, Alhacen unequivocally rejected the intuitiveness of spatial perception and, therefore, the autonomy of vision. Without tangible notions of distance and size for correlation, sight can tell us next to nothing about such things."<sup>[11]</sup>

## Realism and anti-realism

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A traditional [realist](#) position in [ontology](#) is that time and space have existence apart from the human mind. [Idealists](#), by contrast, deny or doubt the existence of objects independent of the mind. Some [anti-realists](#), whose ontological position is that objects outside the mind do exist, nevertheless doubt the independent existence of time and space.

In 1781, [Immanuel Kant](#) published the *Critique of Pure Reason*, one of the most influential works in the history of the philosophy of space and time. He describes time as an *a priori* notion that, together with other *a priori* notions such as [space](#), allows us to comprehend [sense experience](#). Kant holds that neither space nor time are [substance](#), entities in themselves, or learned by experience; he holds, rather, that both are elements of a systematic framework we use to structure our experience.

Spatial [measurements](#) are used to [quantify](#) how far apart [objects](#) are, and temporal measurements are used to quantitatively compare the interval between (or duration of) [events](#). Although space and time are held to be *transcendentally ideal* in this sense—that is, mind-dependent—they are also *empirically real*—that is, according to Kant's definitions, a priori features of experience, and therefore not simply "subjective," variable, or accidental perceptions in a given consciousness.<sup>[12]</sup>

Some idealist writers, such as [J. M. E. McTaggart](#) in *The Unreality of Time*, have argued that time is an illusion (see also [The flow of time](#), below).

The writers discussed here are for the most part realists in this regard; for instance, [Gottfried Leibniz](#) held that his [monads](#) existed, at least independently of the mind of the observer.

## Absolutism and relationalism

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### Leibniz and Newton

The great debate between defining notions of space and time as real objects themselves (absolute), or mere orderings upon actual objects ([relational](#)), began between physicists [Isaac Newton](#) (via his spokesman, Samuel Clarke) and [Gottfried Leibniz](#) in the papers of the [Leibniz–Clarke correspondence](#).

Arguing against the absolutist position, Leibniz offers a number of [thought experiments](#) with the purpose of showing that there is contradiction in assuming the existence of facts such as absolute location and velocity. These arguments trade heavily on two principles central to his philosophy: the [principle of sufficient reason](#) and the [identity of indiscernibles](#). The principle of sufficient reason holds that for every fact, there is a reason that is sufficient to explain what and why it is the way it is and not otherwise. The identity of indiscernibles states that if there is no way of telling two entities apart, then they are one and the same thing.

The example Leibniz uses involves two proposed universes situated in absolute space. The only discernible difference between them is that the latter is positioned five feet to the left of the first. The example is only possible if such a thing as absolute space exists. Such a situation, however, is not possible, according to Leibniz, for if it were, a universe's position in absolute space would have no sufficient reason, as it might very well have been anywhere else. Therefore, it contradicts the principle of sufficient reason, and there could exist two distinct universes that were in all ways indiscernible, thus contradicting the identity of indiscernibles.

Standing out in Clarke's (and Newton's) response to Leibniz's arguments is the [bucket argument](#): Water in a bucket, hung from a rope and set to spin, will start with a flat surface. As the water begins

to spin in the bucket, the surface of the water will become concave. If the bucket is stopped, the water will continue to spin, and while the spin continues, the surface will remain concave. The concave surface is apparently not the result of the interaction of the bucket and the water, since the surface is flat when the bucket first starts to spin, it becomes concave as the water starts to spin, and it remains concave as the bucket stops.

In this response, Clarke argues for the necessity of the existence of [absolute space](#) to account for phenomena like rotation and acceleration that cannot be accounted for on a purely [relationalist account](#). Clarke argues that since the curvature of the water occurs in the rotating bucket as well as in the stationary bucket containing spinning water, it can only be explained by stating that the water is rotating in relation to the presence of some third thing—absolute space.

Leibniz describes a space that exists only as a relation between objects, and which has no existence apart from the existence of those objects. Motion exists only as a relation between those objects. Newtonian space provided the absolute frame of reference within which objects can have motion. In Newton's system, the frame of reference exists independently of the objects contained within it. These objects can be described as moving in relation to space itself. For almost two centuries, the evidence of a concave water surface held authority.

## **Mach**

Another important figure in this debate is 19th-century physicist [Ernst Mach](#). While he did not deny the existence of phenomena like that seen in the bucket argument, he still denied the absolutist conclusion by offering a different answer as to what the bucket was rotating in relation to: the [fixed stars](#).

Mach suggested that thought experiments like the bucket argument are problematic. If we were to imagine a universe that only contains a bucket, on Newton's account, this bucket could be set to spin relative to absolute space, and the water it contained would form the characteristic concave surface. But in the absence of anything else in the universe, it would be difficult to confirm that the bucket was indeed spinning. It seems equally possible that the surface of the water in the bucket would remain flat.

Mach argued that, in effect, the water experiment in an otherwise empty universe would remain flat. But if another object were introduced into this universe, perhaps a distant star, there would now be something relative to which the bucket could be seen as rotating. The water inside the bucket could possibly have a slight curve. To account for the curve that we observe, an increase in the number of objects in the universe also increases the curvature in the water. Mach argued that the momentum

of an object, whether angular or linear, exists as a result of the sum of the effects of other objects in the universe ([Mach's Principle](#)).

## Einstein

[Albert Einstein](#) proposed that the laws of physics should be based on the [principle of relativity](#). This principle holds that the rules of physics must be the same for all observers, regardless of the frame of reference that is used, and that light propagates at the same speed in all reference frames. This theory was motivated by [Maxwell's equations](#), which show that electromagnetic waves propagate in a vacuum at the [speed of light](#). However, Maxwell's equations give no indication of what this speed is relative to. Prior to Einstein, it was thought that this speed was relative to a fixed medium, called the [luminiferous ether](#). In contrast, the theory of special relativity postulates that light propagates at the speed of light in all inertial frames, and examines the implications of this postulate.

All attempts to measure any speed relative to this ether failed, which can be seen as a confirmation of Einstein's postulate that light propagates at the same speed in all reference frames. [Special relativity](#) is a formalization of the principle of relativity that does not contain a privileged inertial frame of reference, such as the luminiferous ether or absolute space, from which Einstein inferred that no such frame exists.

Einstein generalized relativity to frames of reference that were non-inertial. He achieved this by positing the [Equivalence Principle](#), which states that the force felt by an observer in a given gravitational field and that felt by an observer in an accelerating frame of reference are indistinguishable. This led to the conclusion that the mass of an object warps the geometry of the space-time surrounding it, as described in [Einstein's field equations](#).

In classical physics, an inertial reference frame is one in which an object that experiences no forces does not accelerate. In general relativity, an inertial frame of reference is one that is following a [geodesic](#) of space-time. An object that moves against a geodesic experiences a force. An object in [free fall](#) does not experience a force, because it is following a geodesic. An object standing on the earth, however, will experience a force, as it is being held against the geodesic by the surface of the planet.

Einstein partially advocates [Mach's principle](#) in that distant stars explain inertia because they provide the gravitational field against which acceleration and inertia occur. But contrary to Leibniz's account, this warped space-time is as integral a part of an object as are its other defining characteristics, such as volume and mass. If one holds, contrary to idealist beliefs, that objects exist

independently of the mind, it seems that relativistics commits one to also hold the idea that space and temporality have exactly the same type of independent existence.

## Conventionalism

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The position of [conventionalism](#) states that there is no fact of the matter as to the geometry of space and time, but that it is decided by convention. The first proponent of such a view, [Henri Poincaré](#), reacting to the creation of the new [non-Euclidean geometry](#), argued that which geometry applied to a space was decided by convention, since different geometries will describe a set of objects equally well, based on considerations from his [sphere-world](#).

This view was developed and updated to include considerations from relativistic physics by [Hans Reichenbach](#). Reichenbach's conventionalism, applying to space and time, focuses around the idea of [coordinative definition](#).

Coordinative definition has two major features. The first has to do with coordinating units of length with certain physical objects. This is motivated by the fact that we can never directly apprehend length. Instead we must choose some physical object, say the Standard Metre at the [Bureau International des Poids et Mesures](#) (International Bureau of Weights and Measures), or the [wavelength](#) of [cadmium](#) to stand in as our unit of length. The second feature deals with separated objects. Although we can, presumably, directly test the equality of length of two measuring rods when they are next to one another, we can not find out as much for two rods distant from one another. Even supposing that two rods, whenever brought near to one another are seen to be equal in length, we are not justified in stating that they are always equal in length. This impossibility undermines our ability to decide the equality of length of two distant objects. Sameness of length, to the contrary, must be set by definition.

Such a use of coordinative definition is in effect, on Reichenbach's conventionalism, in the General Theory of Relativity where light is assumed, i.e. not discovered, to mark out equal distances in equal times. After this setting of coordinative definition, however, the geometry of spacetime is set.

As in the absolutism/relationalism debate, contemporary philosophy is still in disagreement as to the correctness of the conventionalist doctrine.

## Structure of space-time

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Building from a mix of insights from the historical debates of absolutism and conventionalism as well as reflecting on the import of the technical apparatus of the General Theory of Relativity, details

as to the structure of [space-time](#) have made up a large proportion of discussion within the philosophy of space and time, as well as the [philosophy of physics](#). The following is a short list of topics.

## Relativity of simultaneity

According to [special relativity](#) each point in the universe can have a different set of events that compose its present instant. This has been used in the [Rietdijk–Putnam argument](#) to demonstrate that relativity predicts a [block universe](#) in which events are fixed in four dimensions.

## Historical frameworks

A further application of the modern mathematical methods, in league with the idea of invariance and covariance groups, is to try to interpret historical views of space and time in modern, mathematical language.

In these translations, a theory of space and time is seen as a [manifold](#) paired with [vector spaces](#), the more vector spaces the more facts there are about objects in that theory. The historical development of spacetime theories is generally seen to start from a position where many facts about objects are incorporated in that theory, and as history progresses, more and more structure is removed.

For example, Aristotelian space and time has both absolute position and special places, such as the center of the cosmos, and the circumference. Newtonian space and time has absolute position and is [Galilean invariant](#), but does not have special positions.

## Holes

With the general theory of relativity, the traditional debate between absolutism and relationalism has been shifted to whether spacetime is a substance, since the general theory of relativity largely rules out the existence of, e.g., absolute positions. One powerful argument against spacetime [substantivalism](#), offered by [John Earman](#) is known as the "[hole argument](#)".

This is a technical mathematical argument but can be paraphrased as follows:

Define a function  $d$  as the [identity function](#) over all elements over the manifold  $M$ , excepting a small [neighbourhood](#)  $H$  belonging to  $M$ . Over  $H$   $d$  comes to differ from identity by a [smooth function](#).

With use of this function  $d$  we can construct two [mathematical models](#), where the second is generated by applying  $d$  to proper elements of the first, such that the two models are identical prior to the time  $t=0$ , where  $t$  is a time function created by a [foliation](#) of spacetime, but differ after  $t=0$ .

These considerations show that, since substantivalism allows the construction of holes, that the universe must, on that view, be indeterministic. Which, Earman argues, is a case against substantivalism, as the case between determinism or indeterminism should be a question of physics, not of our commitment to substantivalism.

## Direction of time

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The problem of the [direction of time](#) arises directly from two contradictory facts. Firstly, the fundamental physical laws are time-reversal [invariant](#); if a cinematographic film were taken of any process describable by means of the aforementioned laws and then played backwards, it would still portray a physically possible process. Secondly, our experience of time, at the [macroscopic](#) level, is *not* time-reversal invariant.<sup>[13]</sup> Glasses can fall and break, but shards of glass cannot reassemble and fly up onto tables. We have memories of the past, and none of the future. We feel we can't change the past but can influence the future. There is no future without our past. Today is the time given to shape the outcome of the future and we are individually responsible for the future we want to see for the next generations.

### Causation solution

One solution to this problem takes a [metaphysical](#) view, in which the direction of time follows from an asymmetry of [causation](#). We know more about the past because the elements of the past are causes for the effect that is our perception. We can not affect the past but we can affect the outcome of the future because we learn from our past and utilized ideas from allowing our past incident from reoccurring.

There are two main objections to this view. First is the problem of distinguishing the cause from the effect in a non-arbitrary way. The use of causation in constructing a temporal ordering could easily become circular. The second problem with this view is its explanatory power. While the causation account, if successful, may account for some time-asymmetric phenomena like perception and action, it does not account for many others.

However, asymmetry of causation can be observed in a non-arbitrary way which is not metaphysical in the case of a human hand dropping a cup of water which smashes into fragments on a hard floor,



spilling the liquid. In this order, the causes of the resultant pattern of cup fragments and water spill is easily attributable in terms of the trajectory of the cup, irregularities in its structure, angle of its impact on the floor, etc. However, applying the same event in reverse, it is difficult to explain why the various pieces of the cup should fly up into the human hand and reassemble precisely into the shape of a cup, or why the water should position itself entirely within the cup. The causes of the resultant structure and shape of the cup and the encapsulation of the water by the hand within the cup are not easily attributable, as neither hand nor floor can achieve such formations of the cup or water. This asymmetry is perceivable on account of two features: i) the relationship between the agent capacities of the human hand (i.e., what it is and is not capable of and what it is for) and non-animal agency (i.e., what floors are and are not capable of and what they are for) and ii) that the pieces of cup came to possess exactly the nature and number of those of a cup before assembling. In short, such asymmetry is attributable to the relationship between i) temporal direction and ii) the implications of form and functional capacity.

The application of these ideas of form and functional capacity only dictates temporal direction in relation to complex scenarios involving specific, non-metaphysical agency which is not merely dependent on human perception of time. However, this last observation in itself is not sufficient to invalidate the implications of the example for the progressive nature of time in general.

## **Thermodynamics solution**

The second major family of solutions to this problem, and by far the one that has generated the most literature, finds the existence of the direction of time as relating to the nature of thermodynamics.

The answer from classical [thermodynamics](#) states that while our basic physical theory is, in fact, time-reversal symmetric, thermodynamics is not. In particular, the [second law of thermodynamics](#) states that the net [entropy](#) of a closed system never decreases, and this explains why we often see glass breaking, but not coming back together.

But in [statistical mechanics](#) things become more complicated. On one hand, statistical mechanics is far superior to classical thermodynamics, in that thermodynamic behavior, such as glass breaking, can be explained by the fundamental laws of physics paired with a [statistical](#) postulate. But statistical mechanics, unlike classical thermodynamics, is time-reversal symmetric. The second law of thermodynamics, as it arises in statistical mechanics, merely states that it is *overwhelmingly* likely that net entropy will increase, but it is not an absolute law.

Current thermodynamic solutions to the problem of the direction of time aim to find some further fact, or feature of the laws of nature to account for this discrepancy.

## Laws solution

A third type of solution to the problem of the direction of time, although much less represented, argues that the laws are not time-reversal symmetric. For example, certain processes in [quantum mechanics](#), relating to the [weak nuclear force](#), are not time-reversible, keeping in mind that when dealing with quantum mechanics time-reversibility comprises a more complex definition. But this type of solution is insufficient because 1) the time-asymmetric phenomena in quantum mechanics are too few to account for the uniformity of macroscopic time-asymmetry and 2) it relies on the assumption that quantum mechanics is the final or correct description of physical processes.

One recent proponent of the laws solution is [Tim Maudlin](#) who argues that the fundamental laws of physics are laws of temporal evolution (see Maudlin [2007]). However, elsewhere Maudlin argues: "[the] passage of time is an intrinsic asymmetry in the temporal structure of the world... It is the asymmetry that grounds the distinction between sequences that runs from past to future and sequences which run from future to past" [ibid, 2010 edition, p. 108]. Thus it is arguably difficult to assess whether Maudlin is suggesting that the direction of time is a consequence of the laws or is itself primitive.

## Flow of time

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The problem of the flow of time, as it has been treated in analytic philosophy, owes its beginning to a paper written by [J. M. E. McTaggart](#), in which he proposes two "temporal series". The first series, which means to account for our intuitions about temporal becoming, or the moving Now, is called the [A-series](#). The A-series orders events according to their being in the past, present or future, *simpliciter* and in comparison to each other. The [B-series](#) eliminates all reference to the present, and the associated temporal modalities of past and future, and orders all events by the temporal relations *earlier than* and *later than*. In many ways, the debate between proponents of these two views can be seen as a continuation of the early modern debate between the view that there is [absolute time](#) (defended by [Isaac Newton](#)) and the view that there is only merely [relative time](#) (defended by [Gottfried Leibniz](#)).

McTaggart, in his paper "[The Unreality of Time](#)", argues that time is unreal since a) the A-series is inconsistent and b) the B-series alone cannot account for the nature of time as the A-series describes an essential feature of it.

Building from this framework, two camps of solution have been offered. The first, the A-theorist solution, takes becoming as the central feature of time, and tries to construct the B-series from the A-series by offering an account of how B-facts come to be out of A-facts. The second camp, the B-theorist solution, takes as decisive McTaggart's arguments against the A-series and tries to construct the A-series out of the B-series, for example, by temporal indexicals.

## Dualities

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[Quantum field theory](#) models have shown that it is possible for theories in two different space-time backgrounds, like [AdS/CFT](#) or [T-duality](#), to be equivalent.

## Presentism and eternalism

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According to [Presentism](#), time is an ordering of various [realities](#). At a certain time, some things exist and others do not. This is the only reality we can deal with and we cannot, for example, say that [Homer](#) exists because at the present time he does not. An [Eternalist](#), on the other hand, holds that time is a dimension of reality on a par with the three spatial dimensions, and hence that all things—past, present and future—can be said to be just as real as things in the present. According to this theory, then, Homer really *does* exist, though we must still use special language when talking about somebody who exists at a distant time—just as we would use special language when talking about something far away (the very words *near*, *far*, *above*, *below*, and such are directly comparable to phrases such as *in the past*, *a minute ago*, and so on).

## Endurantism and perdurantism

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The positions on the persistence of objects are somewhat similar. An [endurantist](#) holds that for an object to persist through time is for it to exist completely at different times (each instance of existence we can regard as somehow separate from previous and future instances, though still numerically identical with them). A [perdurantist](#) on the other hand holds that for a thing to exist through time is for it to exist as a continuous reality, and that when we consider the thing as a whole we must consider an aggregate of all its "[temporal parts](#)" or instances of existing. Endurantism is seen as the conventional view and flows out of our pre-philosophical ideas (when I talk to somebody I think I am talking to that person as a complete object, and not just a part of a cross-temporal being), but perdurantists such as [David Lewis](#) have attacked this position. They argue that perdurantism is the superior view for its ability to take account of change in objects.

On the whole, [Presentists](#) are also endurantists and [Eternalists](#) are also perdurantists (and vice versa), but this is not a necessary relation and it is possible to claim, for instance, that time's passage indicates a series of ordered realities, but that objects within these realities somehow exist outside of the reality as a whole, even though the realities as wholes are not related. However, such positions are rarely adopted.

## See also

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- [Arrow of time](#)
- [Being and Time](#)
- [Chronometry](#)
- [Einstein's thought experiments](#)
- [The End of Time](#)
- [Eternal return](#)
- [Measure problem \(cosmology\)](#)
- [Metaphysics](#)
- [Milič Čapek](#)
- [Presentism \(philosophy of time\)](#)
- [Process and Reality](#)
- [Process philosophy](#)
- [Spacetime](#)
- [Temporality](#)
- [Temporal parts](#)
- [Time geography](#)
- [Time Reborn](#)
- [Time travel in science](#) and [time travel in fiction](#)
- [Quentin Smith](#)
- [Zeno's paradoxes](#)

# Notes

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10. [6.54] And it has already been shown that forms of light and color continually generated in air and in all [other] transparent bodies, and forms continually extend through the air, as well as through [other] transparent bodies, in various directions," ... "hence the extramission of [visual] rays is superfluous and useless".—Alhacen (11th c.) as translated by A.Mark Smith p.372 (2001) [Alhacen's Theory of Visual Perception: A Critical Edition, with English Translation and Commentary, of the First Three Books of Alhacen's "De aspectibus", the Medieval Latin Version of Ibn al-Haytham's "Kitāb al-Manāẓir": Volume Two](https://www.jstor.org/stable/pdf/3657357.pdf) (<https://www.jstor.org/stable/pdf/3657357.pdf>) *Transactions of the American Philosophical Society*, New Series, **Vol. 91**, No. 5 (2001), pp. 339-819
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12. See Kant, Critique of Pure Reason, I ["The Elements of Transcendentalism"], Part I ["The Transcendental Aesthetic"], Sections I and II ["Of Space" and "Of Time"])

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