Introduction to the philosophy of space and time

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St Augustin (354-430), Bishop of Hippo

"What, then, is time? If no one asks me, I know what it is. If I wish to explain it to him who asks me, I do not know. Yet I say with confidence that I know that if nothing passed away, there would be no past time; and if nothing were still coming, there would be no future time; and if there were nothing at all, there would be no present time." (*Confessions*, 11.xiv.17)

Do space and time exist?

- Do space and time have independent existence from objects they 'contain'?
- inaccessible by direct observation
- This in itself doesn't imply that they don't exist: neutrinos and force fields are not directly observable either, but many believe they exist.
- Philosophy of space: substantivalism vs relationism

What is the structure of space and time?

- Is space finite or infinite in extension? How many dimensions does it have? Is it Euclidean? Isotropic? Continuous or discrete?
- Is time finite or infinite? Does it have a beginning or an end? Is it one-dimensional? Linear or branching? Anisotropic, i.e. directed? Continuous or discrete?
- Are there different kinds of spaces or times?
- Are space and time affected by the presence and distribution of material bodies?

Why does time, but not space, have a direction?

- Time seems to have inherent directedness from the past towards the future, but space has no analogous feature.
- directedness of time vs. directedness of anything in time
- 'flow' of time, 'passing' of time
- temporal passage: what is future will become present; what is present will become past; what is past was once present
- Is temporal passage objective feature of reality?

Space: the classical debate

Substantivalism vs. Relationalism

Position (Substantivalism)

Space and time exist as independent substances, i.e. they are existing particulars in their own right, over and above the material content of the universe. Space and time are continuous and pervasive media that extend everywhere and everywhen.

Position (Relationalism)

Space and time do not exist as independent substances, there is only the material content of the universe. Space and time are merely defined through spatiotemporal relations among the material objects in the universe.

An intuitive model of space: the void conception

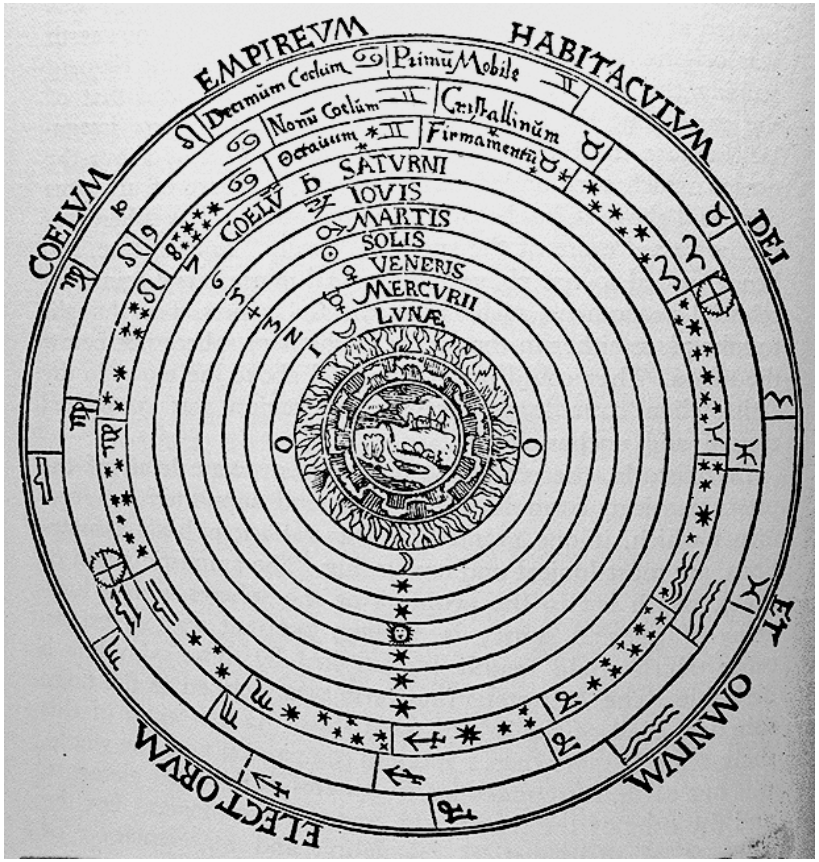
"Space itself is nothing at all; it has no intrinsic features of its own, it is mere absence. Objects can be separated by different spatial distances... and we know this because of the different times it takes to travel or transmit signals between them; we cannot directly measure magnitudes of space, since space is itself featureless void." (Dainton, *Time and Space*, 132)

Consequences:

1. space must be infinite
2. there's only one space
3. question 'What structure does space have?' is empty

Historical objections: The plenum universe

The Christian Aristotelian cosmos, engraving from Peter Apian's Cosmographia, 1524



- "Naturam a vacuo abhorrere" (There can be no vacuum in Nature), idea originating in Aristotle
- Aristotle: sub- and supralunar spheres, space does not continue beyond outermost sphere
- Descartes: interplanetary space filled with subtle fluid

Sir Isaac Newton (1643-1727)

- English physicist, mathematician, astronomer, natural philosopher, theologian, and alchemist
- education at Trinity College, Cambridge
- Lucasian Professor of Mathematics in 1669 at Cambridge
- *Principia Mathematica* (published in 1687)
- synthesis of mechanical results by Galileo, Kepler, etc

Newton: infinite absolute space

"Space is eternal in duration and immutable in nature... Although space may be empty of body, nevertheless it is itself not a void: and something is there, because spaces are there, although nothing more than that." (*De Gravitatione*, as quoted by Dainton, 133)

"Absolute space, in its own nature, without relation to anything external, remains always similar and immovable." (*Principia*, as quoted by Huggett, 118)

The locating of objects in substantival space

By virtue of what is an object located in space that contains it?

1. Relational substantivalism: primitive relation of 'spatial locatedness' holds between objects and places in space
2. Container substantivalism: material objects enclosed by substantival space, but space only outside and between material things
3. Super-substantivalism: space is only existing entity, objects are 'adjectival' on space (cf. Lowe, 267)

- Note: space possesses certain topological and geometrical properties, such as conforming to axioms of Euclidean geometry

Gottfried Wilhelm Leibniz (1646-1716)

- German polymath (mathematician, natural philosopher, legal scholar, theologian, political advisor, historian)
- rationalism: reason as ultimate arbiter of justification of knowledge
- optimism: God created the best of all possible worlds
- calculus, binary numeral system, etc
- Leibniz-Clarke correspondence (1715-16)

Relationalism: a closer look

undetectability, Occam's razor $\Rightarrow$ let's investigate whether we can do without substantival space

Position (Relationalism)

"In claiming that objects inherit their spatial properties from the regions of space that they occupy, the substantivalist is inserting an invisible and redundant intermediary between objects. We cannot observe space itself, but we can observe objects at various distances from one another. The most economical way of making sense of this is simply to say that objects are directly related to one another by spatial relations. Instead of appealing to space-object relations, we can appeal to object-object relations, where the relations in question are of a spatial sort. These spatial relations should not be thought of as material objects in their own right, but as distinctive properties, of a relational sort, that material objects can possess." (Dainton, 141)

- space is constituted by complex relational structure of material objects and their parts and the spatial relations in which all these stand to one another
- concrete, symmetrical, transitive, reflexive relation
- relationalism not cost-free: there must be spatial relations over and above the material objects that exist
- empty space: relationalism is committed to non-existence of unoccupied places and regions, whereas substantivalist account entails possibility of empty places

$\Rightarrow$ How can we meaningfully speak of mid-point between Earth and Mars?

- Relationalist response: since objects can change in their spatial relations, we can give map/representation that reflects these possibilities $\Rightarrow$ 'modal' relationalism
- at any given time, only objects and their actual distance relations exist, all remaining points on map do not correspond to anything real
- relationalists: truthmakers of statements about space are facts about material bodies and the way they are spatially related
- relations operate across, rather than through space
- they relate objects directly, without passing through intervening empty space (whose reality is denied)

Different kinds of shifts

1. static shift: shift location of all material bodies uniformly in one direction without changing the relative distances and motions among them
2. kinematic shift: change the state of motion of all material bodies such that all relative distances and motions among them remain the same
3. dynamic shift: subject all material bodies in universe to force such that they are all accelerated by the same amount in the same direction without changing the relative distances or motions among them

Galilean frames

- Galilean frames: reference frame that are either at rest, or moving uniformly with respect to one another
- uniform motion: rectilinear motion at constant velocity
- with Newtonian absolute space: any Galilean frame is in some state of absolute motion which is uniform
- consider e.g. Newton's law of universal gravitation:

$$F_G = G_N \frac{m_1 m_2}{r^2}$$

  $\Rightarrow$ makes no reference to absolute position, velocity
- turns out all Newtonian physics is like that

$\Rightarrow$ undetectability of both static and kinematic shifts

The argument from sufficient reason

Principle (of Sufficient Reason (PSR))

"Nothing happens without a sufficient reason why it should be so, rather than otherwise." (cited according to Dainton, 165)

- assume that even God is subject to PSR, i.e. assume that God does nothing for which he lacks good reason

$\Rightarrow$ God cannot create substantival space on pain of being faced with a choice for which there is no sufficient reason for favouring one alternative over the others

- theologically loaded argument

The argument from indiscernability

Principle (of the Identity of Indiscernibles (PII))

Any two entities which have the same genuine properties are identical.

1. Substantivalists claim that the two possible worlds either related to one another by a static or kinematic shift as described above are distinct. (Premise to be reduced to absurdity)
2. Two possible worlds related by such shifts share all their genuine properties, i.e. they are 'indiscernible'.
3. PII
4. From (2) and (3), these possible worlds are identical.

$\therefore$ From (1) and (4), substantivalism is false.

Objections to the argument from indiscernability

- PII itself is highly controversial: Max Black's two indiscernible spheres in an otherwise empty universe
- If indiscernability is understood metaphysically, i.e. as not only applying to observable properties, then substantivalists will hardly accept premise (2).
- But this response will not work for empiricist substantivalists, i.e. under the assumption that only properties differences in which are in principle detectable are in fact genuine.

$\Rightarrow$ tension between substantivalism and empiricism, can be released by rejecting PII

- Question: what if PII is interpreted not metaphysically, but methodologically (as something similar to Occam's razor)?

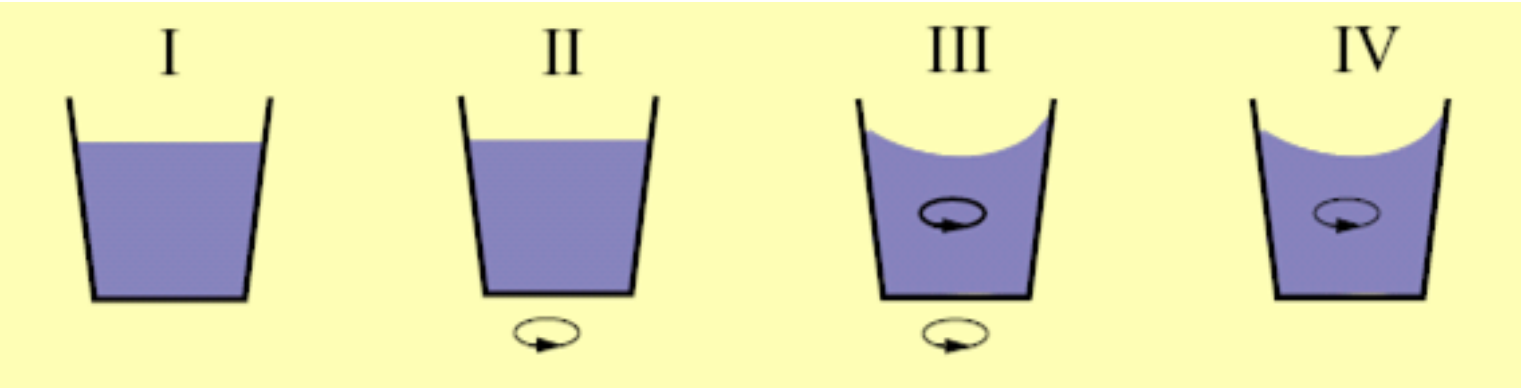
The methodological argument

Leibniz's Fifth Paper in correspondence with Clarke:
"...motion does not depend upon being observed; but it does depend upon being possible to be observed." (Alexander 1956, 74)

- Science routinely posits unobservable entities, thereby assuming scientific realism wrt to unobservable entities
- but: must have observable effects
- debate then hinges on whether absolute space has observable effects
- Unsurprisingly, Newton argues that it does, while Leibniz denies this...

$\Rightarrow$ in the famous Scholium to the Definitions of his *Principia*, Newton illustrates how absolute accelerations have observable effects with one particular type of absolute acceleration: rotation...

Newton's bucket



	I	II	III	IV
Bucket	at rest	rotates	rotates	at rest
Water	at rest	at rest	rotates	rotates
Relative motion	no	yes	no	yes

$\Rightarrow$ Surface form of water (flat or concave) is not determined by relative motion, but...

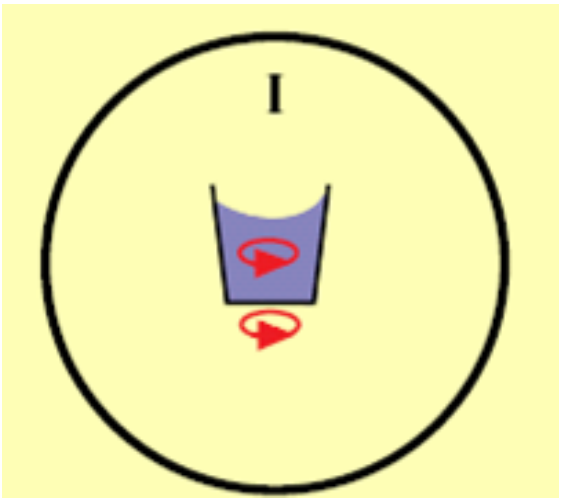
- Newton: by absolute motion of water (relative to absolute space)

Ernst Mach's interpretation of Newton's bucket

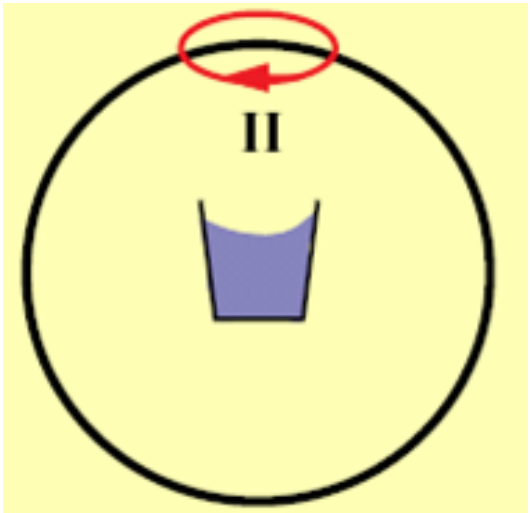
Surface of water concave because of motion of bucket and water relative to shell of distant masses

$\Rightarrow$ equivalence of the following two situations: (1) bucket and water rotate, but the shell of distant masses rests, (2) bucket and water at rest, shell rotates.

(1)



(2)



Newton: surface in (2) remains flat!

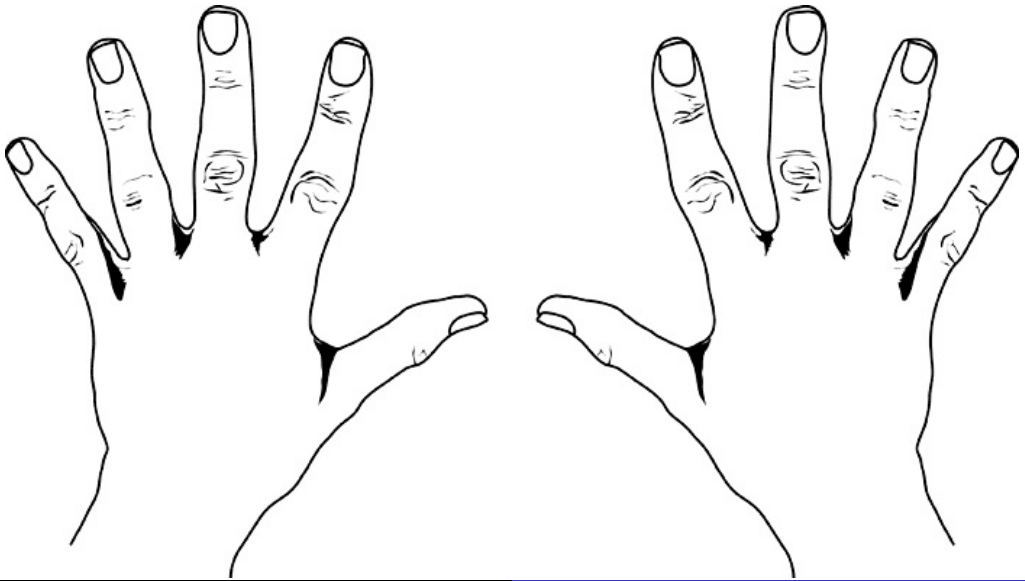
Kant's argument from incongruent counterparts

Immanuel Kant, 'Concerning the ultimate foundation of the differentiation of regions in space', in his *Selected Precritical Writings*, Manchester 1968.

Immanuel Kant, *Prolegomena*, Manchester 1953, §§11-13, pp. 39ff.

Definition (Incongruent counterparts)

"Incongruent counterparts are asymmetrical objects which are mirror images of one another, such as a left and an otherwise exactly similar right hand." (273)



- incongruent counterparts cannot be brought into congruence in the sense that there is no smooth transformation of one object into the other
- space, it seems, can contain incongruent counterparts

$\Rightarrow$ challenge to the relationalist to explicate why this is so in terms actual and possible spatial relations among material objects

Kant's solitary hand

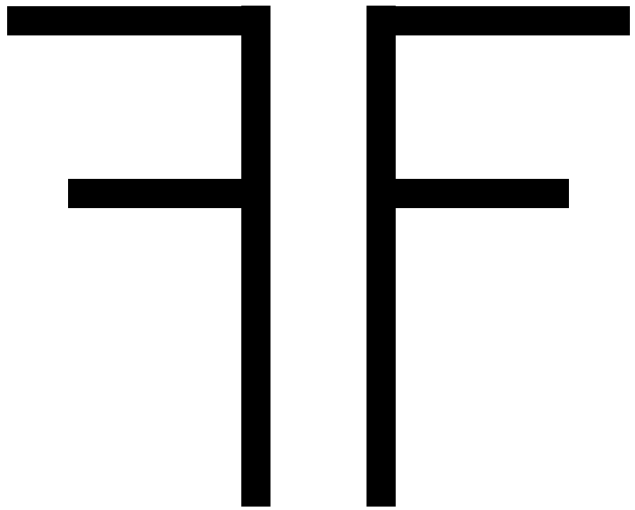
- Suppose there is a world such that the only material object it contains is a solitary, detached hand.
- Surely, this hand is either a left or a right hand, i.e. a hand cannot lack 'handedness', since handedness seems to be an intrinsic property (or a property an object cannot possess only in virtue of some relation to other objects in space it enjoys).
- But if such a solitary hand does have handedness, which relational facts could determine that?

$\Rightarrow$ relationalist has to accept, it seems, that either such a hand would not have a handedness, or else that such a property would be a 'brute' fact

- But: substantivalist can seemingly explain this fact (in terms of relations of the hand to the space it occupies, which thus underwrite an 'orientation' the hand has with respect to space), and so is at an advantage.

A two-dimensional analogy

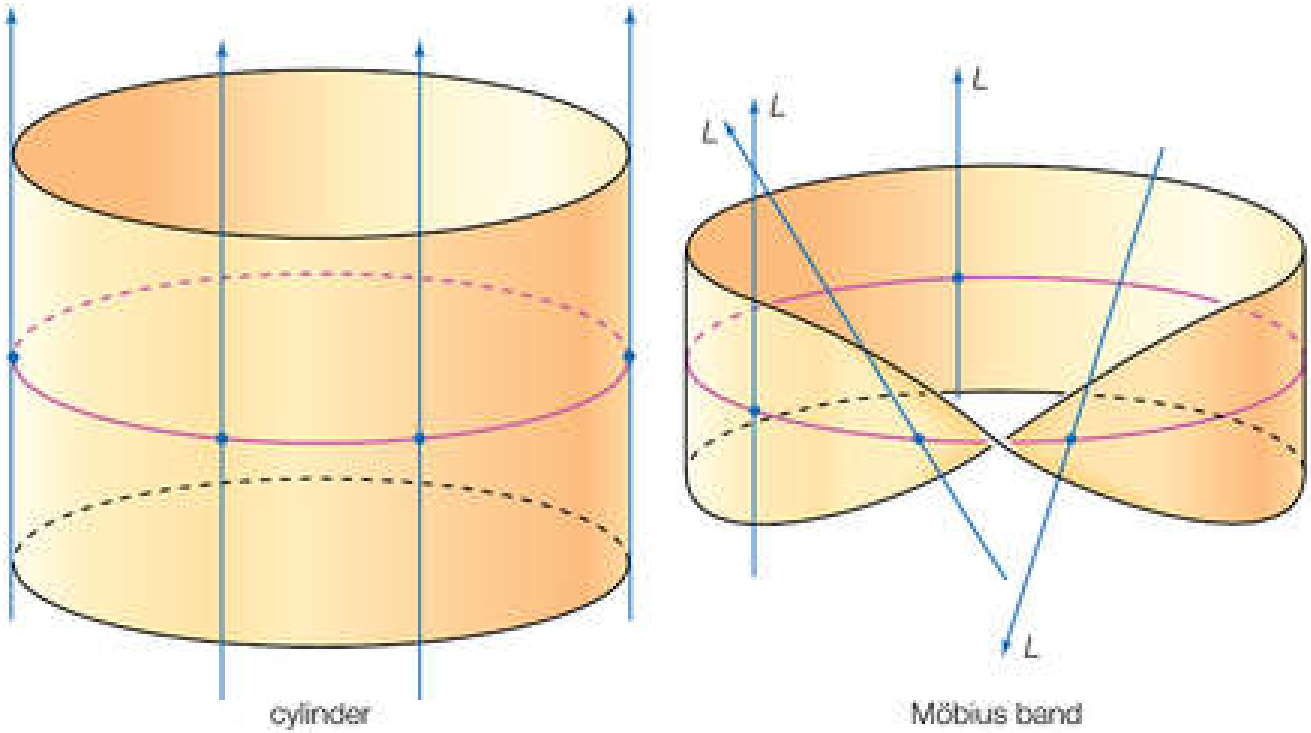
There are incongruent counterparts in two-dimensional space:



- 'Fs' can be flipped over in third dimension, hands can be flipped over in fourth dimension

$\Rightarrow$ Whether or not two objects are incongruent counterparts depends on dimension of space.

Moebius bands and the topology of space



Exercise

Build your own Moebius strip and write down an 'F' somewhere, which you then parallel transport around the strip until you get back to the original position. How does it look like?

⇒ "[A] two-dimensional space with the toplogy of a Moebius band is a space in which there is no incongruent counterparts." (278)

- Three- and higher-dimensional spaces can have analogous topologies.

⇒ Question (for the relationalist): can a solitary-hand world have such a topology, such there would be no incongruent counterparts (and hence no fact that needs explaining)?

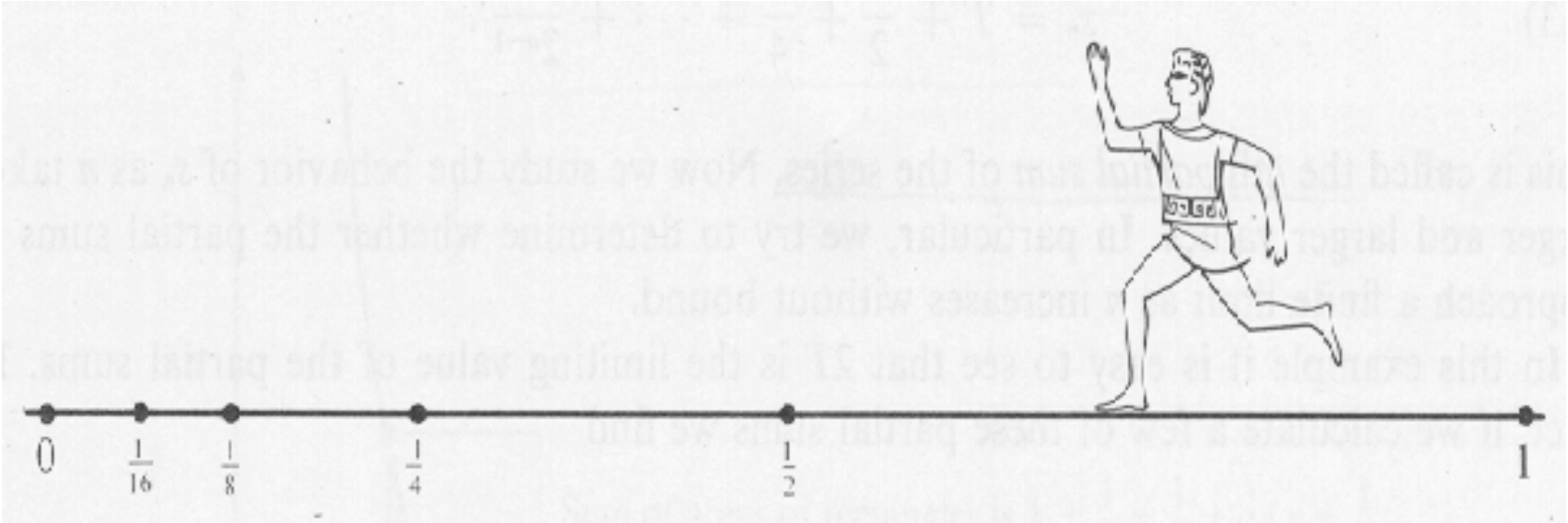
- topology is property of space, which for the relationalist ontologically depends on material objects it contains (and their possible locations and motions)
- Arguably: nothing in solitary hand (and its possible locations and motions), which would underwrite the existence of a space with a Moebius-like topology

Relationalist options

The relationalist can react in one of several ways to Kant's argument:

1. Physical space may have higher dimensions.
   - But: There will in general be higher-dimensional incongruent counterparts.
   - And: is space really more than three-dimensional?
2. Physical space may have a Moebius-like topology.
   - But: what in a single hand could underwrite such a topology?
3. Solitary hands do not, in fact, possess handedness; only once a incongruent counterpart comes into being is there such a property.
4. Distance relations possess intrinsic directions. (Reconsider the 'F's')

Zeno's paradox of the racetrack (or 'dichotomy')



Some teaching material to follow courtesy of John Earman's course on *Paradoxes*, University of Pittsburgh.

Zeno's paradox of the racetrack (suite)

(P1) If Achilles wants to run a finite distance AB, he first has to run the first half of the distance.

(P2) Once he has run the first half of the distance, he must next run the first half of the second half from A to B.

⋮

(P3) Thus, Achilles must run infinitely many (partial) distances in order to get to B.

(P4) It is logically (or physically?) impossible to run infinitely many distances—even for Achilles.

(C) It is impossible to get from A to B.

Exercise

An 'inversion' of the argument claims that it is even impossible to start moving away from A. Can you reconstruct it?

Alternative formulation

(P1) If a task consists of a number of subtasks, then in order to complete the task, there must be a last subtask and that last subtask must be completed.

(P2) Achilles's task—that of getting to the finish line—consists of an infinite number of subtasks: first covering one half of the distance, then covering one half of the remaining distance, etc. *ad infinitum*.

(P3) There is no last subtask for Achilles.

(C) Therefore, Achilles cannot complete the task.

Alternative formulation (suite)

Compare (P1) to

(P1') If a task consists of a number of subtasks, then in order to complete the task, all of the subtasks must be completed.

(P1') is surely true. But (P1') does not imply (P1). (P1) is true if the number of subtasks is finite (in which case (P1) and (P1') are equivalent); but (P1) is false if the number of subtasks if infinite—as is shown by Zeno's construction!
Alternative formulation of argument is valid, but not sound!

Analysis

Fact

An infinite series of finite numbers can have a finite sum.

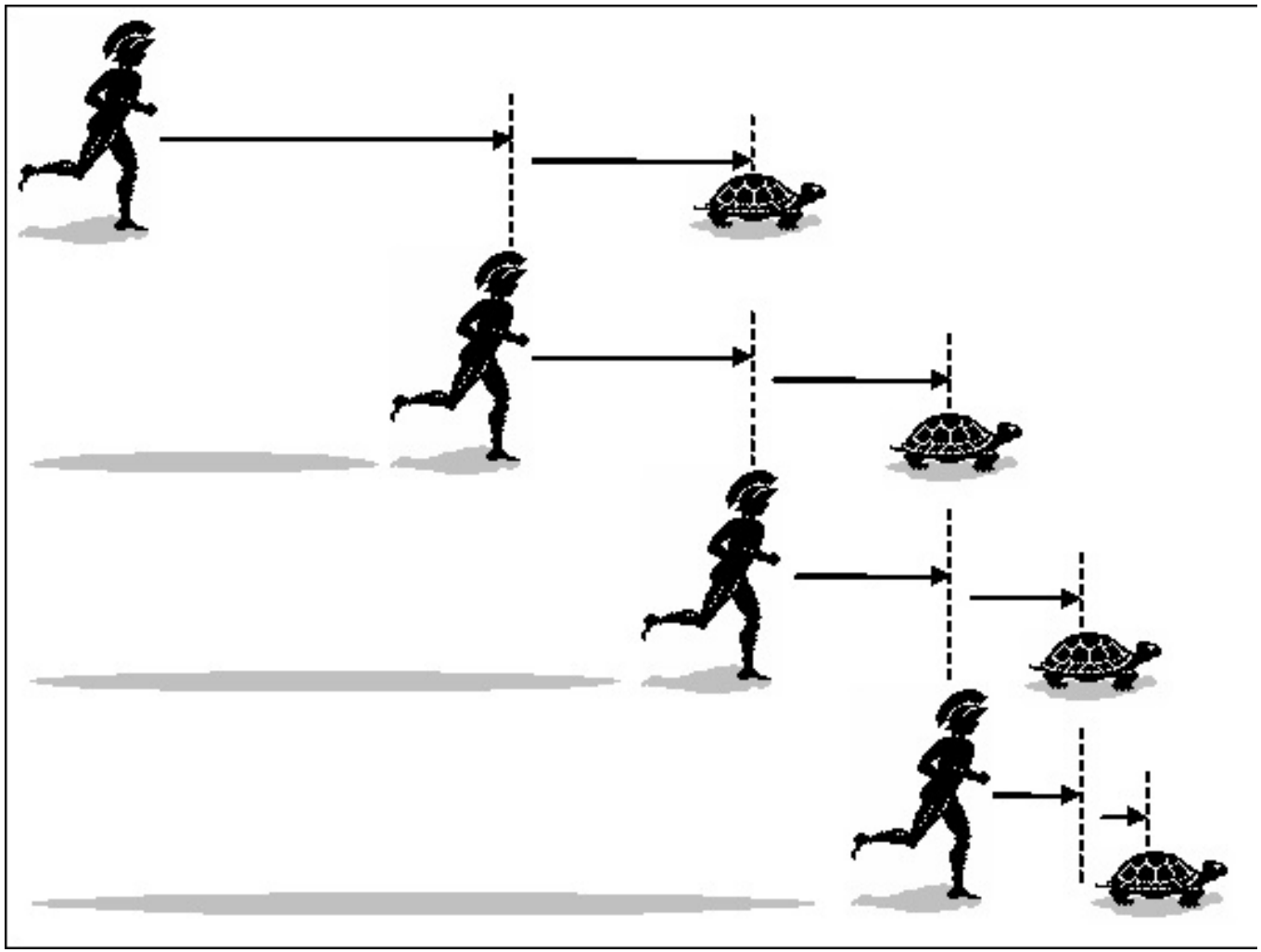
- Mathematically: the distance is split into pieces:

$$\frac{1}{2} + \frac{1}{4} + \frac{1}{8} + \ldots = 1 \tag{1}$$

- The corresponding series of partial sums is $1/2, 3/4, 7/8, \ldots$. This series converges to 1.
- In other words, for an arbitrary $\epsilon > 0$, there exists an n such that for all $m \geq n$,

$$|1 - m\text{th partial sum}| < \epsilon. \tag{2}$$

Similar: the paradox of Achilles and the Tortoise



Supertasks: Zeno's revenge

Definition

Supertask A *supertask* *is a task the fulfillment of which requires the fulfillment of infinitely many physically separate and distinct actions or operations in a finite amount of time.*

Question

Is it logically and physically possible to fulfill such supertasks?

- Zeno's racetrack is not strictly speaking a supertask, as the actions are not separate and distinct.

Staccato run

A runner runs at an average speed of one mile an hour, but the run is broken up into shorter and shorter runs, at an average speed of two miles an hour, plus a rest of equal time:

Stage	Action	Time
1	run from start to 1/2 mile	0-1/4 hour
	pause for 1/4 hour	1/4-1/2 hour
2	run from 1/2 mile to 3/4 mile	1/2-5/8 hour
	pause for 1/8 hour	5/8-3/4 hour
3	run from 3/4 to 7/8 mile	3/4-13/16 hour
	pause for 1/16 hour	13/16-7/8 hour

etc.

- This is a genuine supertask since the actions are separate and distinct.

Thomson's lamp

A lamp is switched on and off according to the following schedule:

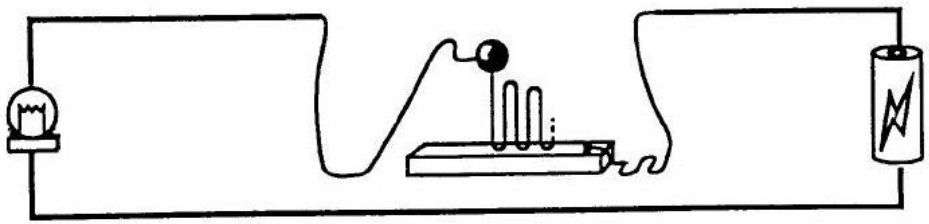
Stage	Time	Action
1	1 min to midnight	switched ON
2	1/2 min to midnight	switched OFF
3	1/4 min to midnight	switched ON
4	1/8 min to midnight	switched OFF

etc.

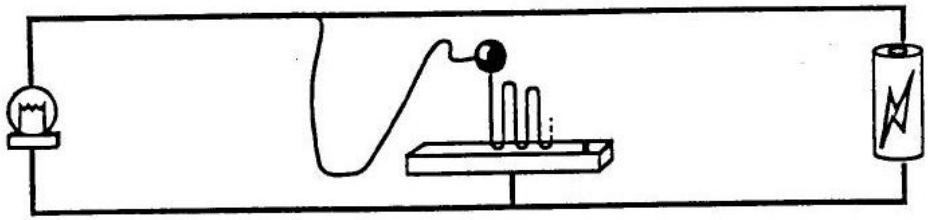
- Thomson claimed that it is logically impossible to complete this supertask. He argued as follows.
- At midnight, the lamp must be either ON or OFF. But either answer seems unacceptable.
- It cannot be ON, since every stage at which it was turned ON is followed by a stage at which it was turned OFF.
- And it cannot be turned OFF, since every stage at which it was turned OFF is followed by a stage at which it was turned ON.

Thomson's lamp (suite)

Both solutions (ON and OFF) are logically consistent. Also possible are electric circuit which realize both alternatives:



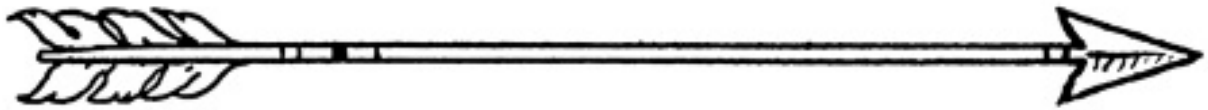
Contact switches lamp ON



Contact switches lamp OFF

In the first circuit, the lamp stays ON at midnight, in the second, it remains OFF.

The paradox of the arrow



(P1) At any instant the arrow is not moving.

(P2) Any stretch of time is composed of (nothing but) instants.

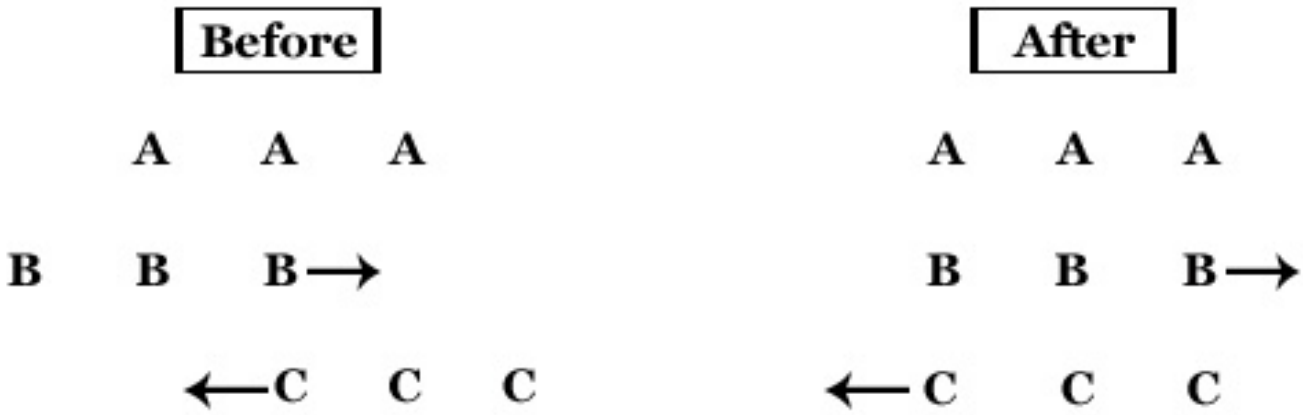
(C) Therefore, over any stretch of time the arrow does not move.

Various ways to understand (P1):

- In the duration of an instant, the arrow does not move. Then (P1) is true. But the argument is not valid.
- The arrow has zero velocity at each instant. Then the argument is valid (assuming that the motion of the arrow is continuous). But under this interpretation, (P1) is (or can be) false.

$\Rightarrow$ Either way, the argument is not sound—on one reading the argument is not valid, and on the other reading a premise is false.

The paradox of the moving blocks



- Puzzle: how can the blocks of row B pass by two blocks of row C when at the same time they pass by one block of row A?
- But, of course, an object can have different relative velocities to different other objects!