The Philosophy of Physics
Lecture Two

Is Space Absolute or Relational?

Rob Trueman
rob.trueman@york.ac.uk

University of York

Is Space Absolute or Relational?

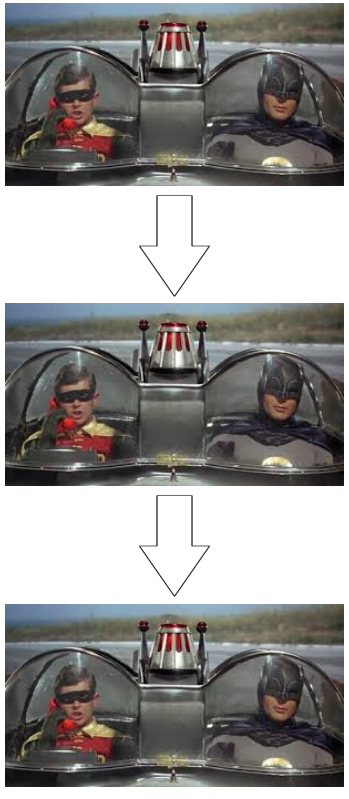
Absolute versus Relative Motion

- Everyday motion is always motion *relative* to something else
- We ordinarily pick a body and just treat it as being at rest
- We then say another body is moving if it is moving if it is moving relative to the first body we chose

Robin's Frame of Reference

- Relative to Robin, Batman isn't moving

The Joker's Frame of Reference



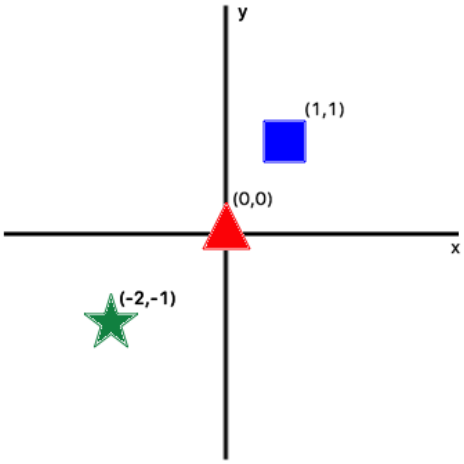
- Relative to the Joker, Batman is moving

Newton's Absolute Motion

- But is Batman *really* moving?
- Of course it is tempting to answer 'Yes'
- That's because we usually assume that the **Earth** is at rest
- Maybe it is a bad question: there is no **real** or *absolute* motion, all motion is relative
- Not according to Newton
- Newton insisted that there is an absolute fact about what is really moving and what is really at rest

What is a Frame of Reference?

- When we choose to treat a body as being at rest, we can plot all the other objects relative to it
- When we do, we get a frame of reference for that body



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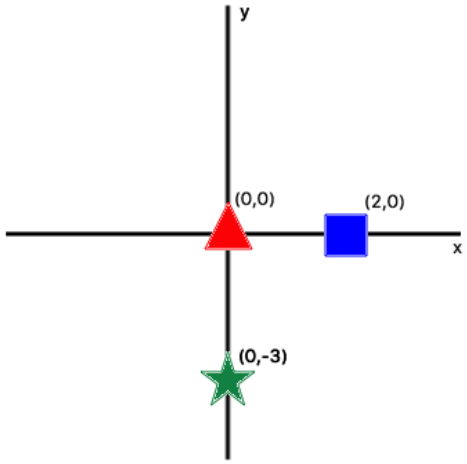

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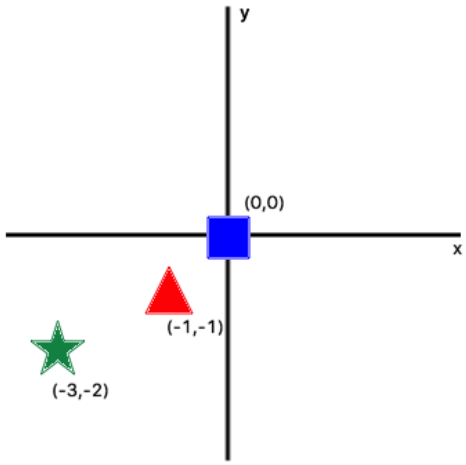

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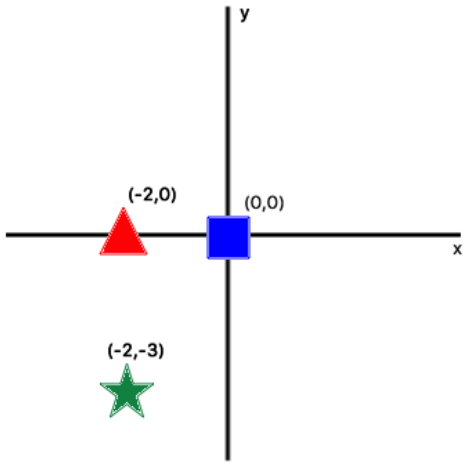

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Inertial Frames

- Put in terms of frames of reference, Newton thought that there was an absolute fact about whether a frame of reference is at rest or moving
  - A frame of reference is **really** at rest iff the bodies "at rest" according to the frame are **really** at rest
- But in Newtonian physics, there is no difference between a frame which is at rest, and a frame which is moving at a constant speed in a straight line
- A frame which is at rest or moving at a constant speed in a straight line is called an *intertial* frame
- The Newtonian Laws are exactly the same in every inertial frame
- This is known as *Galilean Relativity*

Galilean Relativity

> *Shut yourself up with some friend in the main cabin below decks on some large ship, and have with you there some flies, butterflies and other small flying animals. Have a large bowl of water with some fish in it; hang up a bottle that empties, drop by drop into a wide vessel beneath it. With the ship standing still, observe carefully how the little animals fly with equal speed to all sides of the cabin. The fish swim indifferently in all directions; the drops fall into the vessel beneath; and, in throwing something to your friend, you need throw it no more strongly in one direction than another, the distances being equal; jumping with your feet together, you pass equal spaces in every direction. When you observe all these things carefully (though there is no doubt that when the ship is standing still everything must happen in this way), have the ship proceed with any speed that you like, so long as the motion is uniform and not fluctuating this way and that.*

Galilean Relativity

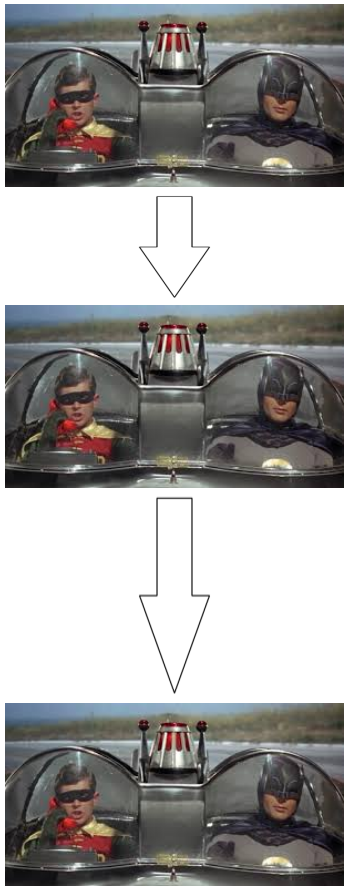
You will discover not the least change in all the effect s named, nor could you tell from any of them whether the ship was moving or standing still. In jumping, you will pass on the floor the same spaces as before, nor will you make larger jumps toward the stern than toward the prow even though the ship is moving quite rapidly, despite the fact that during the time that you are in the air the floor under you will be going in the direction opposite to your jump [...] The droplets will fall as before into the vessel beneath without dropping toward the stern [...] The fish in the water will swim towards the front of their bowl with no more effort than toward the back [...] the butterflies and flies will continue their flight indifferently toward every side. (Galileo, reprinted in Dainton 2010 pp. 169–70)

Absolute Acceleration

- If there is no difference between rest and constant movement in a straight line, then why did Newton believe in absolute motion?
- Because there *is* an absolute difference between an inertial frame and an **accelerating** frame

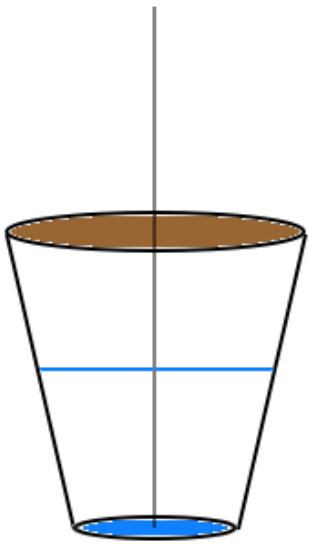
  (A body counts as accelerating if it is changing its speed *or the direction of its movement*. In brief, a body is accelerating iff it is changing its velocity, where velocity is speed in a direction)
- Because it takes a force to accelerate a body, accelerating bodies undergo **measurable** effects, known as *inertial effects*

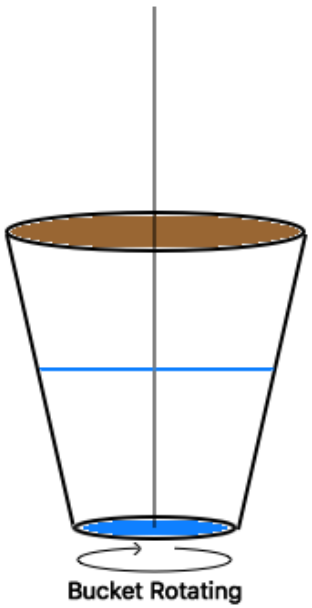
Absolute Acceleration

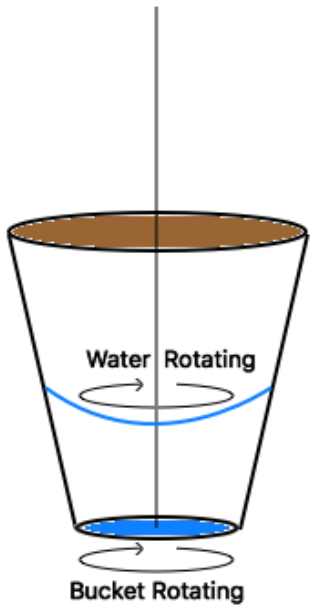


- Relative to the Joker, Batman is accelerating
- Relative to Batman, the Joker is accelerating
  - But Batman is the one **really** accelerating: only Batman is pushed back into his seat

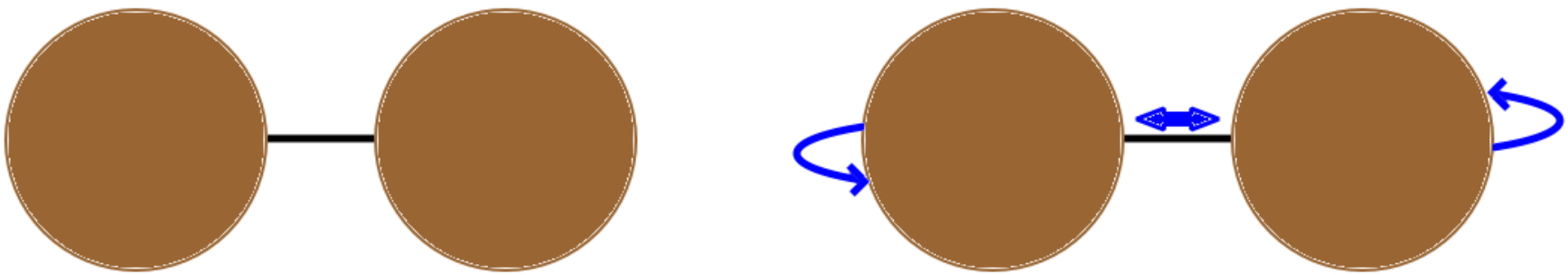
Newton's First Example: the Spinning Bucket







Newton's Second Example: The Two Spheres



From Absolute Acceleration to Absolute Motion

- It seems, then, that there are absolute facts about which bodies are accelerating, (and even of what their acceleration is!)
- Acceleration is the rate of change in velocity

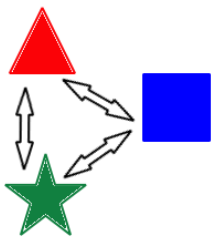
  (A body's velocity is its speed taken along with the direction in which it is moving)
- So there are absolute facts about which bodies are changing their velocities
- But doesn't that just obviously require absolute facts about what the velocities of bodies are?
- If so, then Newton is right: there is an absolute difference between rest and motion

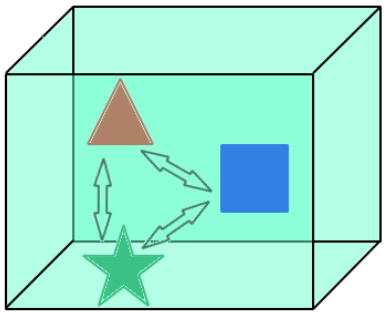
Is Space Absolute or Relational?

Substantivalism

- Newton thought that a body is at absolute rest just in case it is at rest **relative to space itself**
- A body is moving just in case it is moving **relative to space itself**
- Newton thought that space was a kind of substance, a three-dimensional continuum made up of infinitely many points
- To be at absolute rest was to stay at the same point in space
- Newton's view of space is now known as *substantivalism*

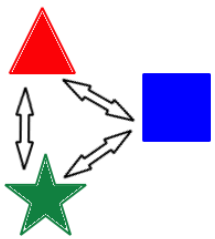
Relationism

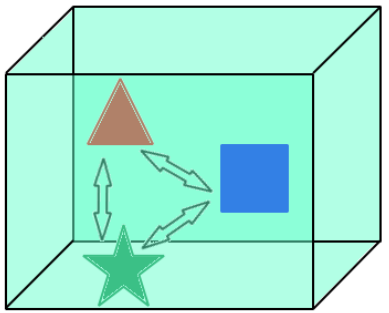




- According to *Relationism*, space is not a substance, but a system of spatial relations between bodies
- An analogy:
  - An extended family contains lots of people bearing lots of relations to each other (mother to son, brother to sister, aunt to nephew, etc)
  - But there is no 'family substance' that all of these people are embedded in
  - To say that someone is 'in' the extended family is just to say that it bears familial relations to certain people

Relationism





- To say that a body is 'in' space is just to say that it bears spatial relations to things
- We need to be a little bit more sophisticated:
  - A relationist does not want to ban all talk about spatial regions
  - It just doesn't want to take that talk *too* seriously
  - To say that there is a point in space halfway between the Earth and Saturn is to say that a body could be equidistant from the Earth and Saturn
  - This can be true even if as a matter of fact, no body actually is equidistant from the Earth and Saturn

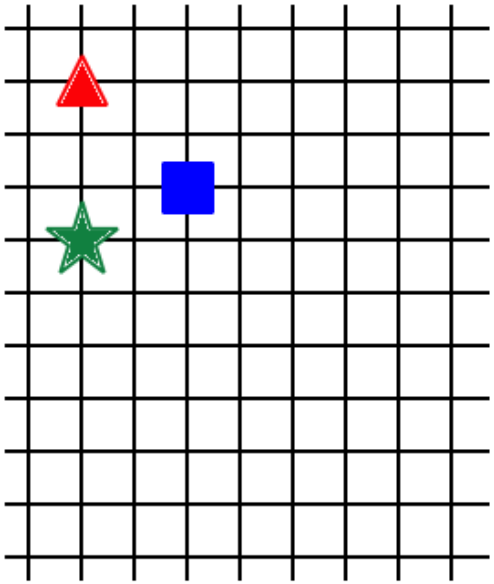
The Debate Applied to Time

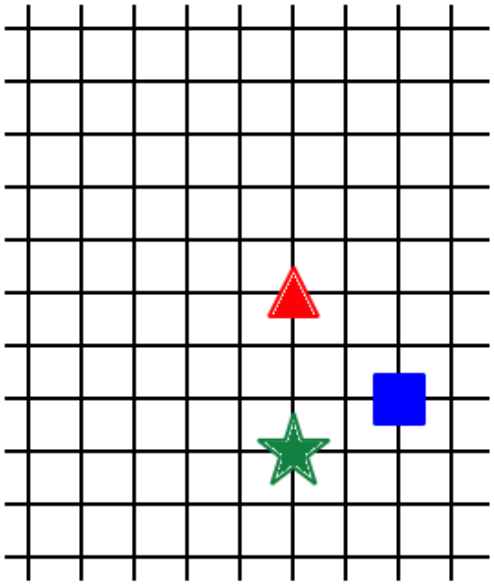
- Exactly the same debate can be played out in relation to **time**, rather than space
- According to substantivalism, time is also a substance, made up a continuum of temporal points
- According to relationism, time is not a substance, but a system of temporal relations between bodies
- Newton was a substantivalist about space **and time**

The Leibniz-Clarke Correspondence

- Leibniz was the great relationist (about both space and time)
- Between 1715 and 1716, Leibniz had a correspondence with Samuel Clarke
  - Clarke was representing Newton's views, and it is believed that Clarke consulted Newton in the course of preparing his letters
  - Newton and Leibniz had a very difficult relationship, because they were both convinced that the other had stolen calculus from them
  - It is now generally accepted that Newton and Leibniz both discovered calculus independently of the other
- Leibniz's arguments against substantivalism begin by pointing out that there are undetectably different ways for us to be related to substantival space

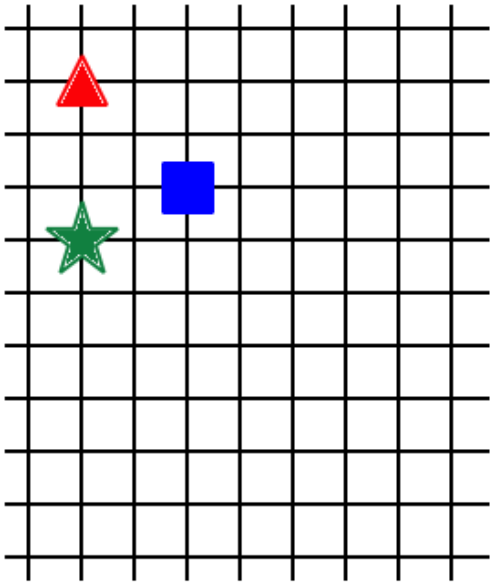
Static Shift

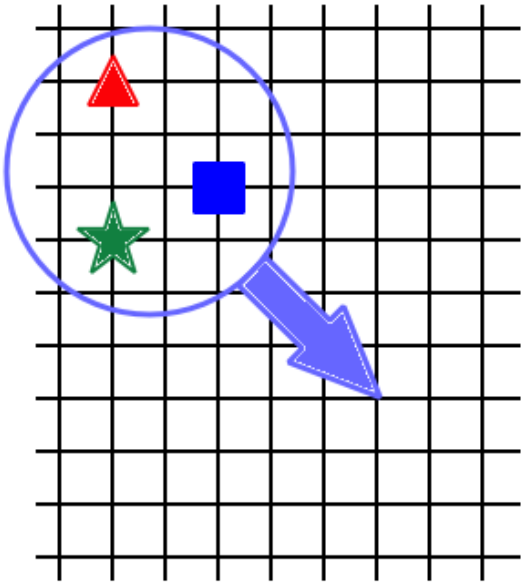




- We could not tell if everything in the Universe was located at different points in space

Kinematic Shift





- We could not tell if everything in the Universe was moving at the same speed in the same straight-line direction

The Principle of Sufficient Reason 1: Static Shift

- PSR: there is always a sufficient reason for *why* things are as they are
- So there must be a sufficient reason for locating the Universe in one region of substantival space rather than another
- But there is no reason!
- But if substantivalism is true, then the Universe must be located in some particular region of substantival space
- Hence substantivalism must be false

The Principle of Sufficient Reason 2: Kinematic Shift

- PSR: there is always a sufficient reason for *why* things are as they are
- So there must be a sufficient reason for the Universe having one (straight line) velocity rather than another
- But there is no reason!
- But if substantivalism is true, then the Universe must have a (straight line) velocity
- Hence substantivalism must be false

The PSR and Theology

- Leibniz and Clarke both accept the PSR
- They both connect it to theology: the choices of God are the ultimate reasons for the Universe being as it is
  - Although, the PSR does not *start off* as a theological principle for Leibniz, since he thinks that you can use the PSR to prove the existence of God!
- What Leibniz and Clarke **disagree** about is how to apply the PSR

God's Will

'Tis very true, that nothing is, without a sufficient reason why it is, and why it is thus rather than otherwise. And, therefore, where there is no cause, there can be no effect. But this sufficient cause is oft-times no other, than the mere will of God. For instance: why this particular system of matter, should be created in one particular place, and that other in another particular place; when, (all place being absolutely indifferent to all matter,) it would have been exactly the same thing vice versa, supposing the two systems (or the particles) of matter to be alike; there can be no other reason but the mere will of God. (Clarke to Leibniz)

God's Reason

The author [Clarke] grants me this important principle [the PSR...] But he grants it only in words, and in reality denies it [...] 'tis impossible that there should be reason why God, preserving the same situation of bodies among themselves, should have placed them in space after one particular manner, and not otherwise (Leibniz to Clarke)

God's Free Will

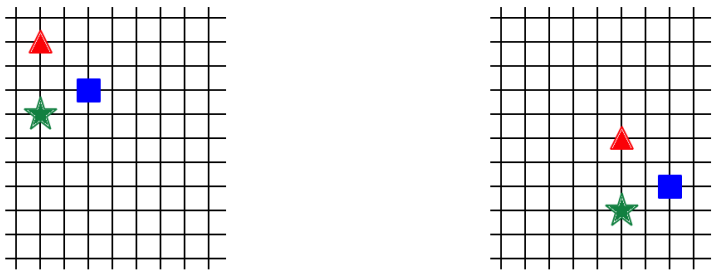
When two ways of acting are equally and alike good [...] to affirm in such cases that God cannot act [...] because he can have no external reason to move him to act one way rather than the other, seems to be denying God to have in himself any original principle or power of beginning to act, but that he must needs (as it were mechanically) be always determined by things extrinsic. (Clarke to Leibniz)

The PSR without Theology

- The PSR does not have to be bound up with theology
- It is just the insistence that we can always give a good explanation of *why* things are as they are
- There is definitely something attractive about this idea, but it is also very debatable
  - We'll see one threat to it later in the form of Quantum Mechanics

The Identity of Indiscernibles

- *The Identity of Indiscernibles* (PII)
  $$\forall x \forall y (\forall F(Fx \leftrightarrow Fy) \rightarrow x = y)$$
- *The Indiscernibility of Identicals* (Leibniz's Law)
  $$\forall x \forall y (x = y \rightarrow \forall F(Fx \leftrightarrow Fy))$$



- If substantivalism is true, these are two numerically different worlds
- But the worlds are indiscernible
- Hence they are identical
- Hence substantivalism is false

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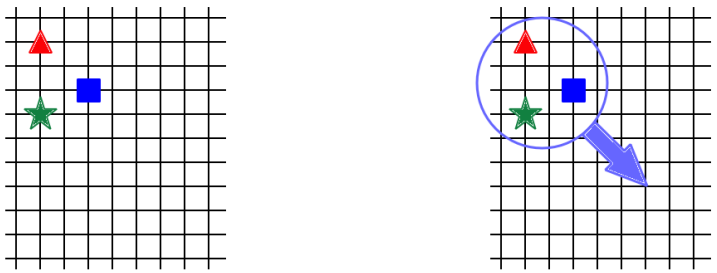

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Indiscernible How?

- PII: $\forall x \forall y(\forall F(Fx \leftrightarrow Fy) \rightarrow x = y)$
- The power of the PII all depends on what we mean by 'indiscernible'
  - i.e. on what properties are being quantified over by '$\forall F...F...$'
- If we allow **any** property in, including properties like *being identical to x*, then the PII is utterly trivial
- Clearly, Leibniz has some kind of empirical indiscernibility in mind
  - If x has no property which makes it possible for us to **empirically** discern it from y, then $x = y$
- But that makes the PII **very** controversial

Where are We?

- Leibniz seems to have some good, although not totally definitive, arguments against substantivalism
- But Newton also has a good argument **for** substantivalism:
  - There is an empirically detectable difference between accelerating and inertial bodies
  - So acceleration is absolute
  - Acceleration is the rate of change of velocity, so velocity must be absolute
  - Velocity is the rate of change of position, so position must be absolute
  - So there must be a substantival space
- Leibniz never offered a satisfying reply to this argument

Is Space Absolute or Relational?

From Space to Spacetime

- We are used to thinking of Space as a three-dimensional continuum of spatial points
- We can represent each spatial point with three numbers, (x, y, z)
- Each spatial point is the potential location of some body

- Spacetime is a **four**-dimensional continuum of points
- We can represent each spacetime point with four numbers, (x, y, z, t)
  - The first three co-ordinates are spatial, the fourth is temporal
- Each spacetime point is the potential location of some **event**

Newtonian Spacetime

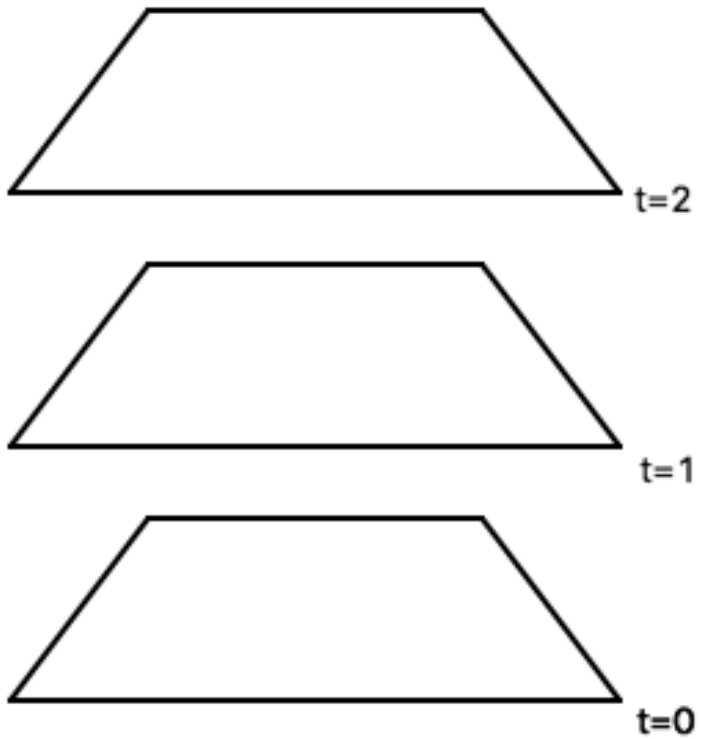
(1) Spacetime can be divided up into absolute 'simultaneity hyperplanes'

(A simultaneity hyperplane is a 3-dimensional 'slice' on which every point is simultaneous with every other point)

(2) There is a definite spatial distance between any two points on a given simultaneity hyperplane

(3) There is also a definite spatial distance between any two points **on different simultaneity hyperplane**

Newtonian Spacetime



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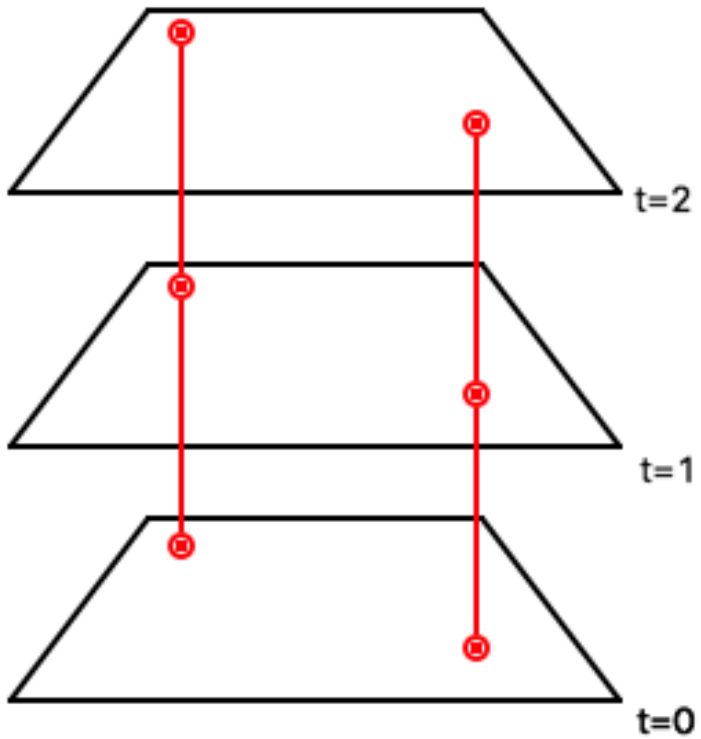

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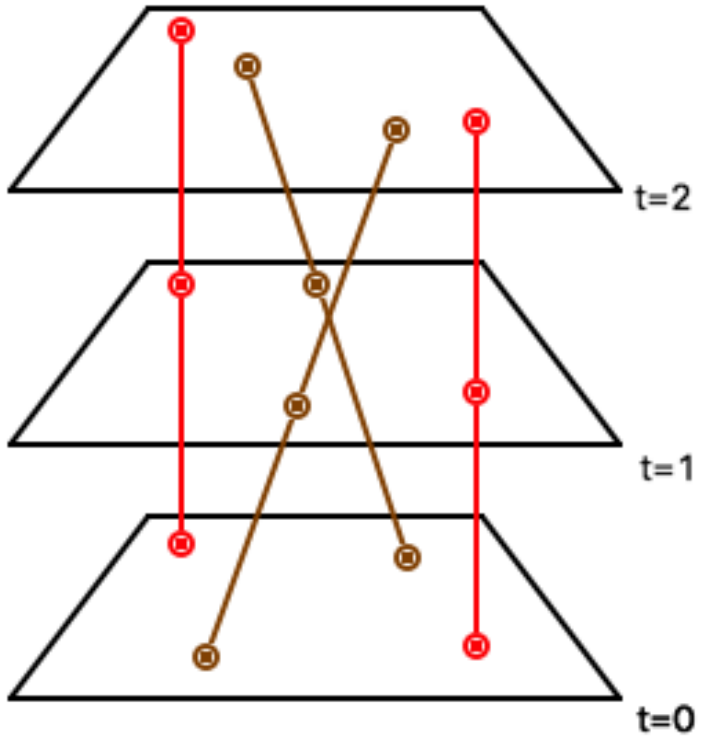

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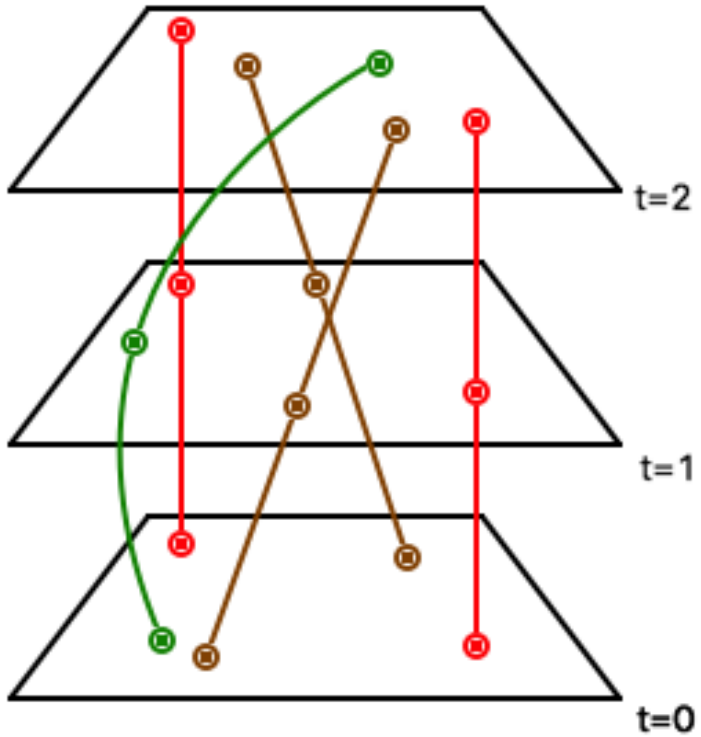
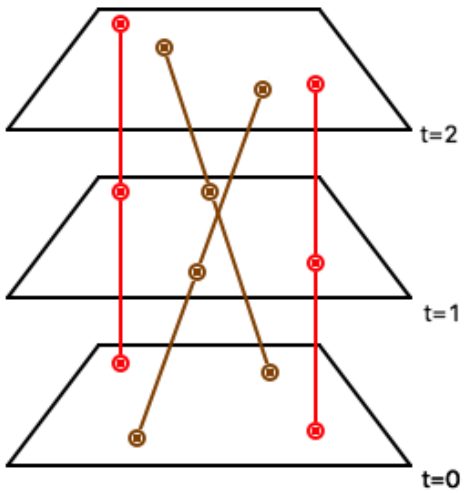
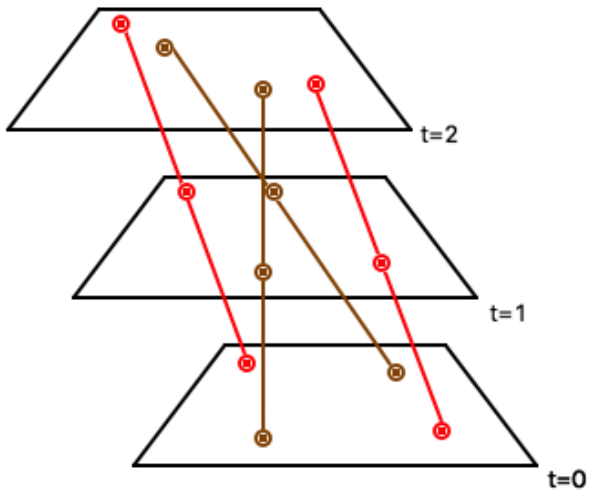


Neo-Newtonian Spacetime

- There is more structure in Newtonian spacetime than we need to do Newtonian physics!
- We still need (1) and (2)
  - (1) Spacetime can be divided up into absolute 'simultaneity hyperplanes'
  - (2) There is a definite spatial distance between any two points on a given simultaneity hyperplanes
- But we **do not** need (3)
  - (3) There is also a definite spatial distance between any two points **on different simultaneity hypeprplanes**
- *Neo-Newtonian* spacetime keeps (1) and (2) and rejects (3): there is no answer to the question of how far apart two points are on different simultaneity slices
  - Although there is still a difference between spacetime points which can be connected by a straight line, and ones which cannot

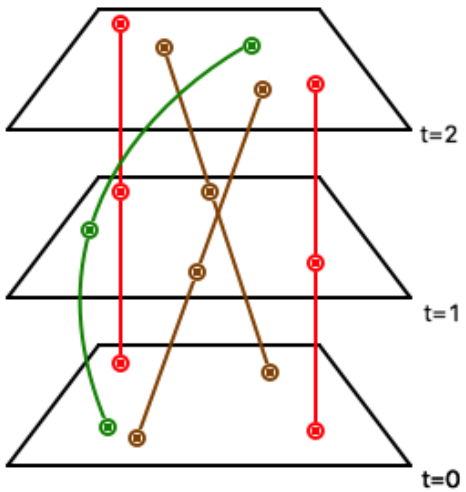
Neo-Newtonian Spacetime

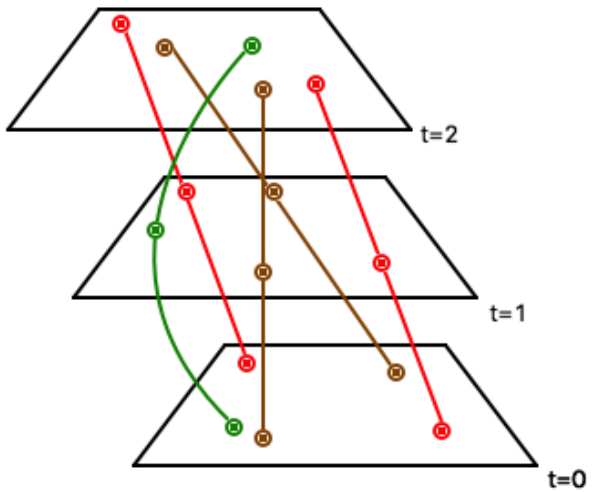




- No intertial paths are absolutely at rest: we can choose to treat **any** of them as being at rest

Neo-Newtonian Spacetime





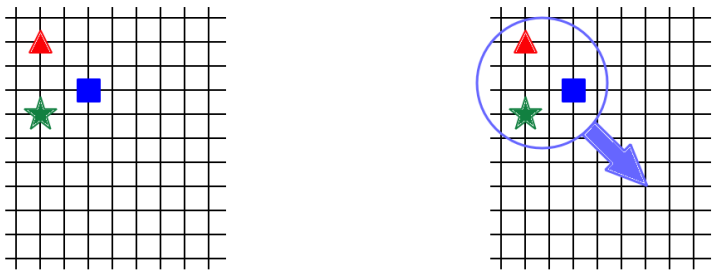
- No intertial paths are absolutely at rest: we can choose to treat **any** of them as being at rest
- But there is still a difference between inertial paths and accelerating ones: intertial paths are straight, and accelerating ones are curved

More on neo-Newtonian Spacetime

- A good textbook explanation of what is going on with neo-Newtonian spacetime:
  - Dainton, B. (2010) *Time and Space*, chapter 12
- Another textbook explanation, but one which requires some background knowledge of Minkowski spacetime (the spacetime of Special Relativity):
  - Sklar, L. (1992) *Philosophy of Physics*, pp. 38–40
- A more advanced (but still not **too** complicated) discussion:
  - Maudlin, T (2012) *Philosophy of Physics: Space and Time*, chapter 3

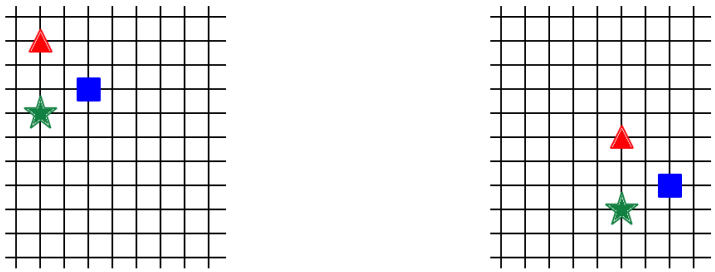
Is Space Absolute or Relational?

Kinematic Shift



- Since no intertial frame is treated as being at absolute rest, these worlds **are** identical

Static Shift



- Imagine that these diagrams represented different simultaneity slices in one world
- We could easily stipulate that these objects count as being at rest
- But this means that we can stipulate that these bodies have not moved, i.e. are in the same position
- And **this** means that if we go back to thinking of these diagrams as two worlds at the same time, we can stipulate that they are identical
  - The only thing stopping us identifying them before was that the bodies seemed to be in different locations!

Substantivalism without Absolutism

- Neo-Newtonian spacetime still looks pretty substantial
  - It is very hard to know how you would give a relationist account of neo-Newtonian spacetime
- But there is a clear sense in which neo-Newtonian spacetime is no longer absolute
  - There is no absolute fact of the matter whether you are changing your location in space!
- So we seem to have a middle path between Newton and Leibniz:
  - We have kept Newton's substantivalism
  - But we have abandoned his absolutism