The Philosophy of Physics
Lecture One

Is Space Absolute or Relational?

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Is Space Absolute or Relational?

Teaching

- **Contact Hours**
  - 9 × 1.5 hour lectures (Monday 12:30–14:00)
  - 9 × 1.5 hour seminar (Friday morning — check your timetable!)
  - Weekly Office Hours (Thursday & Friday 14:00–15:00)

- **Procedural Requirements**
  - Attend lectures
  - Complete all required reading
  - Attend, and fully participate in, seminars

The Reading List

- There is a full Reading List on the VLE site
- Readings marked **Essential** must be read in preparation for this module
  - Some of the **Essential** readings are also labelled as *Seminar Readings*, and they must be read before each seminar
- Readings marked **Recommended** would be good to read to get a fuller understanding of the material
- Readings marked **Background** are usually more advanced texts, and you only need to read them if you really want a deeper understanding

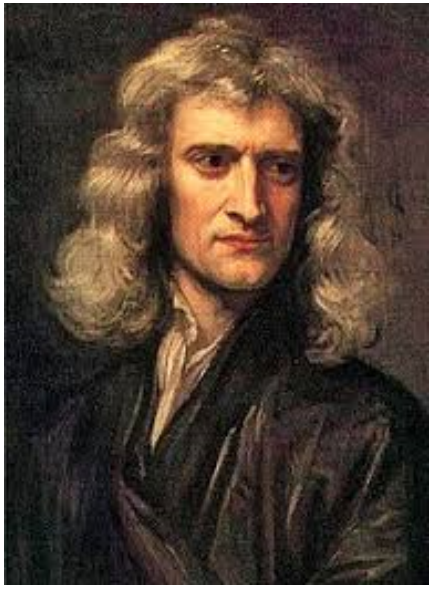
Assessment

- **Summative Assessment**
  - 4,000 word essay
  - Due Monday Week 2, Spring Term
  - A list of questions is available on the VLE
  - You may propose your own essay question, but it must be submitted by Thursday Week 10
- **Formative Assessment**
  - 1,000 word essay
  - E-mail to me (rob.trueman@york.ac.uk) by noon, Monday Week 8
  - Title: *What puzzles me the most is...*
  - You should lay out an issue that has been puzzling you, explain why it has been puzzling you, and then do your best to resolve that puzzle or difficulty

Is Space Absolute or Relational?

- Newton and Leibniz were two great geniuses of the Enlightenment
- They disagreed over whether space was **absolute** or merely **relative**

Gottfried Leibniz



Isaac Newton

- They didn't get on because they both thought that the other stole the idea of calculus
- We now know they both invented it independently

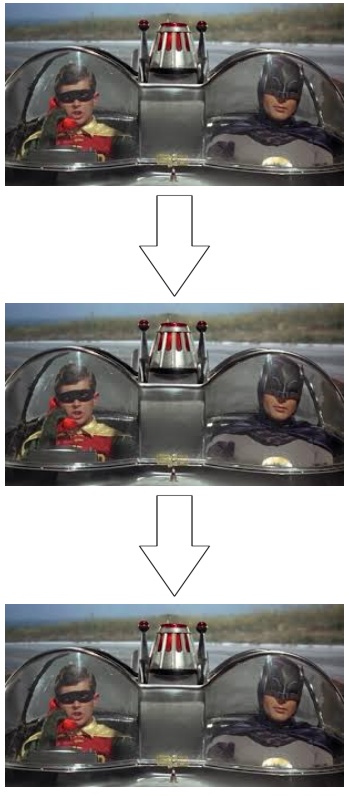
Relative Motion

- 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



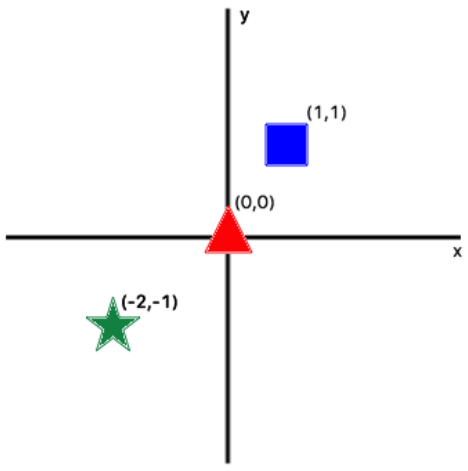
- Relative to the Joker, Batman is moving

Newton's Absolute Motion

- But is Batman *really* moving?
- Of course it is tempting to answer 'Yes', but that's because we usually assume that the Earth is at rest
- Maybe it is a bad question: maybe 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 the position of every other object relative to it
- When we do, we get a frame of reference for that body



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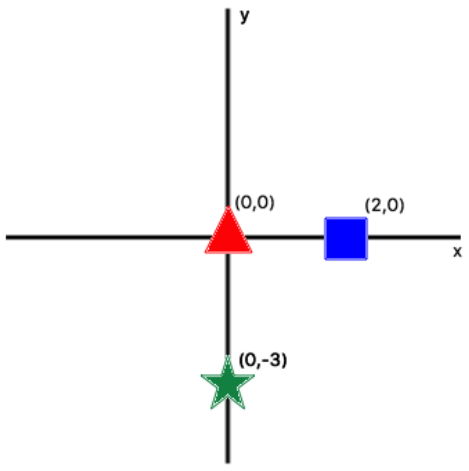

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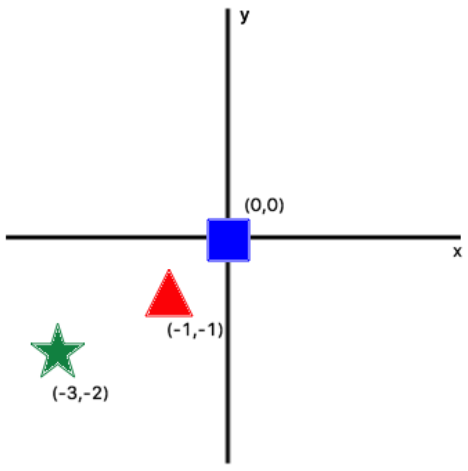

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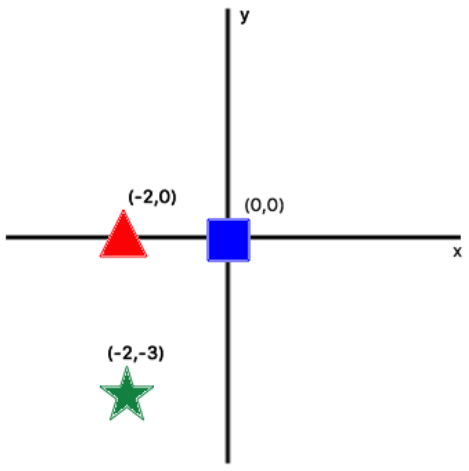


Time = 1

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 **absolutely** at rest iff the bodies "at rest" according to the frame are *really* at rest
- This is a bit surprising, because Newtonian physics doesn't recognise any 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

Galilean Relativity

- Imagine you are on a plane, sitting on the runway waiting to take off
- If you dropped a pen, it would obviously fall straight down

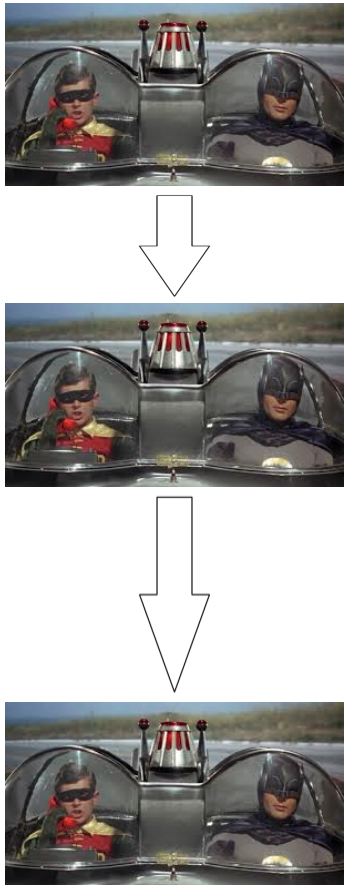
- Now imagine that you are on the plane after it has taken off, and you are now cruising at 500 miles per hour relative to the Earth
- If you dropped your pen, it would *still* fall straight down!

- The fact that the laws of physics are the same in every inertial frame was first pointed out by Galileo
- It is known as **Galilean Relativity**

Absolute Acceleration

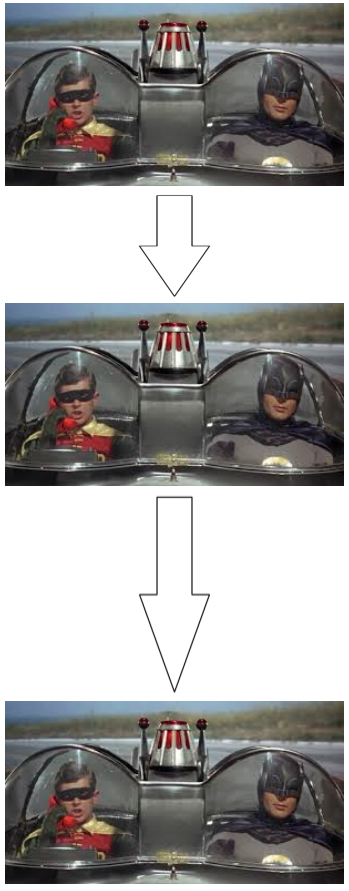
- If there is no difference between rest and constant movement in a straight line, then why did Newton believe in absolute motion?
- Because there *is* an absolute difference between an inertial frame and an **accelerating** frame
  - A body counts as accelerating if it is changing its speed *or the direction of its movement*
  - In brief, a body is accelerating iff it is changing its velocity, where velocity is speed in a direction
- It takes a force to accelerate a body, and so accelerating bodies undergo **measurable** effects, known as *inertial effects*

Absolute Acceleration



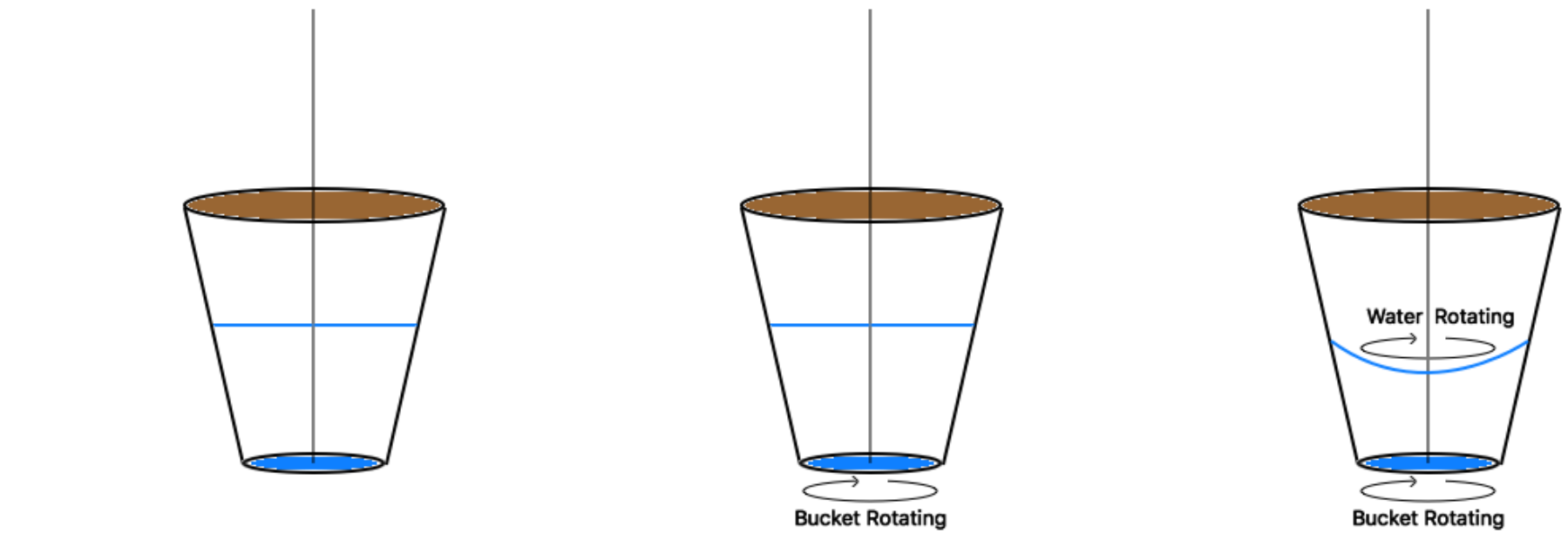
- Relative to the Joker, Batman is accelerating
- Relative to Batman, the Joker is accelerating

Absolute Acceleration

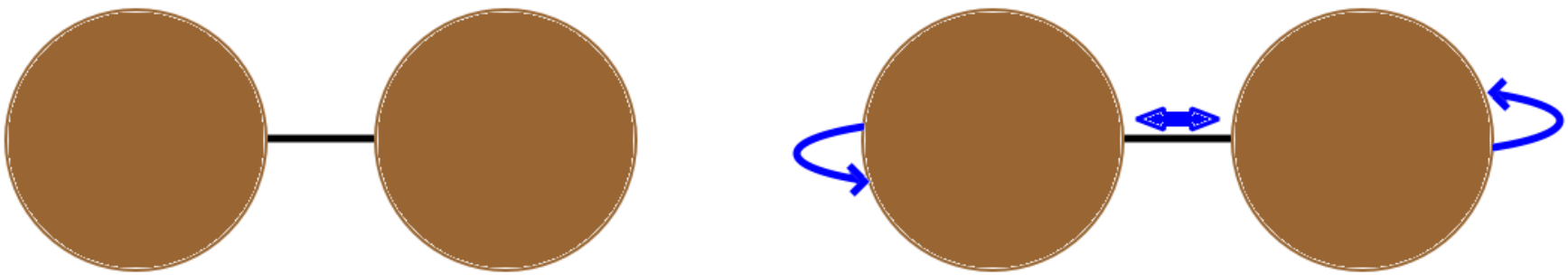


- But Batman is the one **really** accelerating
- Only Batman is pushed back into his seat!

Newton's First Example: the Spinning Bucket



Newton's Second Example: The Two Spheres



From Absolute Acceleration to Absolute Motion

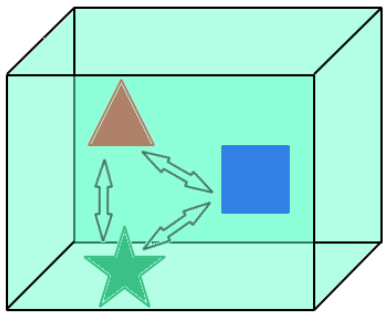
- It seems, then, that there are absolute facts about which bodies are accelerating
- Acceleration is the rate of change in velocity
- So there are absolute facts about which bodies are changing their velocities
- But doesn't that just obviously require absolute facts about what the velocities of bodies are?
- If so, then Newton is right: there is an absolute difference between rest and motion

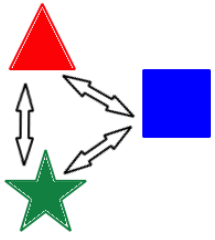
Is Space Absolute or Relational?

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**

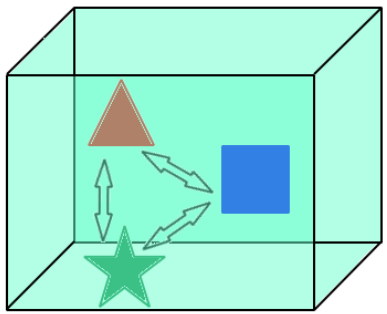
Relationalism

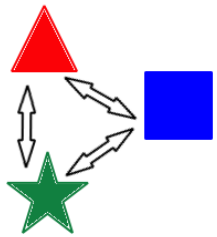




- According to **Relationalism**, space is not a substance, but a system of spatial relations between bodies
- To say that a body is 'in' space is just to say that it bears spatial relations to things

Relationalism





- A relationalist does not want to ban all talk about spatial regions, they just don'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

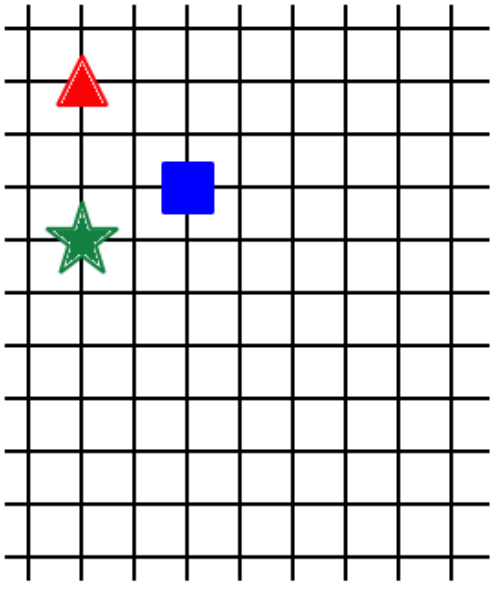
The Debate Applied to Time

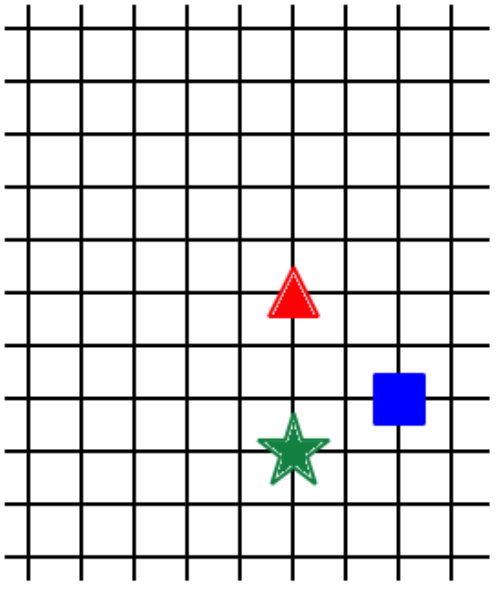
- Exactly the same debate can be played out in relation to **time**, rather than space
- According to substantivalism, time is also a substance, made up a continuum of temporal points
- According to relationalism, time is not a substance, but a system of temporal relations between bodies
- Newton was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

The Leibniz-Clarke Correspondence

- Leibniz was the great relationalist (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 wouldn't speak directly because of their disagreement about calculus
- Leibniz's arguments against substantivalism begin by pointing out that there are undetectably different ways for us to be related to substantival space

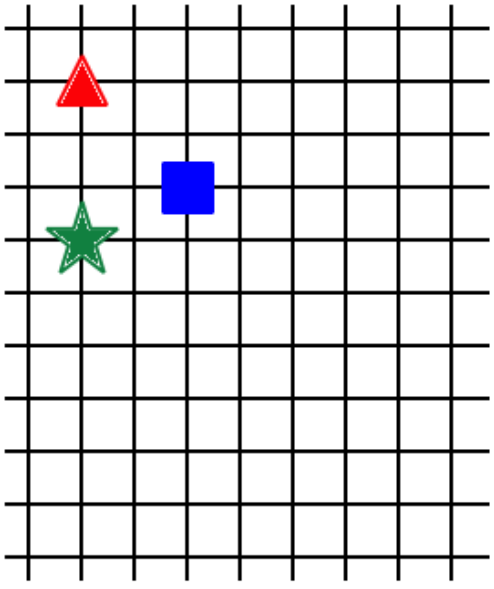
Static Shift

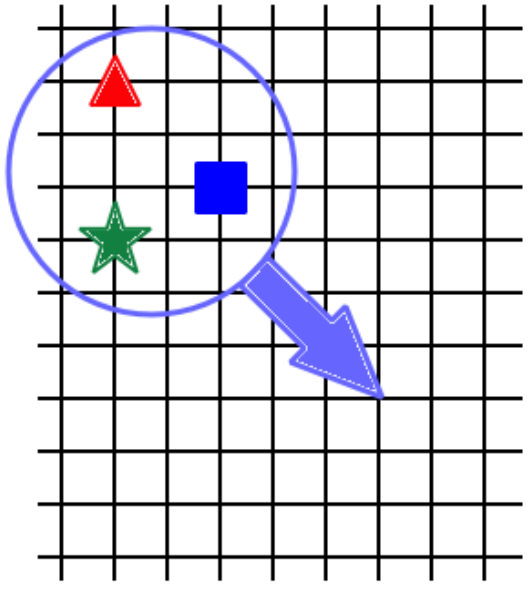




- We could not tell if everything in the Universe was located at different points in space

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
- If substantivalism is true, then the Universe must be located in some particular region of substantival space
- But there is no reason for locating the Universe in one region rather than another!
- 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
- If substantivalism is true, then the Universe must have some particular velocity relative to substantival space
- But there is no reason for the Universe to have one velocity rather than another!
- 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)

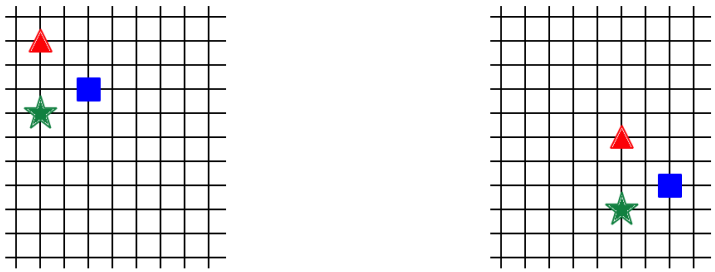
The PSR without Theology

- 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 Principle of the Identity of Indiscernibles**

  $$\forall x \forall y (\forall F (Fx \leftrightarrow Fy) \rightarrow x = y)$$



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

The Identity of Indiscernibles

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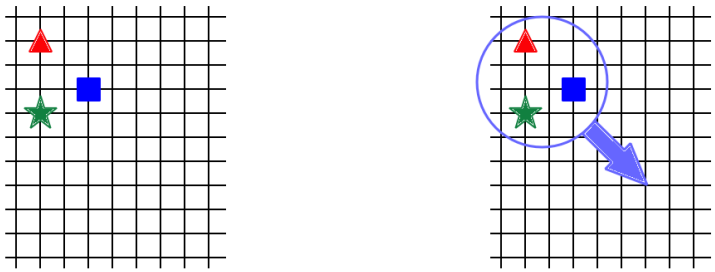

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Indiscernible How?

- **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'
  - What properties are we quantifying over with '$\forall F \ldots F \ldots$'?
- 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 $x = y$
- Again, there is something attractive about this version of PII, but it is very debatable

Where are We?

- Leibniz seems to have some good, although not knock-down, arguments against substantivalism
- But Newton also has a good argument **for** substantivalism:
  - There is an empirically detectable difference between accelerating and inertial reference frames
  - 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

From Space to Spacetime

- 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

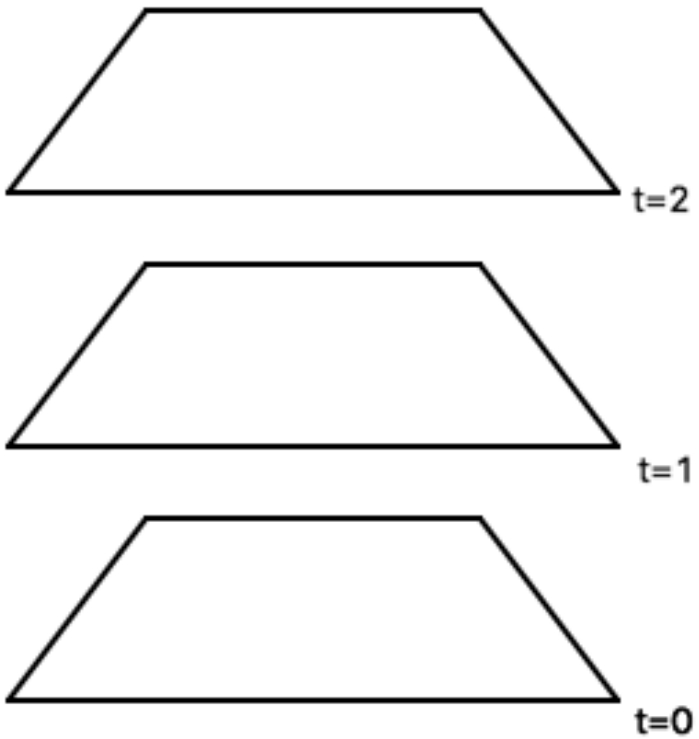
(1) Spacetime can be divided up into absolute 'simultaneity hyperplanes'

- A simultaneity hyperplane is a 3-dimensional 'slice' of spacetime, 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 hyperplanes**

Newtonian Spacetime



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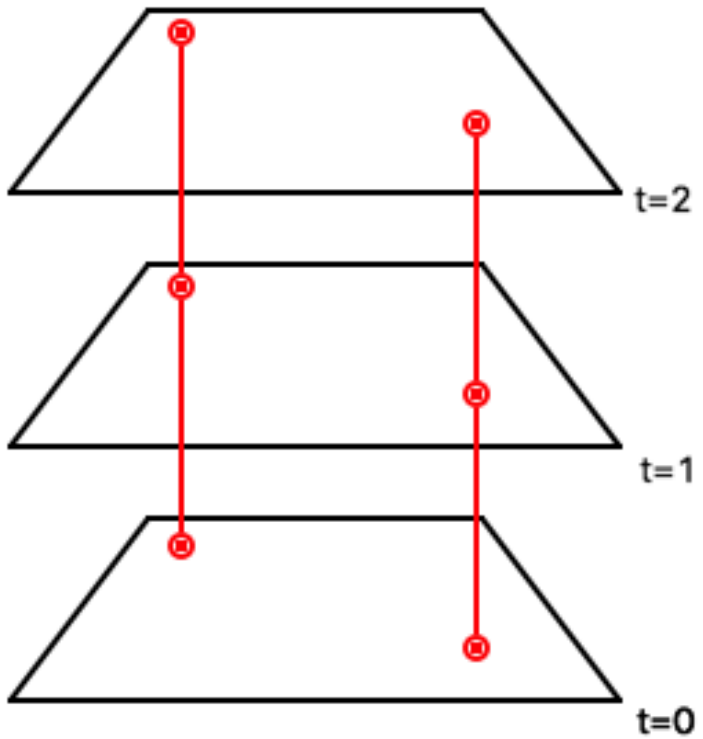

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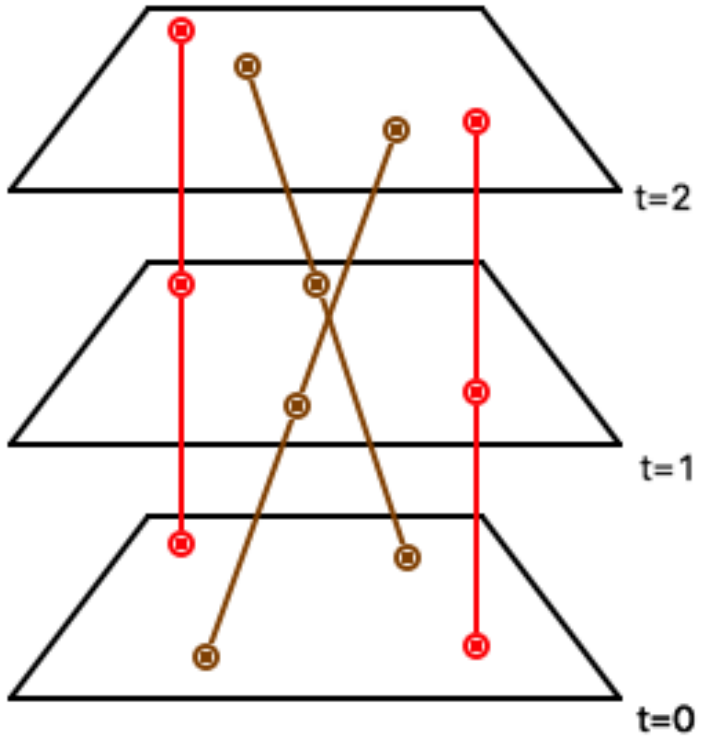

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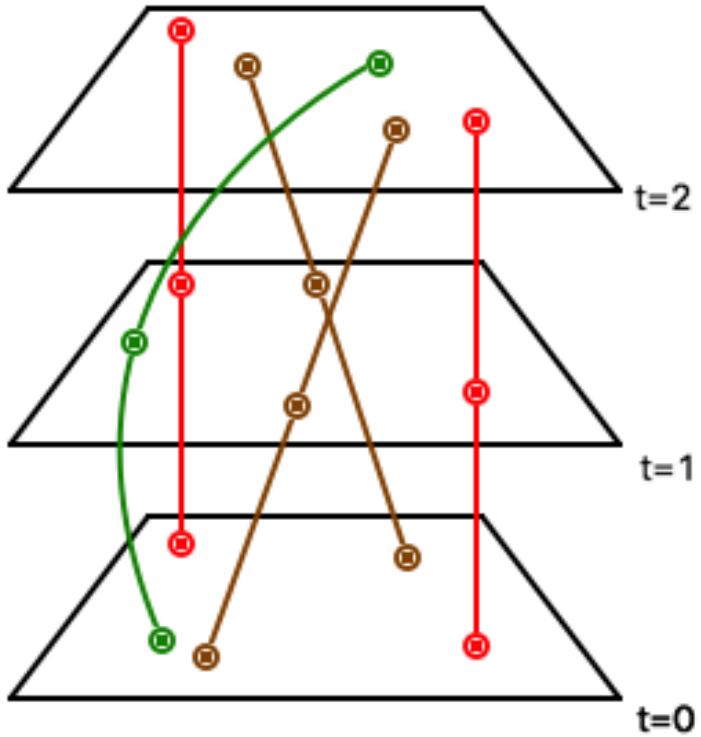


Galilean Spacetime

(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 hyperplane

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

- There is more structure in Newtonian spacetime than we need to do Newtonian physics!
- We still need (1) and (2), but we don't need (3)!

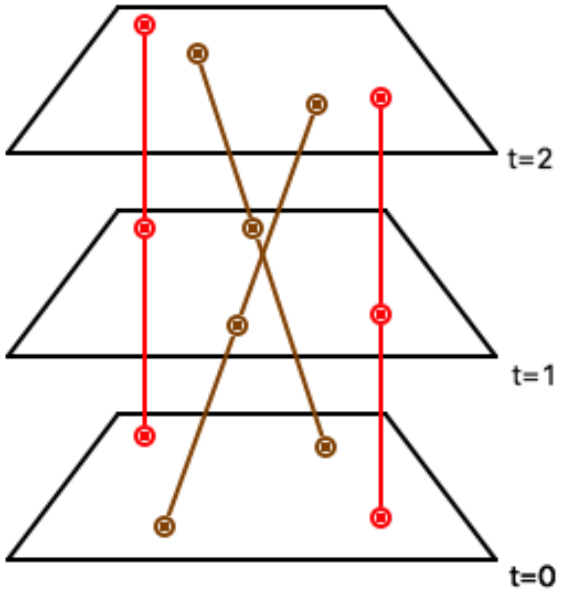
Galilean Spacetime

(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 hyperplane

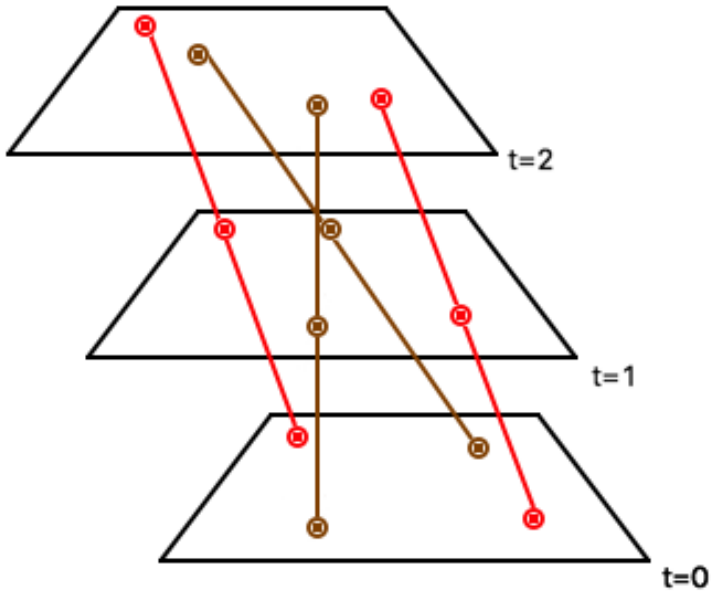
- **Galilean Spacetime** keeps (1) and (2), and rejects (3)
  - There is no answer to the question of how far apart two points are on different simultaneity slices
- However, there is still a difference between spacetime points which can be connected by a straight line, and ones which cannot

Galilean Spacetime



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

Galilean Spacetime



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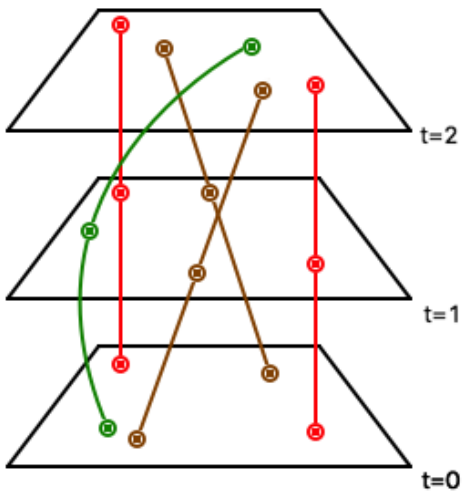
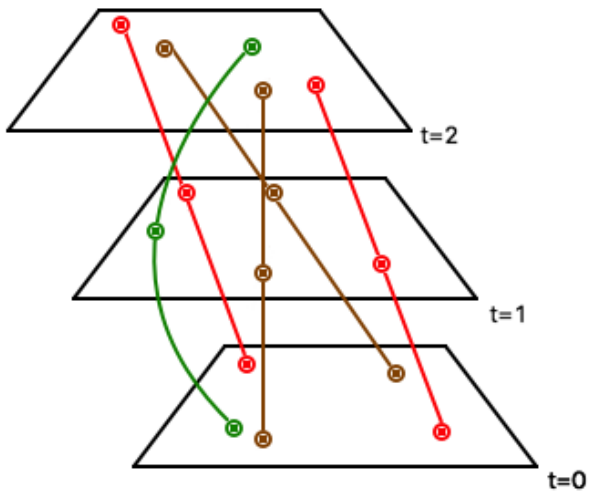
Galilean Spacetime



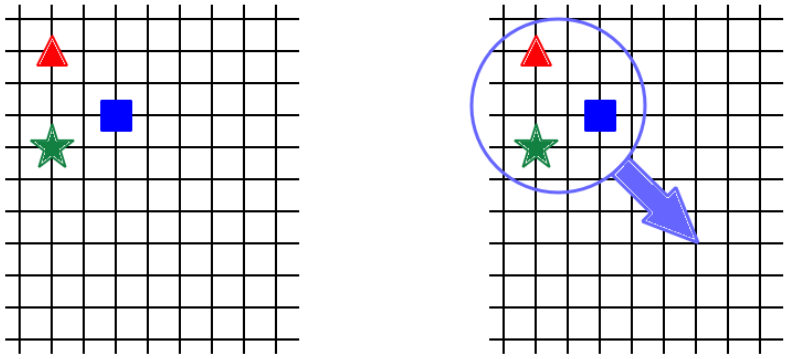


- But there is still a difference between inertial paths and accelerating ones: inertial paths are straight, and accelerating ones are curved

More on Galilean Spacetime

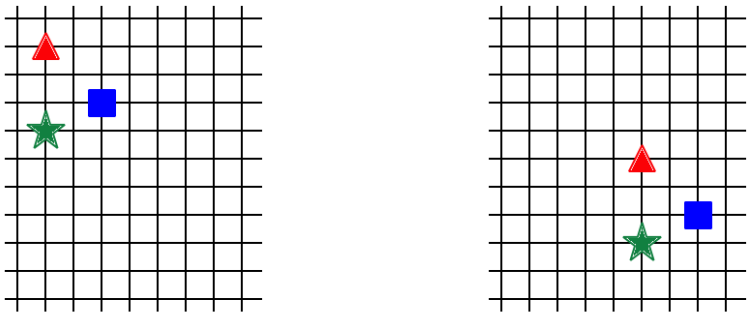
- A good textbook explanation of what is going on with Galilean spacetime:
  - Dainton, B. (2010) *Time and Space*, chapter 12
- Another textbook explanation, but one which requires some background knowledge of Minkowski spacetime (the spacetime of Special Relativity):
  - Sklar, L. (1992) *Philosophy 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

Kinematic Shift



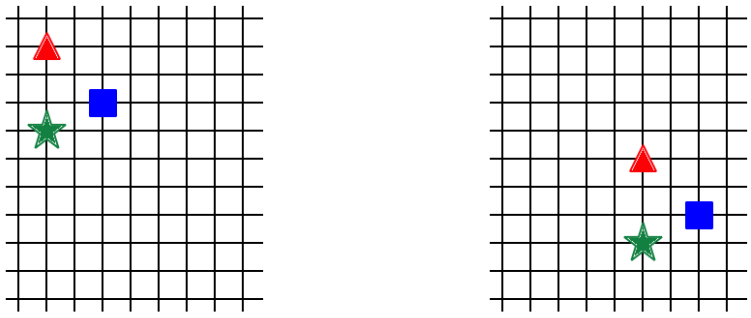
- Since no intertial frame is treated as being at absolute rest, these worlds **are** identical

Static Shift



- Imagine that these diagrams represented different simultaneity hyperplanes in one world
- We could easily stipulate that these objects count as being at rest — i.e. they stay in the same position

Static Shift



- Now go back to thinking of these diagrams as representing worlds
- We can surely still stipulate that these diagrams represent objects located in the same places
- So surely we can stipulate that the diagrams both represent the same world!

Substantivalism without Absolutism

- Galilean spacetime still looks pretty substantial
  - It is not obvious how to give a relationalist account of Galilean spacetime!
- But there is a clear sense in which Galilean 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

Seminar Reading

- For the seminar, please read:
  - The Leibniz-Clarke Correspondence
  - Dasgupta's, 'Substantivalism vs Relationalism about Space in Classical Physics'
- Both are available via the Reading List on the VLE