First Course Topic: Time and Change

Is time real? Is time an illusion?

Does the world change? Or is change just an appearance?

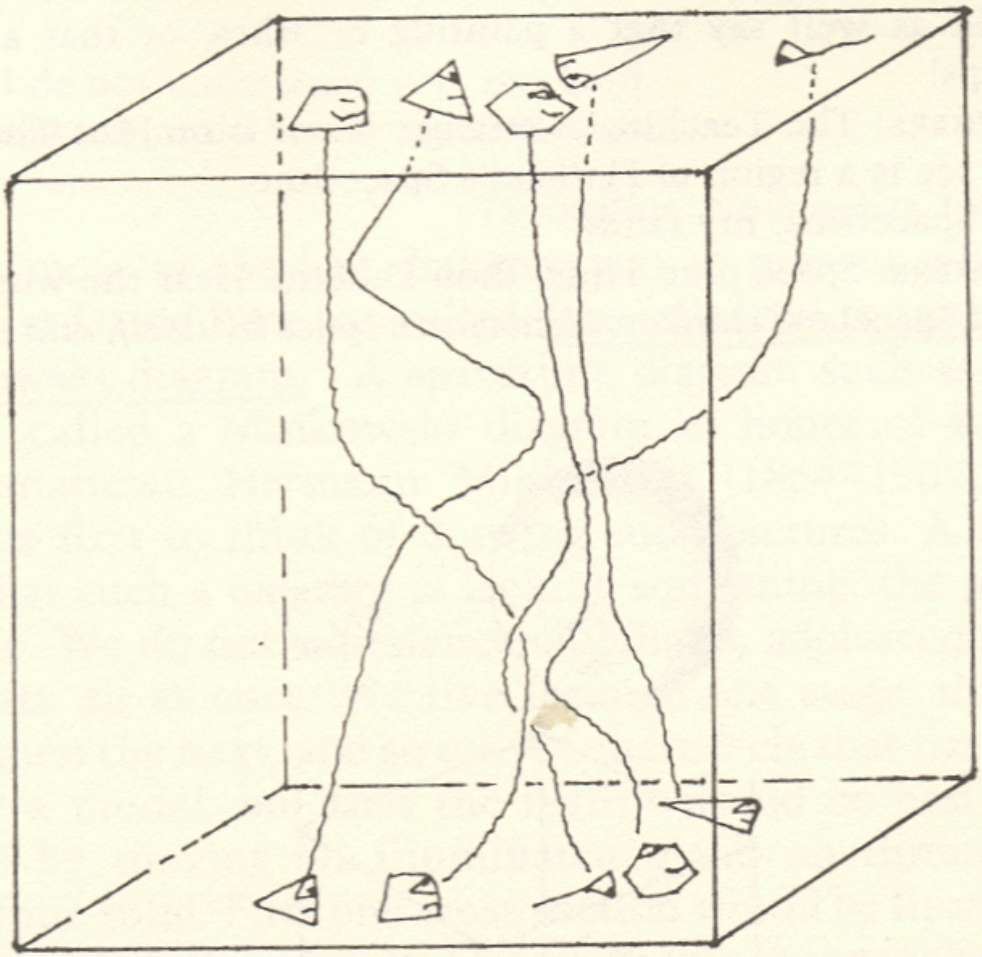


Fig. 140. A tangled tale.

Augustine's Life

He was born in Tagaste (now in current Algeria) in 354

In young age, he had a hedonist and dissolute life

He taught rhetoric (roughly, public speaking and speech writing) in North Africa and Italy

He *converted to Christianity* in 386 and was baptized in 387

He was ordained priest in 391 and became bishop of Hippo in 395 Hippo

He died in Hippo (now in current Algeria) in 430

We will read closely book 11 of Augustine's *Confession*

The Challenge (roughly p. 121)

What was God doing before He made heaven and earth?

For if (say they) He were unemployed and wrought not, why does He not also henceforth, and for ever, as He did heretofore?

For did any new motion arise in God, and a new will to make a creature, which He had never before made, how then would that be a true eternity, where there ariseth a will, which was not?

For the will of God is not a creature, but before the creature; seeing nothing could be created, unless the will of the Creator had preceded. The will of God then belongeth to His very Substance. And if aught have arisen in God's Substance, which before was not, that Substance cannot be truly called eternal.

But if the will of God has been from eternity that the creature should be, why was not the creature also from eternity?"

Augustine's Answer

Seeing then Thou art the Creator of all times, if any time was before Thou madest heaven and earth, why say they that Thou didst forego working? For that very time didst Thou make, nor could times pass by, before Thou madest those times.

But if before heaven and earth there was no time, why is it demanded, what Thou then didst? For there was no "then," when there was no time.

Nor dost Thou by time, precede time: else shouldest Thou not precede all times.

Challenge and Answer

- **Challenge**:

  If God created the world *at some point*, a change must have occurred in him at some point. A new will or motion must have occurred in him to make creation possible. But a God that changes is not a God because God is unchanging.

  If, on the other hand, the will to create the world has always been within God, the created world would have existed for ever. But the created world is not eternal; it has a beginning and an end.

- **Augustine's answer:**

  God created time itself. It makes no sense to talk about time before God created the world. There was no time "then".

A New Challenge — What Is Time?

For what is time?

Who can readily and briefly explain this? Who can even in thought comprehend it, so as to utter a word about it?

But what in discourse do we mention more familiarly and knowingly, than time?

And, we understand, when we speak of it; we understand also, when we hear it spoken of by another.

What then is time? If no one asks me, I know: if I wish to explain it to one that asketh, I know not.

The Flow of Time Seems Obvious

*I say boldly that I know, that if nothing passed away, time **past** were not; and if nothing were coming, a **time to come** were not; and if nothing were, time **present** were not.*

How Can Past and Future Exist If They Don't Exist Now?

Those two times then, past and to come, how are they, seeing the past now is not, and that to come is not yet?

Can The Present Exist If It Tends to Non-Existence?

But the present, should it always be present, and never pass into time past, verily it should not be time, but eternity.

If time present (if it is to be time) only cometh into existence, because it passeth into time past, how can we say that either this is, whose cause of being is, that it shall not be; so, namely, that we cannot truly say that time is, but because it is tending not to be?

The Puzzle About the **Flow of Time**

- The past does not exist: it does not exist anymore
- The future does not exist: it does not exist yet
- The present does not exist: it tends to non-existence

How can we experience the flow of time if past, present and future do not exist? Of what do we experience the flow?

A Further Complication: Measuring Time

How Do We Measure The Past and the Future?

And yet we say, "a long time" and "a short time"; still, only of time past or to come.

A long time past (for example) we call an hundred years since; and a long time to come, an hundred years hence.

But a short time past, we call (suppose) often days since; and a short time to come, often days hence. ***But in what sense is that long or short, which is not? For the past, is not now; and the future, is not yet.***

If We Cannot Measure the Past and the Future, Can We at Least Measure the Present?

Let us see then, thou soul of man, whether present time can be long …

Are an hundred years, when present, a long time? See first, whether an hundred years can be present. For if the first of these years be now current, it is present, but the other ninety and nine are to come, and therefore are not yet, but if the second year be current, one is now past, another present, the rest to come. …

But see at least whether that one [year] which is now current, itself is present; for if the current month be its first, the rest are to come; if the second, the first is already past, and the rest are not yet.

Therefore, neither is the year now current present … neither is that current month present; but one day only; the rest being to come

The Present Cannot Be Measured Either Because it Has No "Space"

If an instant of time be conceived, which cannot be divided into the smallest particles of moments, that alone is it, which may be called present. Which yet flies with such speed from future to past, as not to be lengthened out with the least stay. For if it be, it is divided into past and future. ***The present hath no space.***

Augustine's Puzzle About **Measuring Time**

- The past does not exist: it does not exist anymore
- The future does not exist: it does exist yet
- The present has no space, no extension

How can we measure time if past and future do not exist and the present has not extension? Of what do we measure that it is longer or shorter?

Augustine's Proposal — Finally! — Namely, Time as Protraction of the Mind

Whence it seemed to me, that ***time is nothing else than protraction; but of what, I know not; and I marvel, if it be not of the mind itself?***

For what, I beseech Thee, O my God, do I measure, when I say, either indefinitely "this is a longer time than that," or definitely "this is double that"?

That I measure time, I know; and yet I measure not time to come, for it is not yet; nor present, because it is not protracted by any space; nor past, because it now is not. ***What then do I measure? Times passing, not past? for so I said.***

The Mind is Being Measured, Not Time Itself

It is in thee, my mind, that I measure times.

…In thee I measure times; the impression, which things as they pass by cause in thee, remains even when they are gone; this it is which still present, I measure, not the things which pass by to make this impression.

This I measure, when I measure times. Either then this is time, or I do not measure times.

Time as Expectation and Memory

Who therefore denieth, that things to come are not as yet? and yet, there is in the mind an ***expectation*** *of things to come.*

And who denies past things to be now no longer? and yet is there still in the mind a ***memory*** *of things past.*

And who denieth the present time hath no space, because it passeth away in a moment? and yet our ***consideration*** *continueth, through which that which shall be present proceedeth to become absent.*

*It is not then future time, that is long, for as yet it is not: but a long future, is "****a long expectation of the future****," nor is it time past, which now is not, that is long; but a long past, is "****a long memory of the past.****"*

Augustine on Measuring Time *…in Brief*

QUESTION: When we say that an interval of time is shorter or longer than another, what do we measure as shorter or longer?

PUZZLE: We cannot measure the past because the past no longer exists, and what does not exist cannot be short or long. We cannot measure the future either because the future does not exist yet, and again, what does not exist cannot be measured. Finally, we cannot measure the present because the present has no extension at all. But if we cannot measure the present, the past or the future, what do we measure when we measure time?

ANSWER: Times only exists in the mind. We measure the *expectation* of an event, which can be long or short. We measure the *memory* of an event, which also can be long or short.

Aspects of our Experience of Time

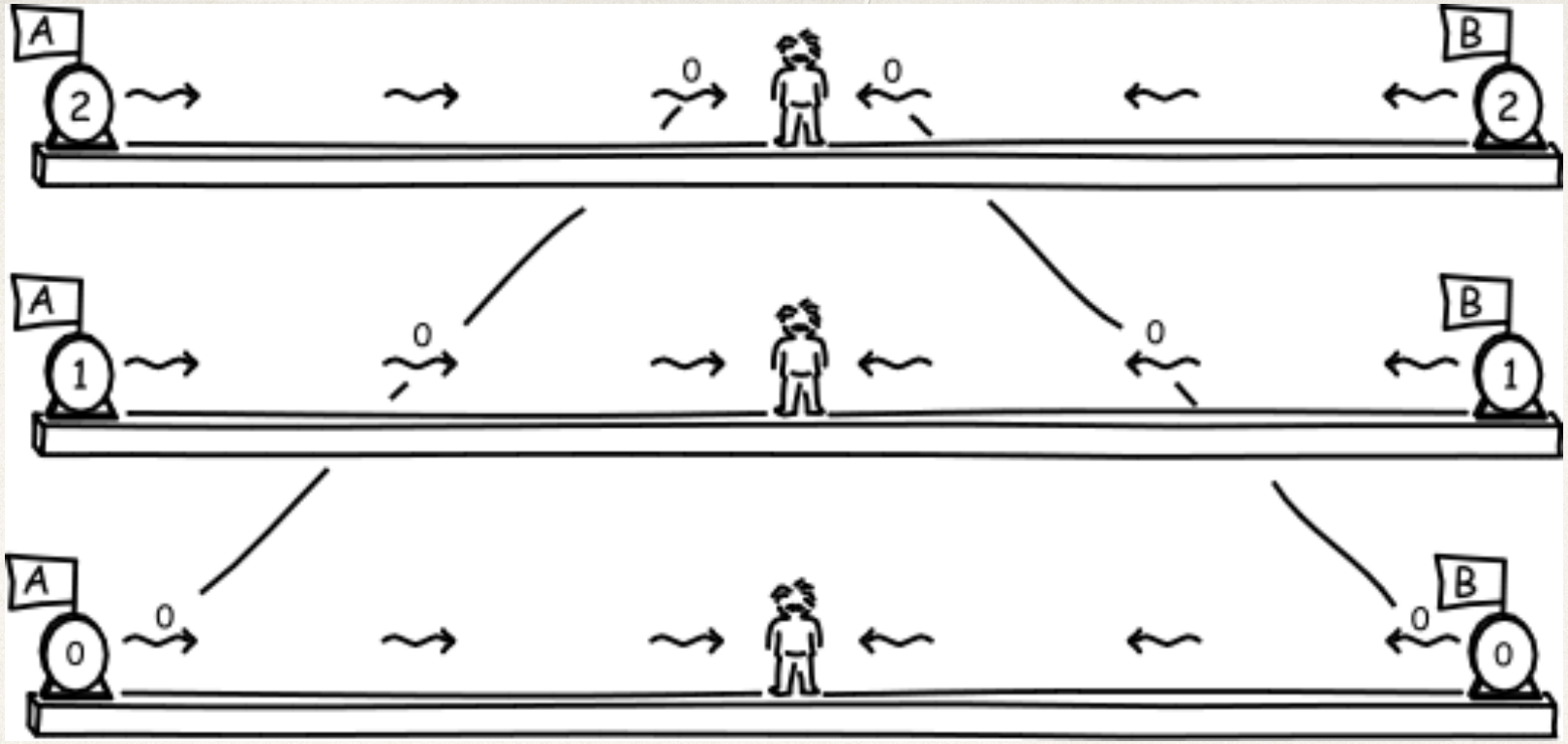
- **The flow of time.** *Why cannot we experience the past or the future? Why does time seem to flow?*
- **Duration**. *How can a time period be longer than another?*

Did Augustine offer a satisfactory account of these two aspects of our experience of time?

Let's Now Turn from the **Experience** of Time to the **Physics** of Time

Time in modern physics and the question of change will be the topics of next week

Let's Now Turn from the **Experience** of Time to the **Physics** of Time



Event **P1** = *pingpong ball leaves A when clock reports time 0 and moves left-to-right*

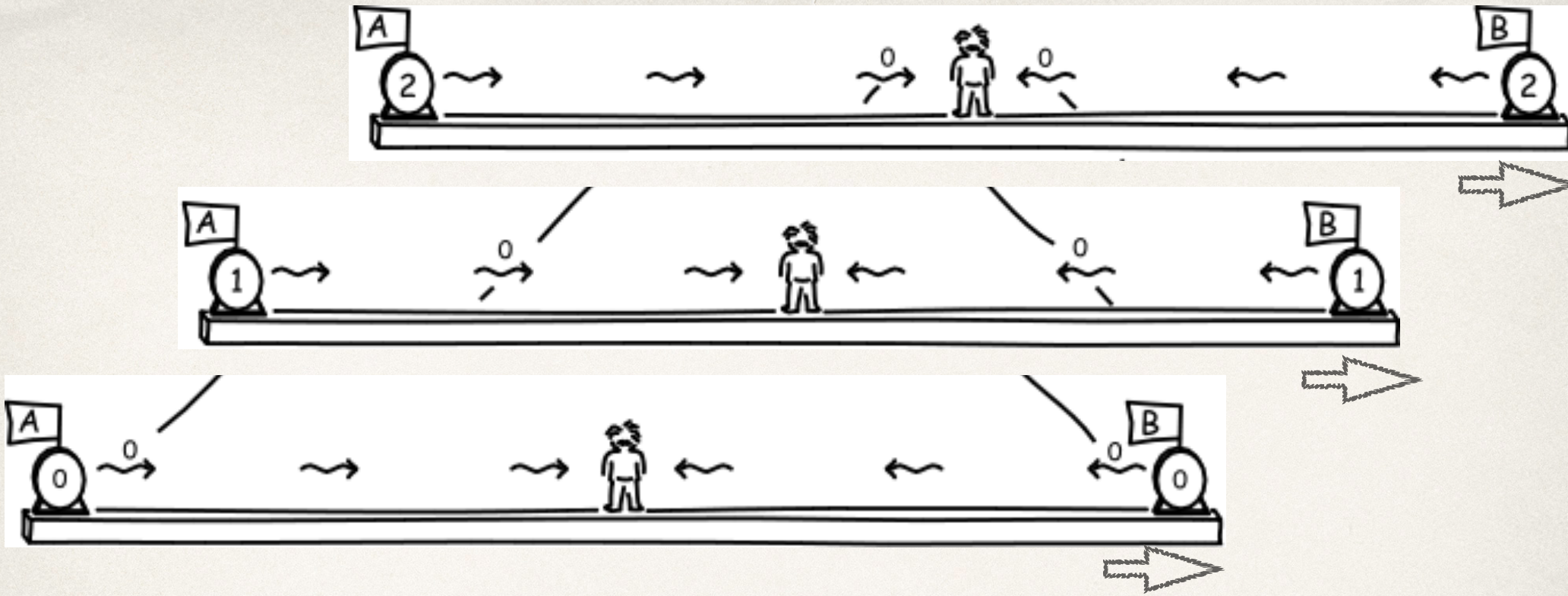
*E*vent **P2** = *pingpong ball leaves B when clock reports time 0 and moves right-to-left*

Assume **(1)** the **distance** *from A to the man-in-the-middle* and the **distance** *from B to the man-in-the-middle* are the **same**, say **2 meters**.

Assume **(2)** the *pingpong ball from A* and the *pingpong ball from B* **travel at the same speed,** say, **1 meter per second.**

It follows that **(3)** the *pingpong ball from A* and the *pingpong ball from B* will **reach** the man-in-the-middle at the same time **after 2 seconds**.

So, events **P1** and **P2** are **simultaneous** because the pingpong balls travel the same distance and reach the man-in-the-middle at the same time. The clocks at A and B are **synchronized** because they both report time 0 when **P1** and **P2** occur.



Now assume (4) that the **platform** on which the man-in-the-middle and the clocks stand is moving at **1 meter per second from left to right**. *The other assumptions are the same.*

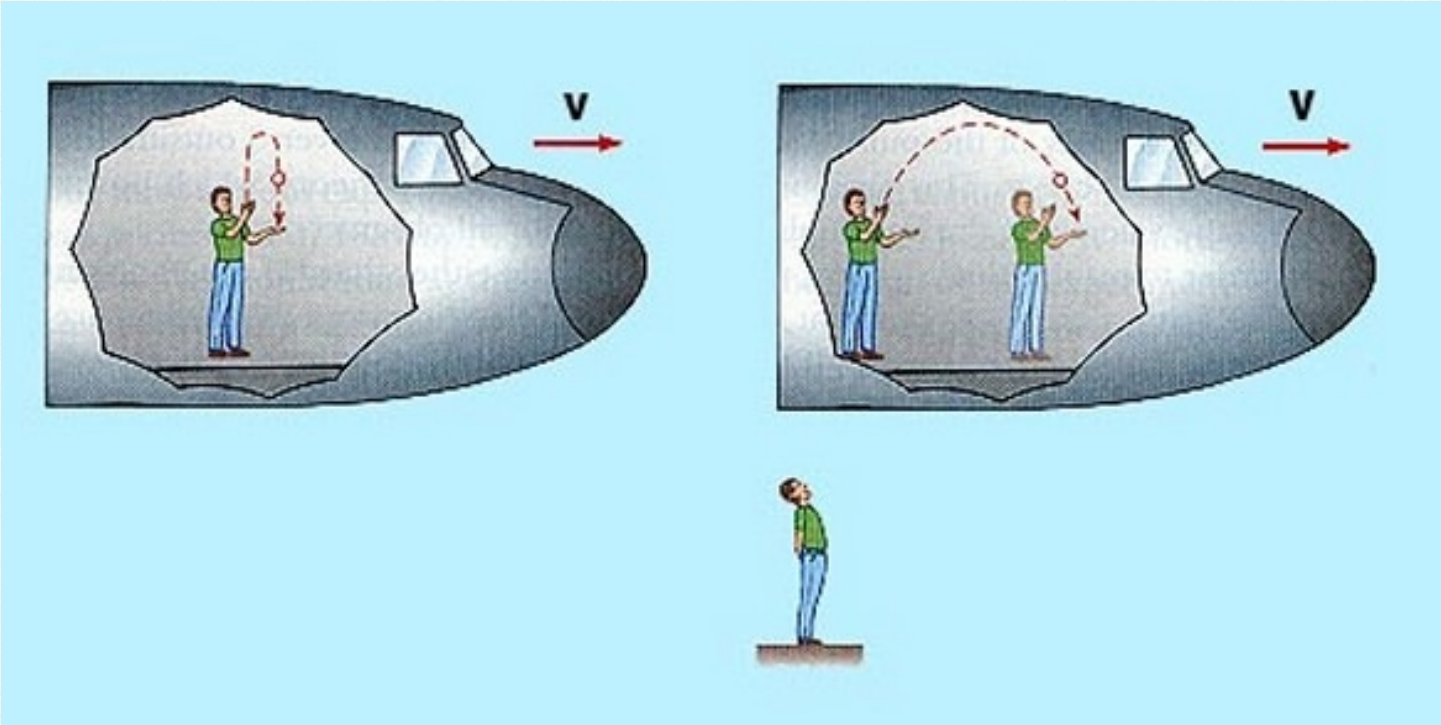
What is the speed of the pingpong ball leaving point A and moving right, from the viewpoint <u>outside</u> the moving platform?

2 m/s + 1 m/s = 3 m/s

What is the speed of the pingpong ball leaving point B and moving left, from the viewpoint <u>outside</u> the moving platform?

2 m/s - 1 m/s = 1 m/s

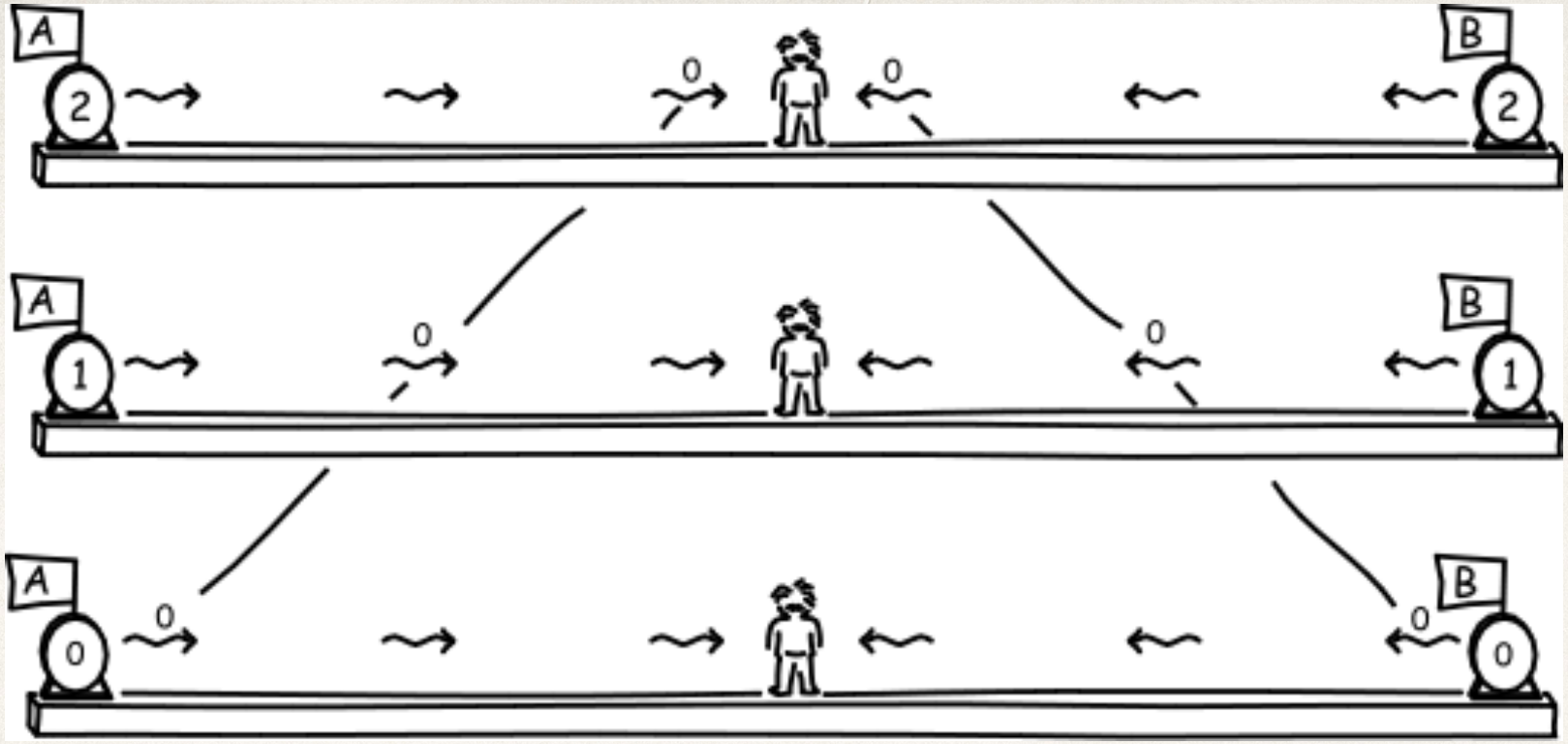
What You Have Seen is a Consequence of Galileo's and Newton's Relativity



Time flows uniformly for all observers, viewpoints, frames of reference, although velocity is relative.

Let's Now Consider a Special Case

We will now consider not a pingpong ball that travels at two meters per second, but a light signal that travels at the speed of light.



Event **L1** = *light signal leaves A when clock reports time 0 and moves left-to-right*

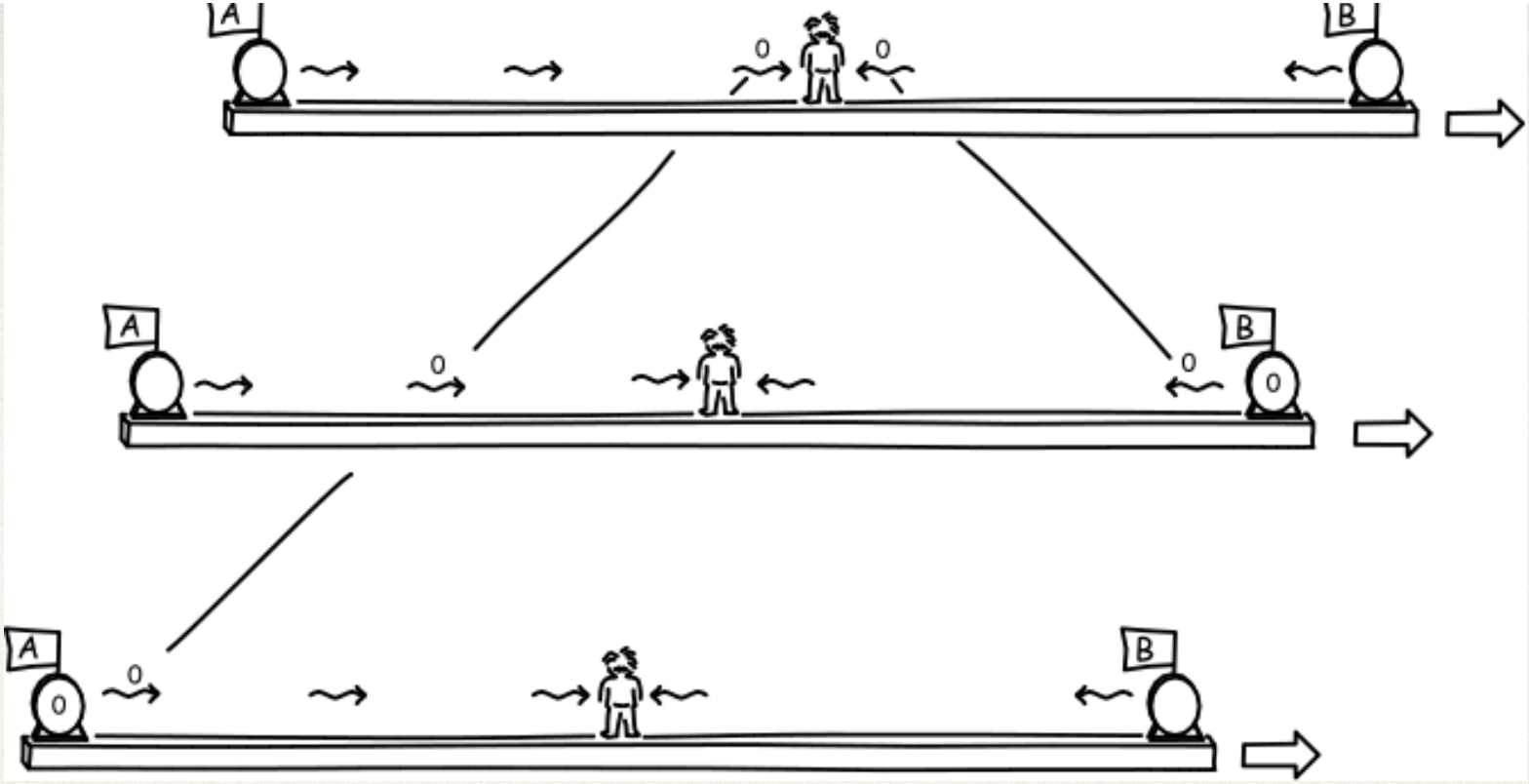
*E*vent **L2** = *light signal leaves B when clock reports time 0 and moves right-to-left*

Assume **(1)** the **distance** *from A to the man-in-the-middle* and the **distance** *from B to the man-in-the-middle* are the **same**, say **2 meters**.

Assume **(2)** the *light signal from A* and the *light signal from B* **travel at the same speed,** namely **the speed of light, call it c.**

It follows that **(3)** the *light signal from A* and the l*ight signal from B* will **reach** the man-in-the-middle at the same time.

So, events **L1** and **L2** are **simultaneous** because both light signals reach the man-in-the-middle at the same time. The clocks at A and B are **synchronized** because they both report the same time when **L1** and **L2** occur.



Now assume (4) the **platform** is moving at 1 meter per second **from left to right.** *The other assumptions are the same*.

What is the speed of the signal leaving point A and moving right, from the viewpoint <u>outside</u> the moving platform? Shouldn't it be **c + 1 m/s**?

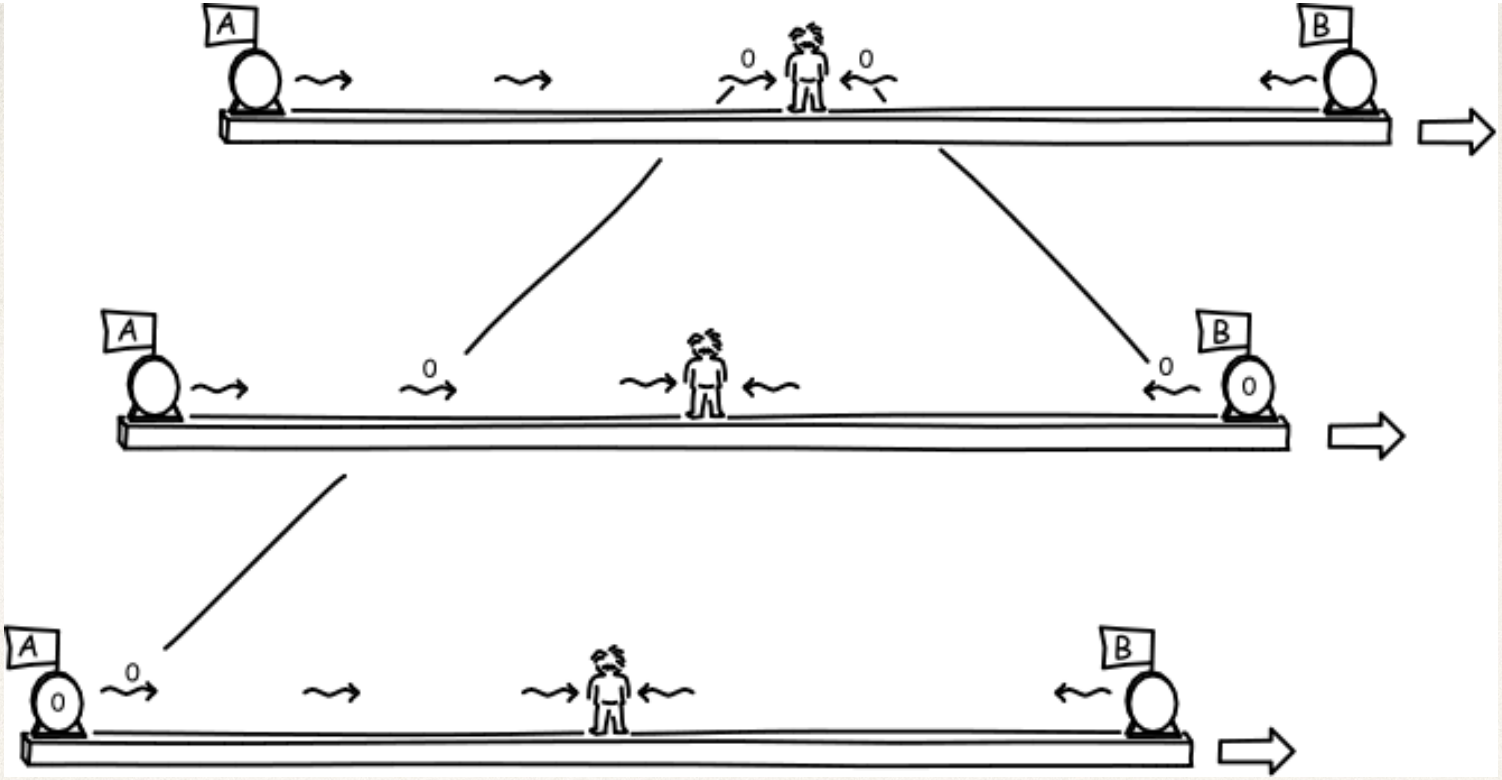
NO. *It is still* **c**.

What is the speed of the signal leaving point B and moving left, from the viewpoint <u>outside</u> the moving platform? Shouldn't it be **c - 1 m/s**?

NO. *It is still* **c**.

However Mysterious that Might Be, the Speed of Light (in a Vacuum at Least) Is **Constant Across Different Viewpoints**

In 1879 it was thought that light must propagate through a medium in space called ether. Michelson and Morley set up an experiment to detect the ether, by observing relative changes in the speed of light as the Earth changed its direction of travel relative to the sun during the year. But the two scientists failed to detect any change in the speed of light.



Again, assume (4) the **platform** is moving at 1 meter per second from left to right, (3) the signals reach the man-in-middle at the same time, and (2) the signals from A and B are moving at the speed of light, call it c.

> *From the viewpoint outside the moving platform*, the **signal from A** must cover a **greater distance** to reach the man-in-the-middle.
>
> *From the viewpoint outside the moving platform*, the **signal from B** must cover a **shorter distance** to reach the man-in-the-middle.

Now, if the speed at which both signals travel is the same, what does it follow?

The *signal from A* must leave A **before** the *signal from B* leaves B. So, events **L1** and **L2** are **no longer simultaneous** *from outside the moving platform*.

If the Two Light Signals Could Move at Different Speeds, One Signal Could Be Faster than the Other. This Would Be the Obvious Conclusion According to Galileos' and Newton's Relativity

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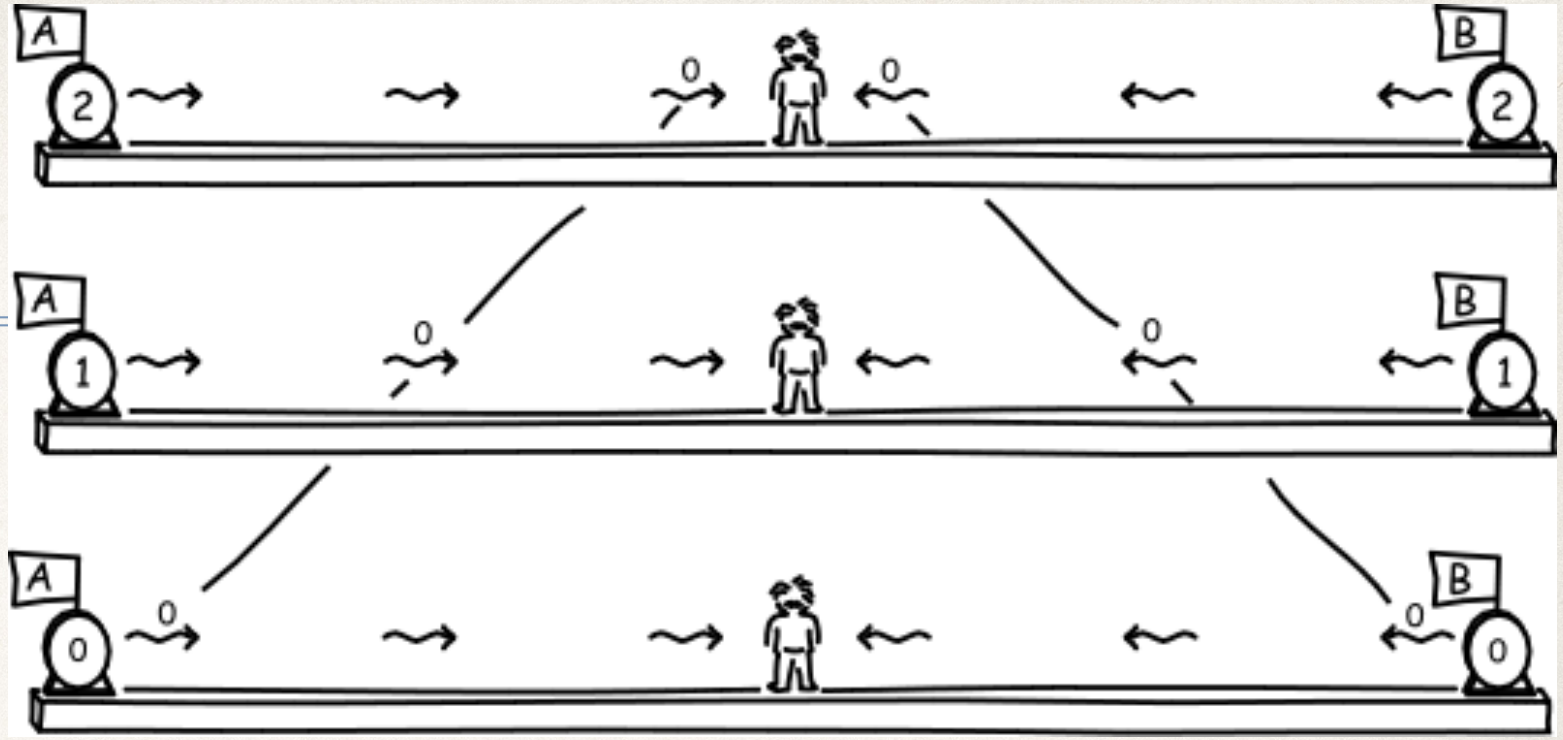
But Since the Speed of Light Is Constant Across Viewpoints, We Must Conclude that One Light Signal Left Earlier Than the Other

Just to be Clear



We considered:

Event **L1** = *light signal leaves A when clock reports time 0 and moves right*

Event **L2** = *light signal leaves B when clock reports time 0 and movies left*

We found that:

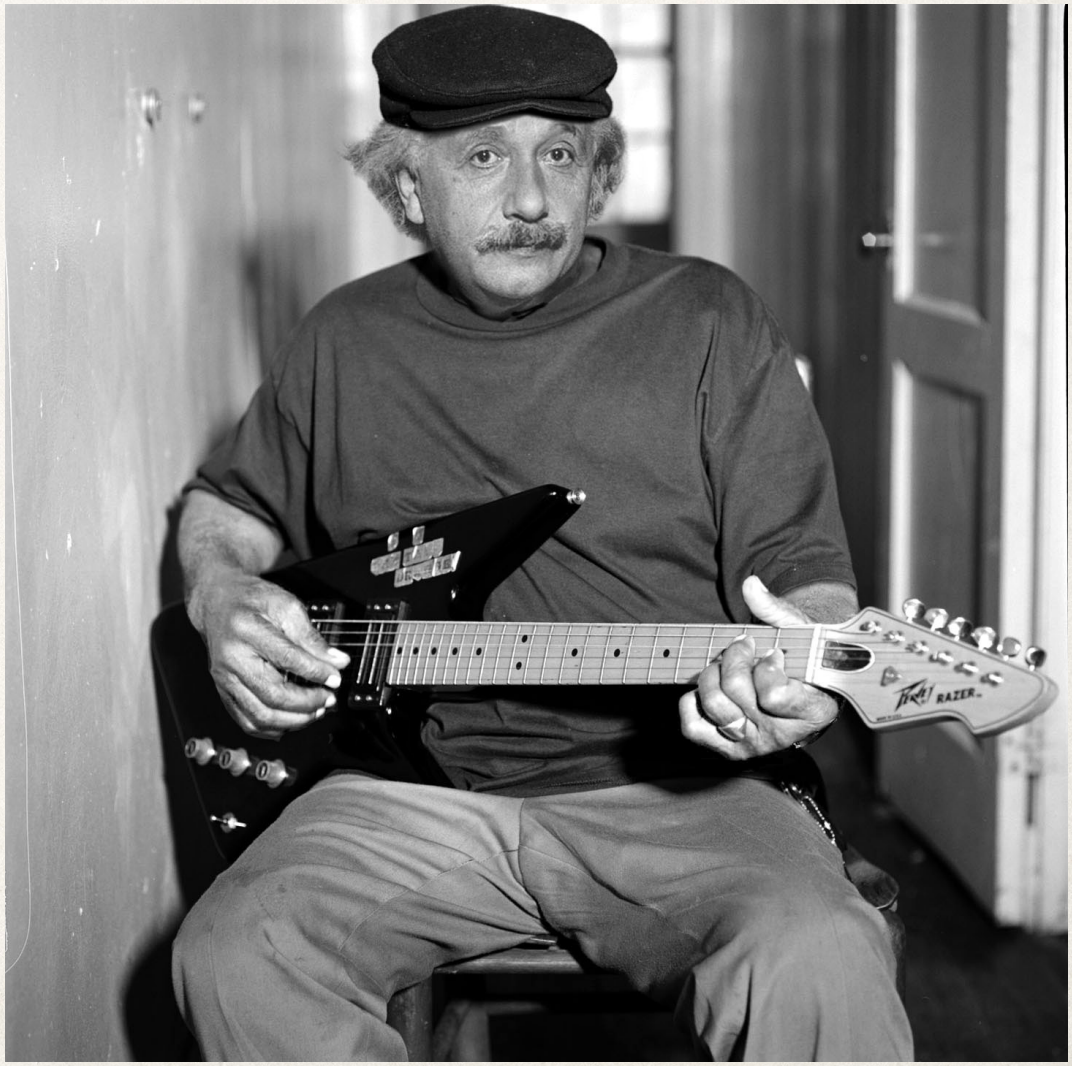
*E*vents **L1** and **L2** are **simultaneous** from the viewpoint within the platform.

*E*vents **L1** and **L2** are **not simultaneous** from the viewpoint outside the platform.

The Relativity of Simultaneity

The **simultaneity** of two events is **relative** to the viewpoint.

This is the main insight of Einstein's theory of special relativity.



What Does it Mean That Simultaneity is Relative, According to the Theory of Special Relativity?

Does it mean that depending on where an observer is located, she might perceive two events as simultaneous or as non-simultaneous?

For example, an observer who is equidistant from two explosions A and B, she'll perceive both explosions as simultaneous. Another observer, who is closer to explosion A, will perceive explosion A before explosion B.

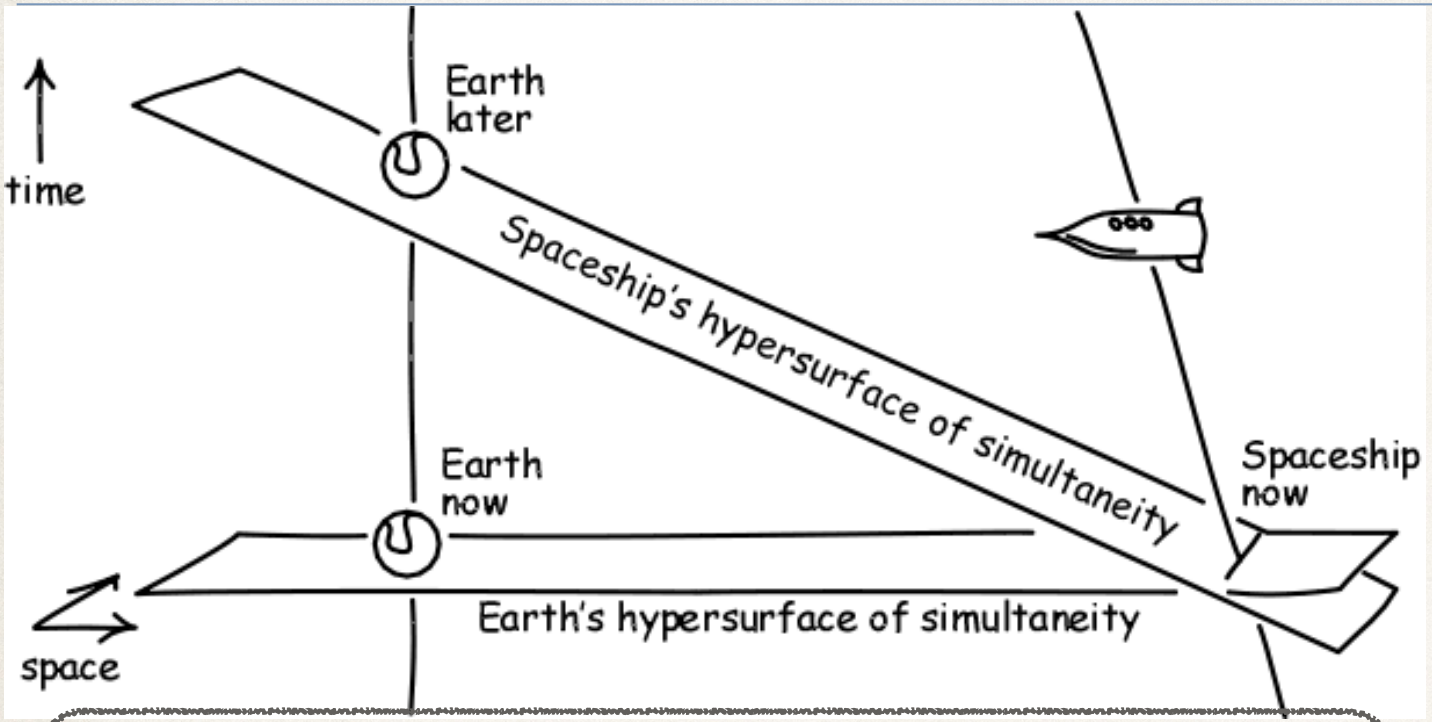
That our perceptions of time, simultaneity, shape, etc. vary depending on our viewpoint is certainly true, but ***that's not the relativity of the Theory of Special Relativity!***

If You Are Still Not Convinced That Einstein's Relativity Has to Do With Physics, and Not With the Relativity of Our Perceptions…

Twins Thought Experiment. Consider two twins. One is sent off in space and returns to the earth after few years. The other twin remains on earth. The twin who was sent off in space will have aged much less.

The *Twins Thought Experiment* has been confirmed by atomic clocks. Consider two atomic clocks that have been perfectly synchronized. One cloak is sent off in space and the other remains on earth. The clock in space is slower than the clock on earth.

(1) What Does the Relativity of Simultaneity Tell us About Time?



An event that belongs to the future **from the Earth viewpoint** is instead part of the present from the Spaceship Viewpoint.

A conclusion we can drawn here is that *the present is relative, not absolute*. There is not one present, but possibly many "presents".

(2) What Does the Relativity of Simultaneity Tell us About Time?

If, as Special Relativity suggests, there is not one present, but possibly many "presents", we can think of time **not** as a **uniform flow** but rather as a **block** in which all time instants coexist.

Erasing The Flow of Time

Alice was hoping for a white Christmas, but when the day came she was disappointed that it only rained; however, she was happy that it snowed the following day.

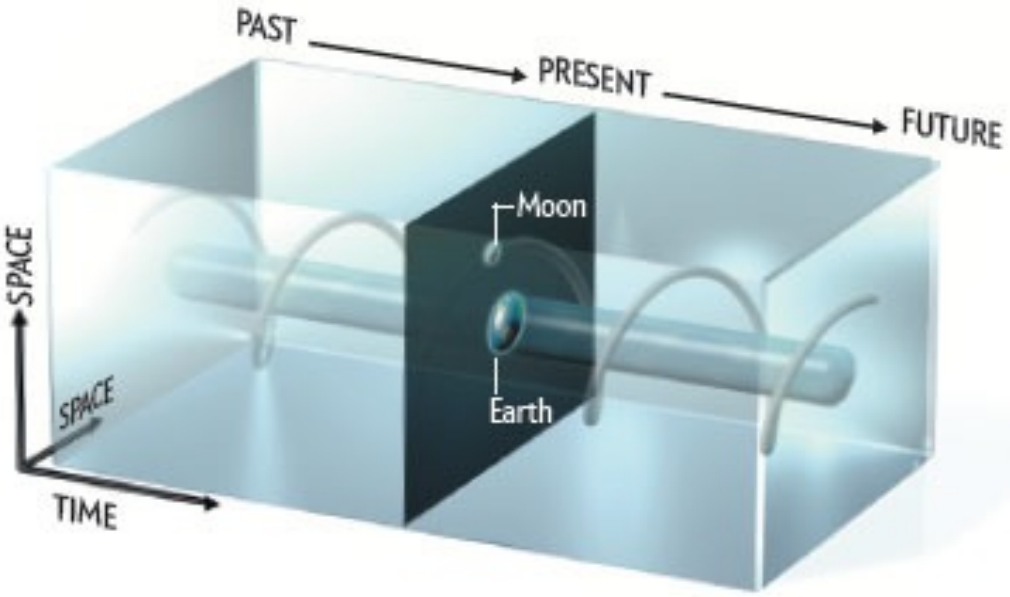
December 24: Alice hopes for a white Christmas.

December 25: There is rain. Alice is disappointed.

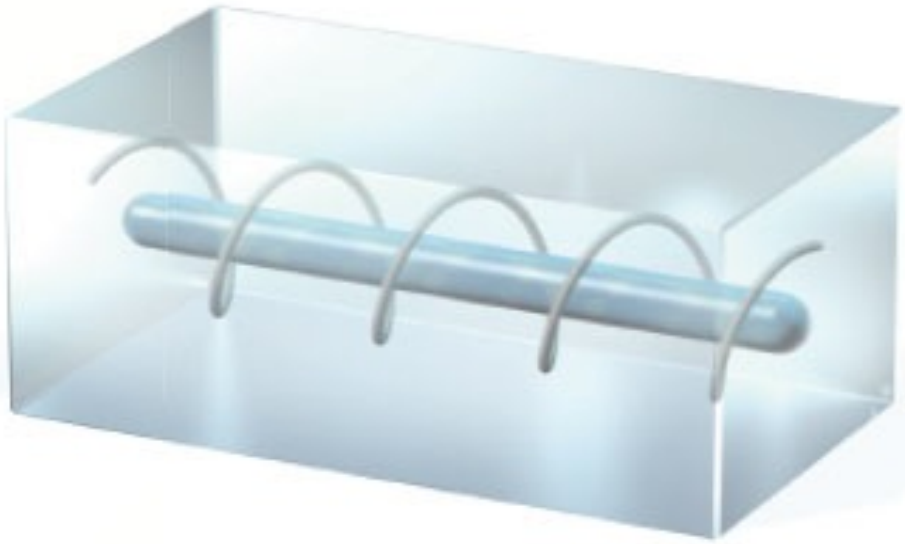
December 26: There is snow. Alice is happy.

In the second description the flow of time has been eliminated. Every event is described in the present tense and is assigned a date. There is no flow of time.

Time as Flow *versus* Time as Block



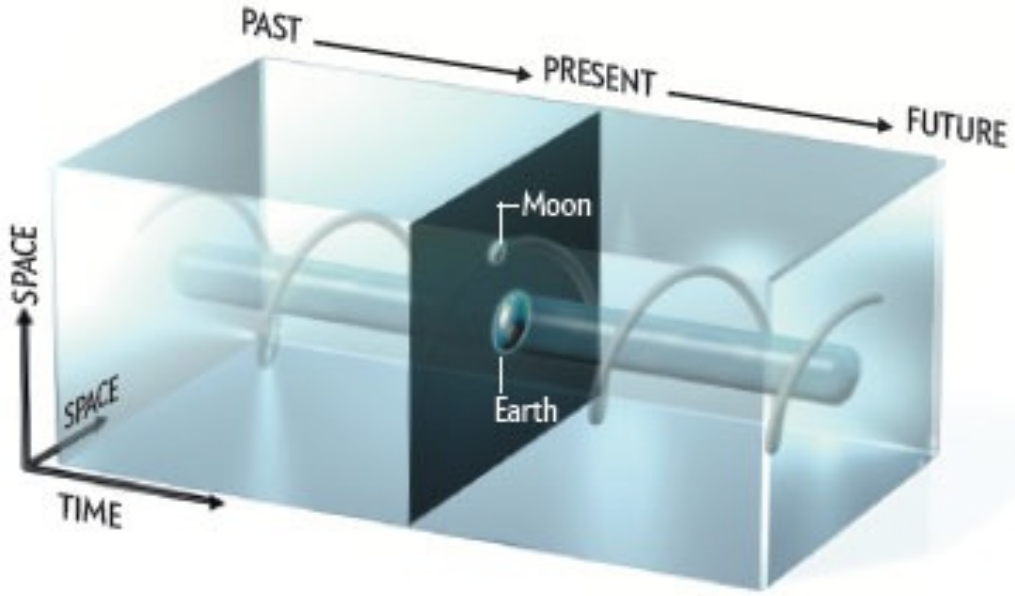
Conventional view: Only the present is real



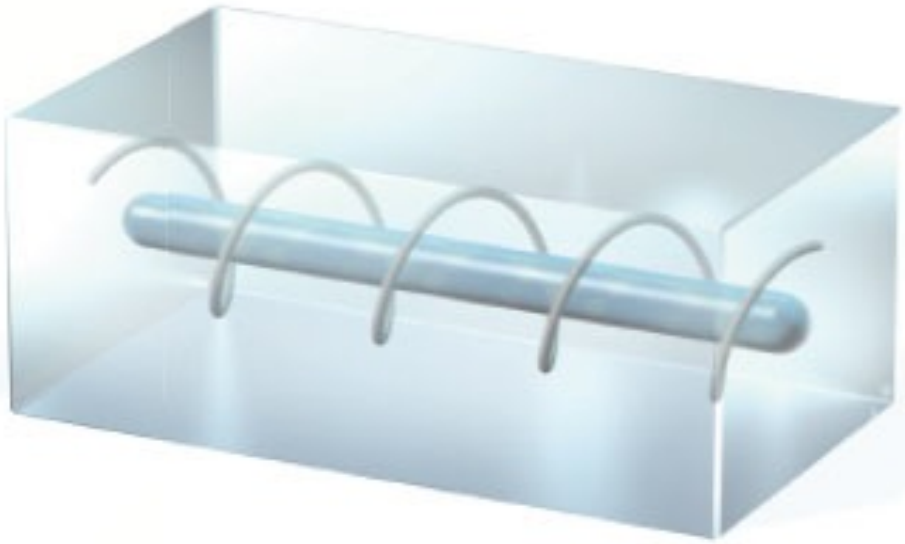
Block universe: All times are equally real

Which View of Time is Correct?

The Two Views Are Complementary



Conventional view: Only the present is real



Block universe: All times are equally real

Time-as-a-flow better aligns with our psychological experience of time.

Time-as-a-block better aligns with physics and Special Relativity.

***Question**: How does the psychological experience of **time as flow** arise from the physics of **time as a block**?*

From “Time” to “Change”

Parmenides' Thesis: Change is Impossible

Imagine a new building is made. *Looks like a change just happened because a new building came into being!*

Parmenides thinks change is impossible.

If the building did not exist earlier, but it exists now, between "now" and "earlier" the building must have come from nothing.

But nothing can come from nothing. So the building cannot have come into being.

Is Parmenides Right?

Objection: *The building did not really come out of nothing!* Most of the building already existed, for example, the materials and the architect's plan existed before.

Reply on behalf of Parmenides: Most of the building already existed, yes, but not all of it. *Something* of the building did not exist. Although the materials already existed, **the arrangement of the materials in a particular way did not exist before**. *So, the arrangement of the materials must have come out of nothing, but nothing can come from nothing.*

Is Parmenides Right? (Continued)

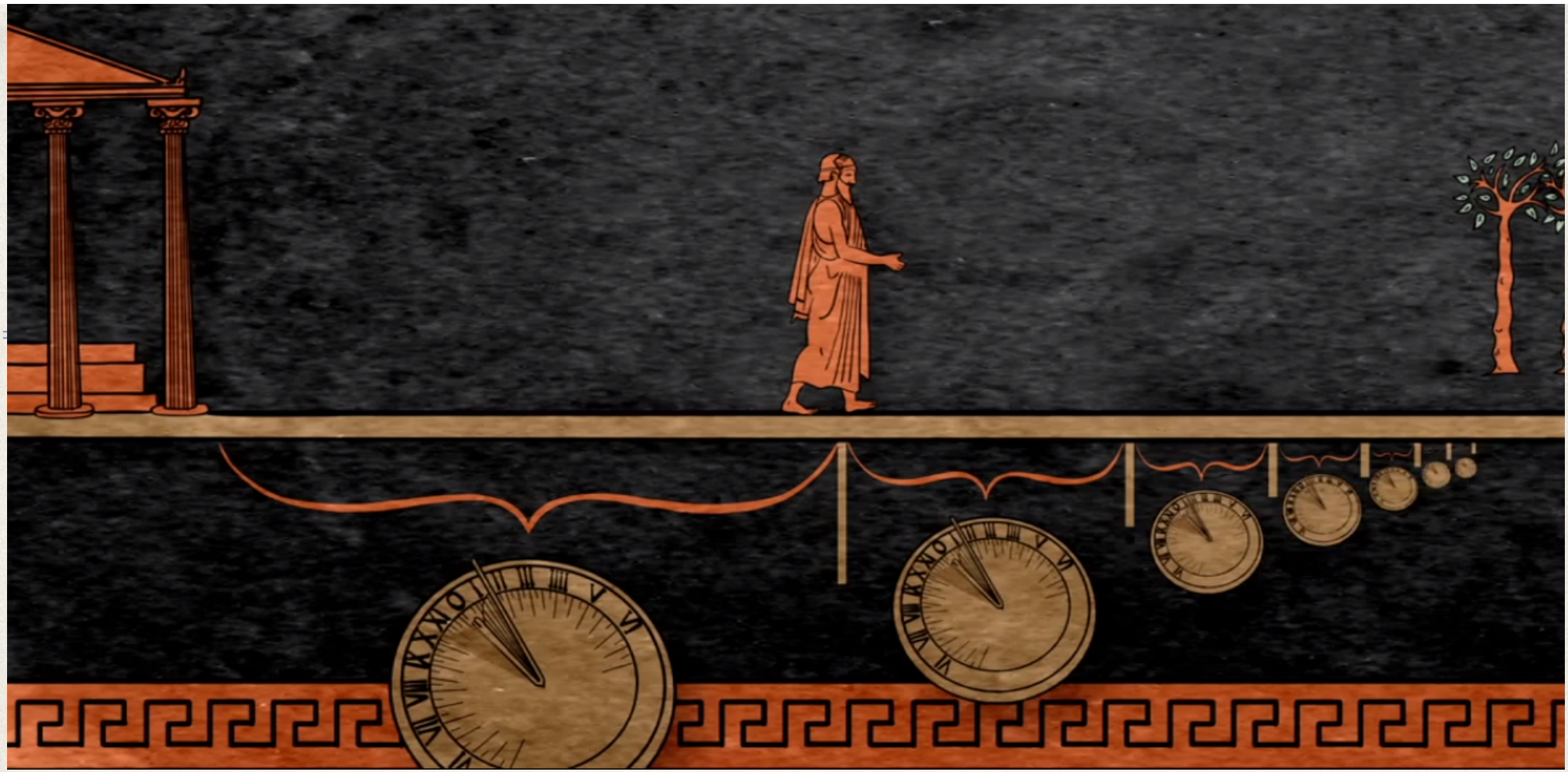
Objection: The arrangement of the building materials doesn't really come out of nothing. The arrangement itself is not a thing, but a relation of things.

Reply on behalf of Parmenides: Sure, the arrangement of the building materials is a relation of things. But **either** this relation always existed and therefore the building always existed, **or** the relation came into being at some point, and if it did, it must have come from nothing. But the latter is impossible, so the building always existed.

Zeno's Paradoxes of Motion

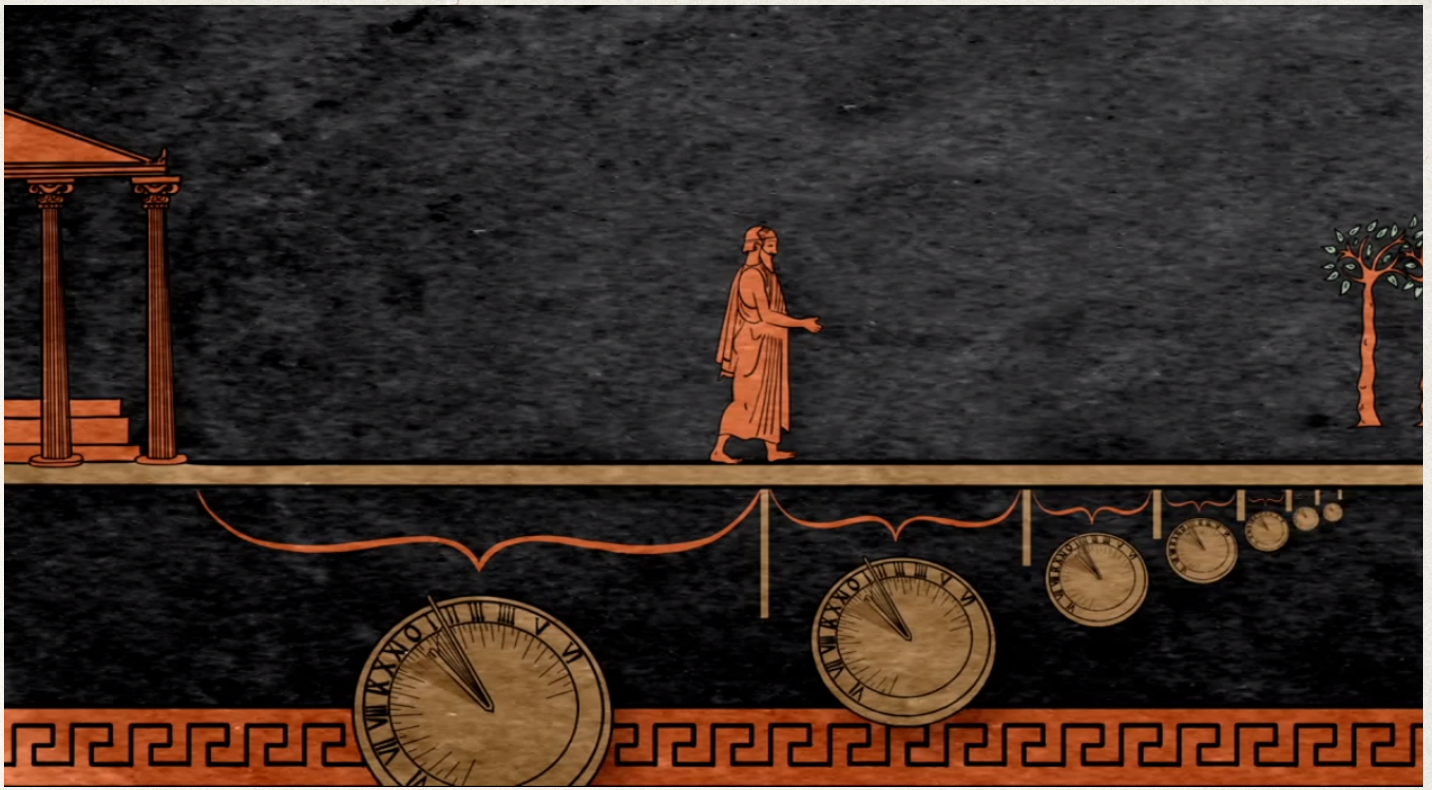
Zeno's Paradox of Dichotomy

there is no motion because that which is moving must reach the midpoint before the end. . . . It is always necessary to traverse half the distance, but these are infinite, and it is impossible to get through things that are infinite. ...



If you want to cover a *finite distance* in a *finite time*, you first have to cover **half of the distance.** Next, you have to cover **half of half of the distance**. Next, you have to cover **half of half of half of the distance**. And so on. You'll have to cover an infinite number of space intervals. *But covering an infinite number of space intervals in a finite time is impossible*. So, movement is impossible.

A Mathematician's Response



Consider the infinite series

$$1/2 + 1/4 + 1/8 + 1/16 + 1/32 + \ldots = 1$$

The series converges to 1. So, there is no paradox. It is possible that a finite space interval be the result of adding an infinite number of space intervals, such as **1/2 + 1/4 + 1/8 …**

The Mathematician's Response Misses the Point of Zeno's Dichotomy

Consider the infinite series

1/2 + 1/4 + 1/8 + 1/16 + 1/32 + … = 1

The mathematician is telling that adding an infinite number of items can still give us a finite quantity.

But the problem in Zeno's Dichotomy is not whether adding an infinite number of items gives us a finite quantity. The problem is whether we can go through an infinite number of space intervals in a finite time. That's impossible, just as it is impossible to perform an infinite sequence of tasks in a finite time.

Parmenides and Zeno's Arguments Lead to Conclusions That Seem Absurd Because They Contradict Experience

Zeno's Dichotomy Is a Paradox

A **paradox** is a piece of reasoning whose steps are all plausible, but whose conclusion is clearly absurd.

If you want to cover a *finite distance* in a *finite time*, you first have to cover **half of the distance.** Next, you have to cover **half of half of the distance**. Etc. You'll have to cover an infinite number of space intervals. *But covering an infinite number of space intervals in a finite time is impossible*. So, movement is impossible.

In order to reject Zenos' absurd conclusion, we need to reject one of the steps in Zeno's reasoning. But the problem is, which step in Zeno's reasoning is wrong?

Rational Arguments v. Experience

A **rational argument** tells us that change does not exist, that it is impossible, and that it is an illusion.

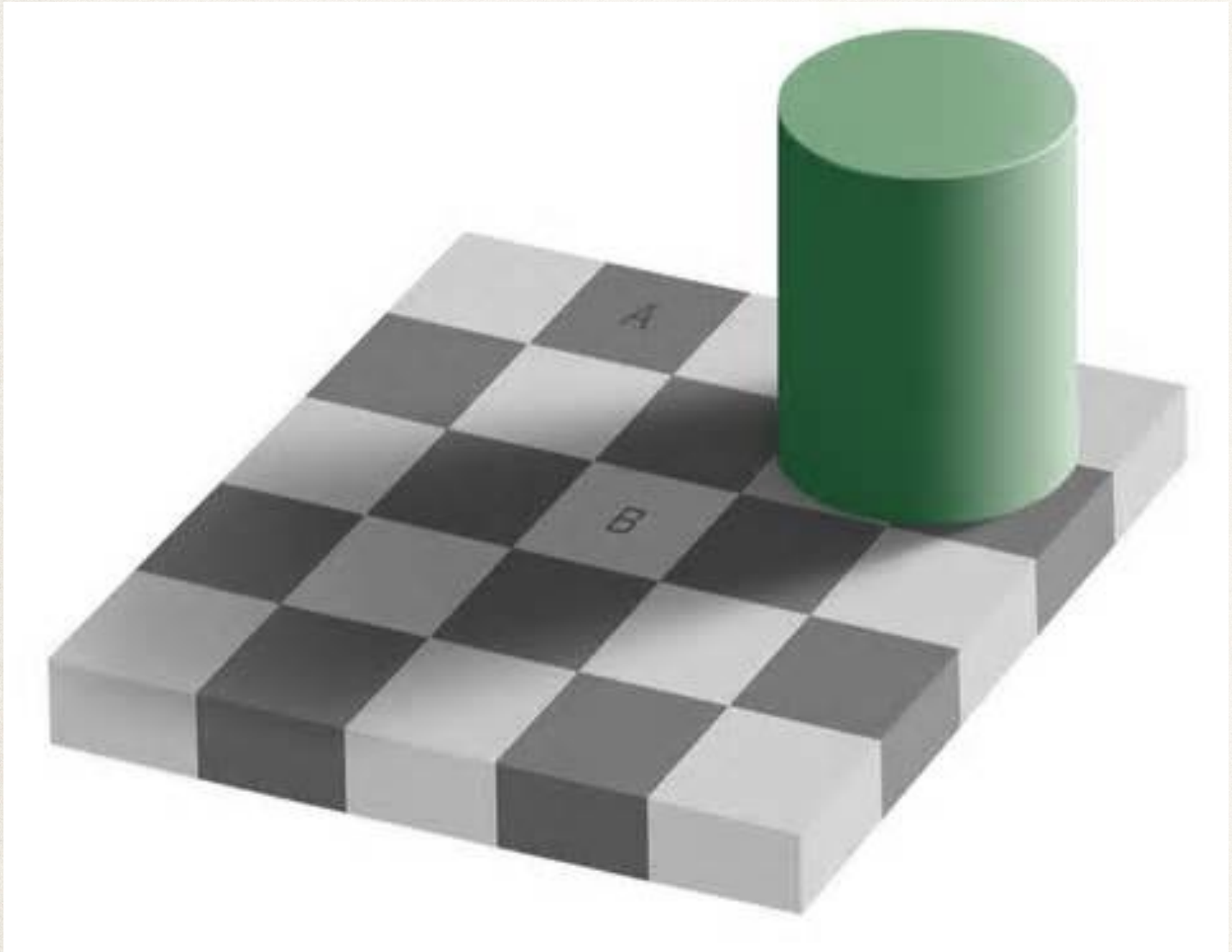
Experience tells us that change and transformation obviously exist.

Should we trust more our experience or a rational argument?

Both Rational Arguments and Experience Are Important

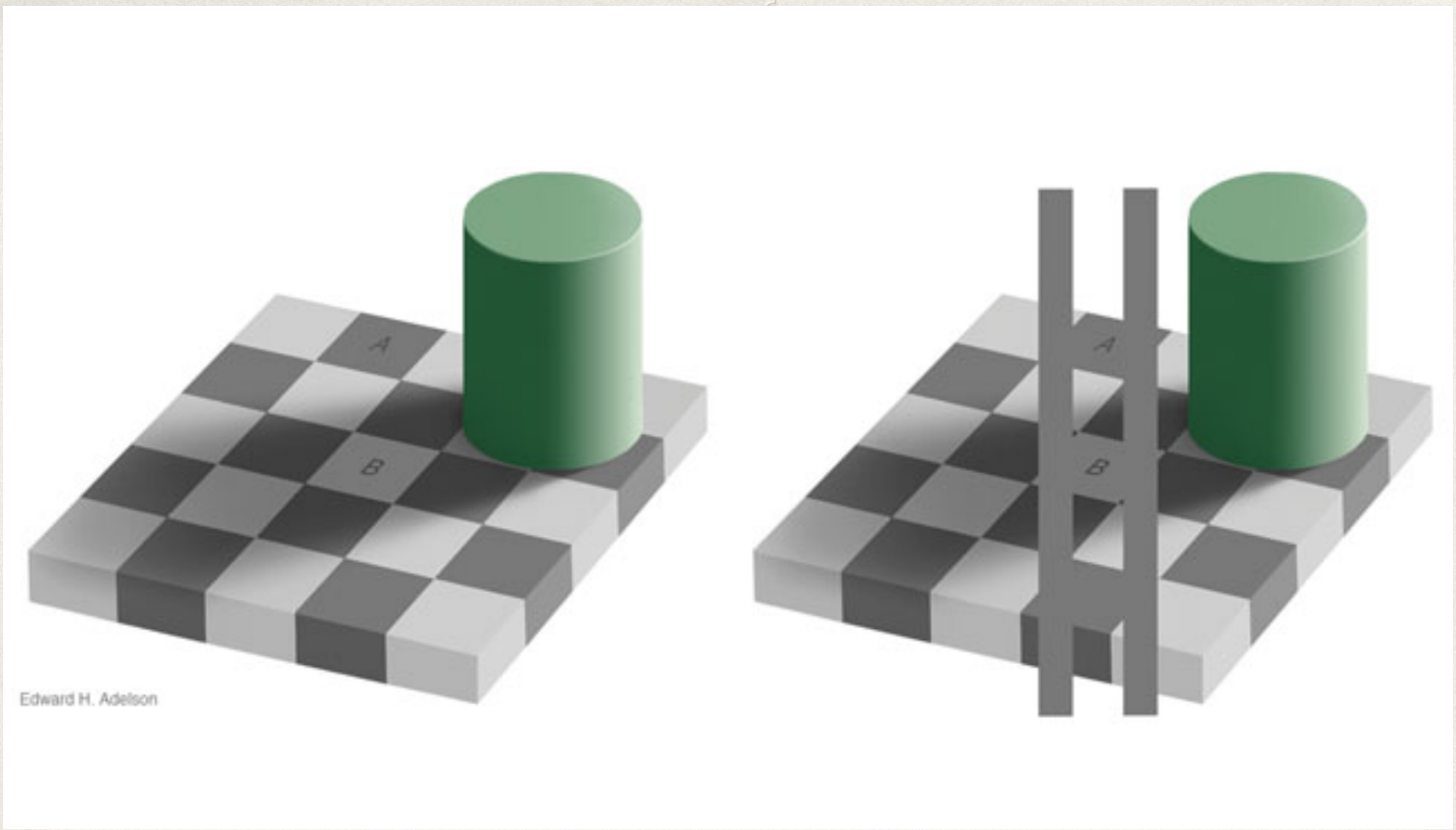
The challenge is to reconcile the two. This is the challenge that Parmenides and Zeno pose to you.

We Cannot Rely on Experience Alone



The A-square **seems darker** than the B-square. But is it **actually darker**?

Maybe not.



In fact the A-square and B-square are of the same color.

Couldn't our experiences of
change and the flow of time be as illusionary
as our experiences of colors?

We Should Rely on Both Experience and Reasoning to Understand the World and Ourselves

Different Ways to Understand The World and Ourselves

Personal experience	Rational arguments and abstract reasoning	Scientific observations, experiments and data collection	Religious faith and personal beliefs

We can assign different degrees of importance to each way of understanding. How we should combine them is itself a philosophical question.