Relativity — Lecture 2

- Summary of Lecture 1
- The Michelson-Morley Experiment
- Postulates of Special Relativity
- Simultaneity

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Lecture 1

Revision

What is Relativity?

Definition — Relativity:
Relativity is a theory describing the relation between observations (measurements) of the *same* process by *different* observers in motion *relative* to each other.

Special Relativity refers to the special case of *inertial* observers.

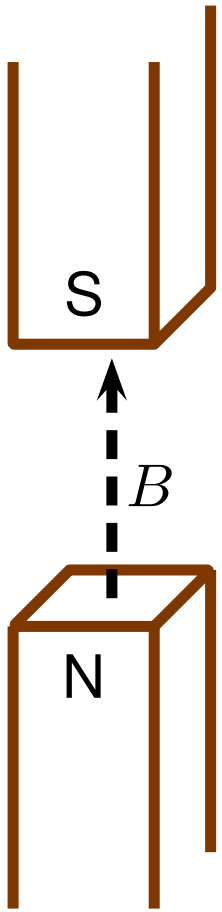
General Relativity refers to the general case of *accelerated* observers and provides a theory of gravity.

Galilean Relativity

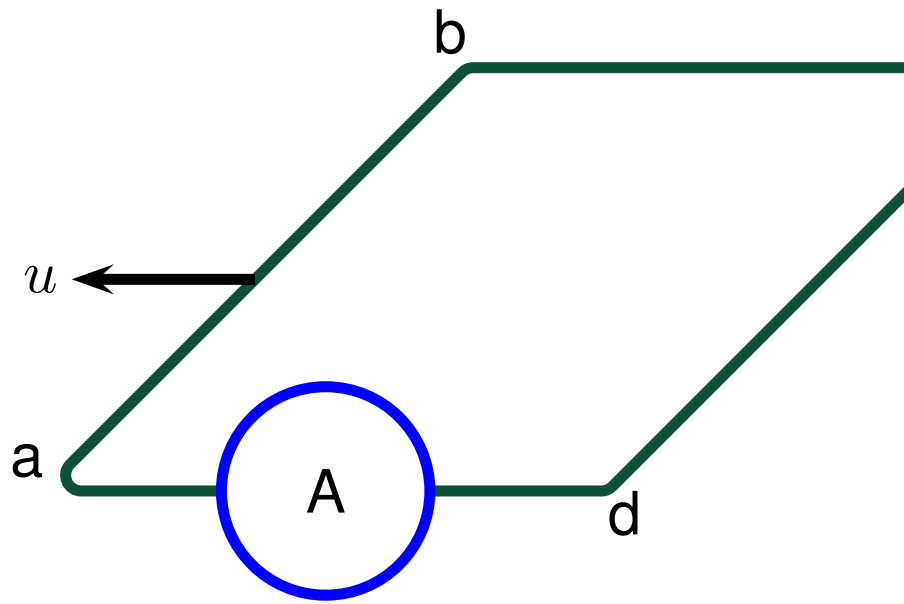
Definition — Inertial frame:
A reference frame in which the first Newton law holds. An isolated body maintains a uniform velocity relative to any inertial frame.

Galileo's relativity :
The laws of Mechanics are the same in all inertial frames.

A Moving Coil

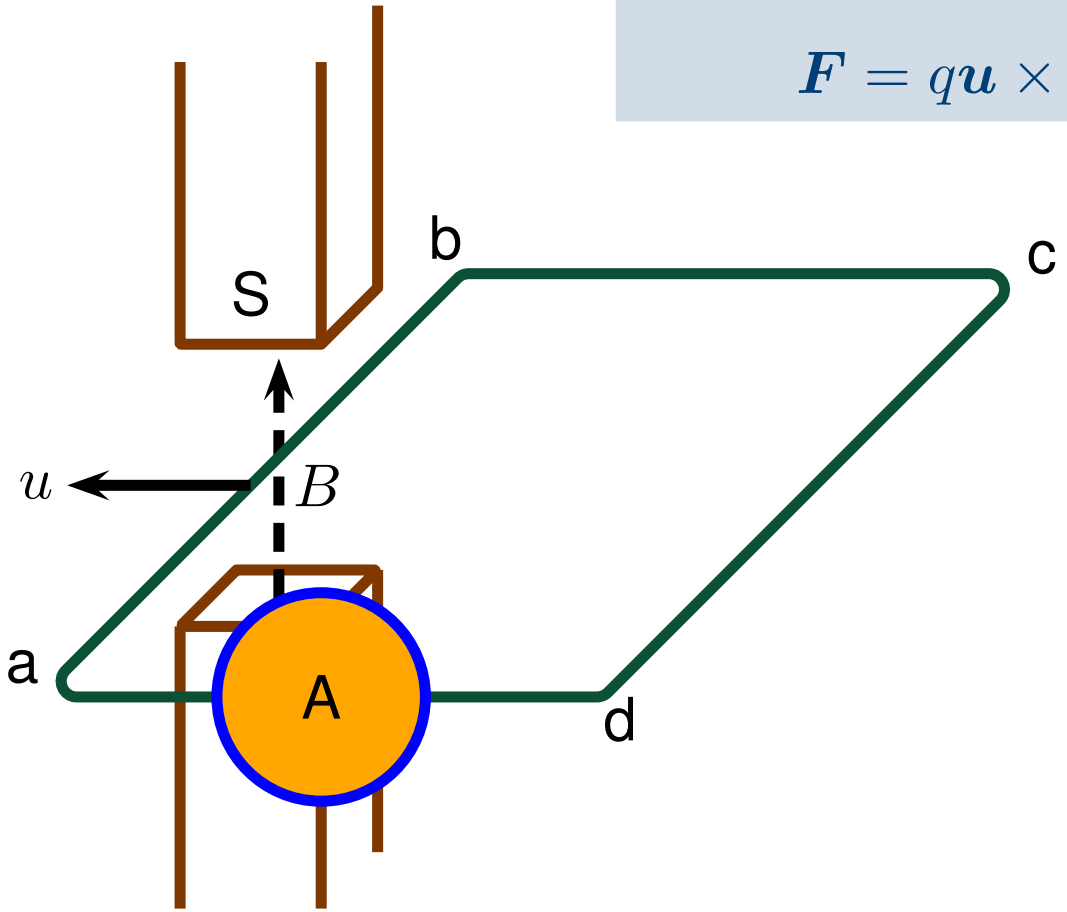


A coil moves at speed u towards a magnet.



A Moving Coil

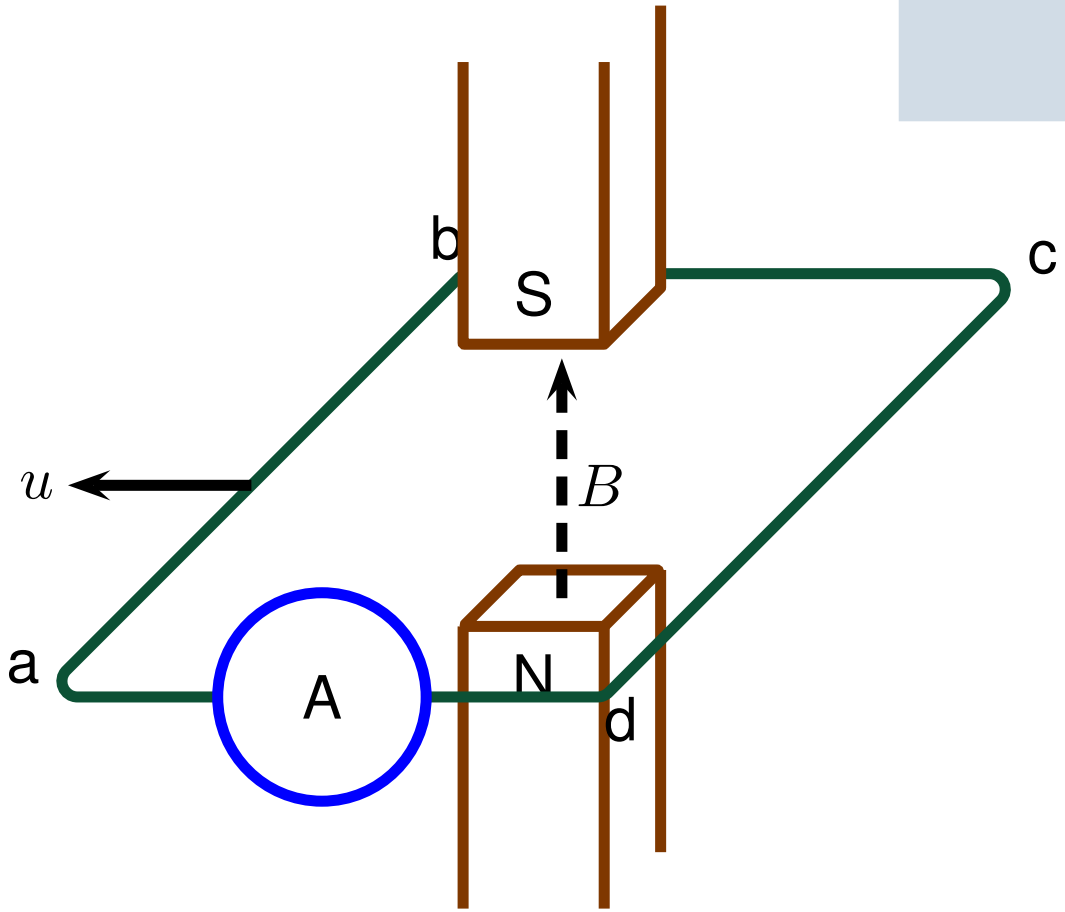
$$\boldsymbol{F} = q\boldsymbol{u} \times \boldsymbol{B}$$



Charges in ab in B field $\rightarrow$ F $\rightarrow$ Current

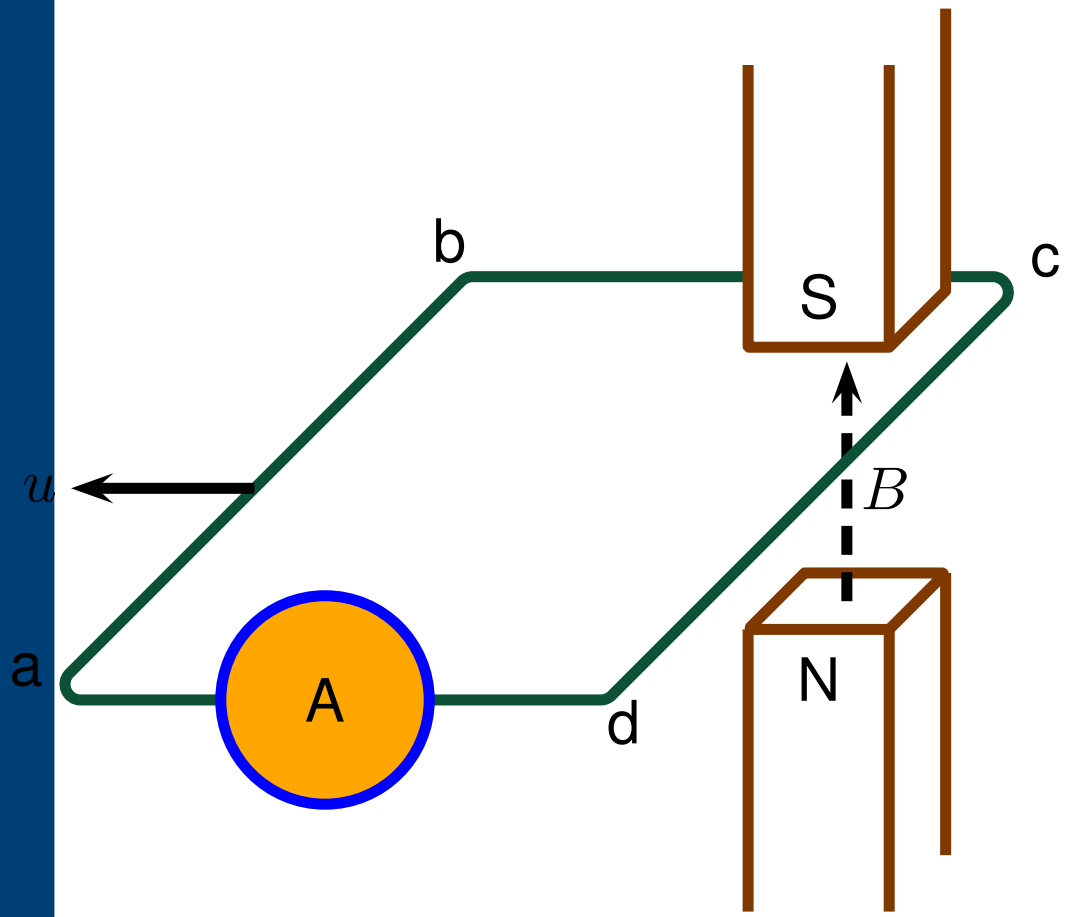
A Moving Coil

$$\boldsymbol{F} = q\boldsymbol{u} \times \boldsymbol{B}$$



No charges in B field $\rightarrow$ No current

A Moving Coil



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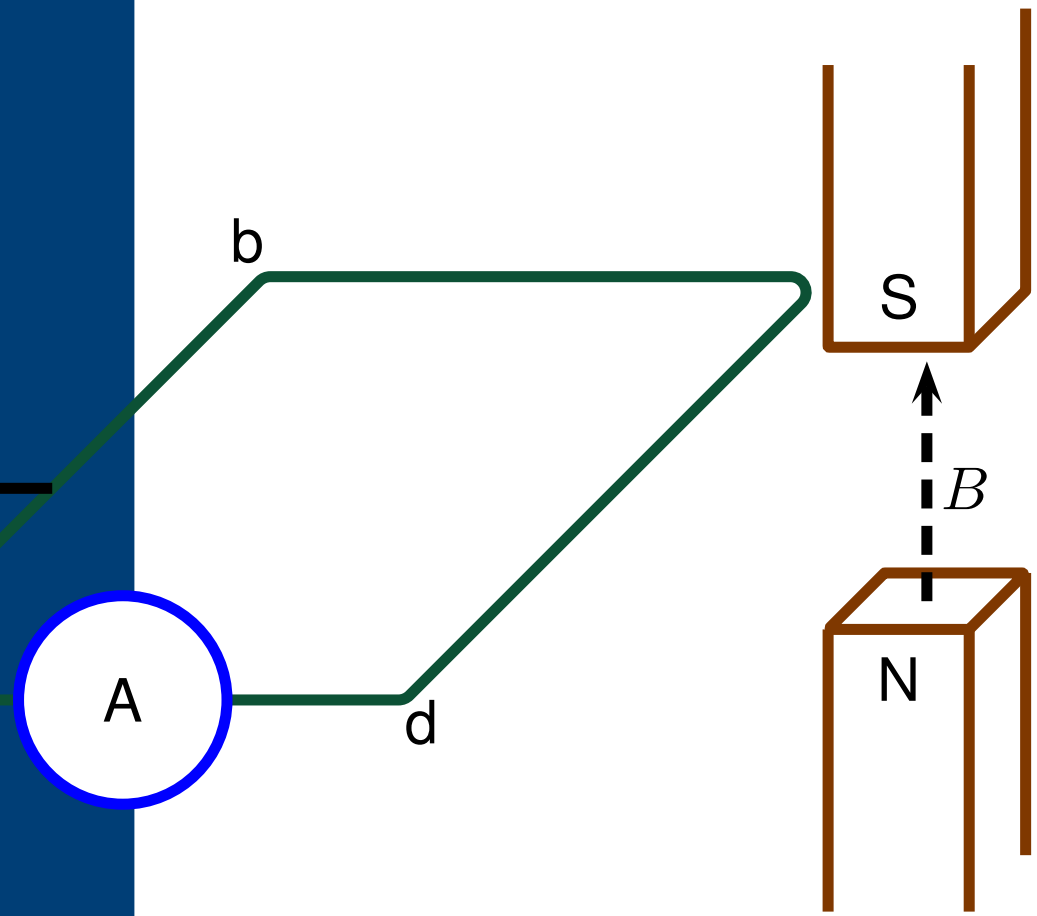
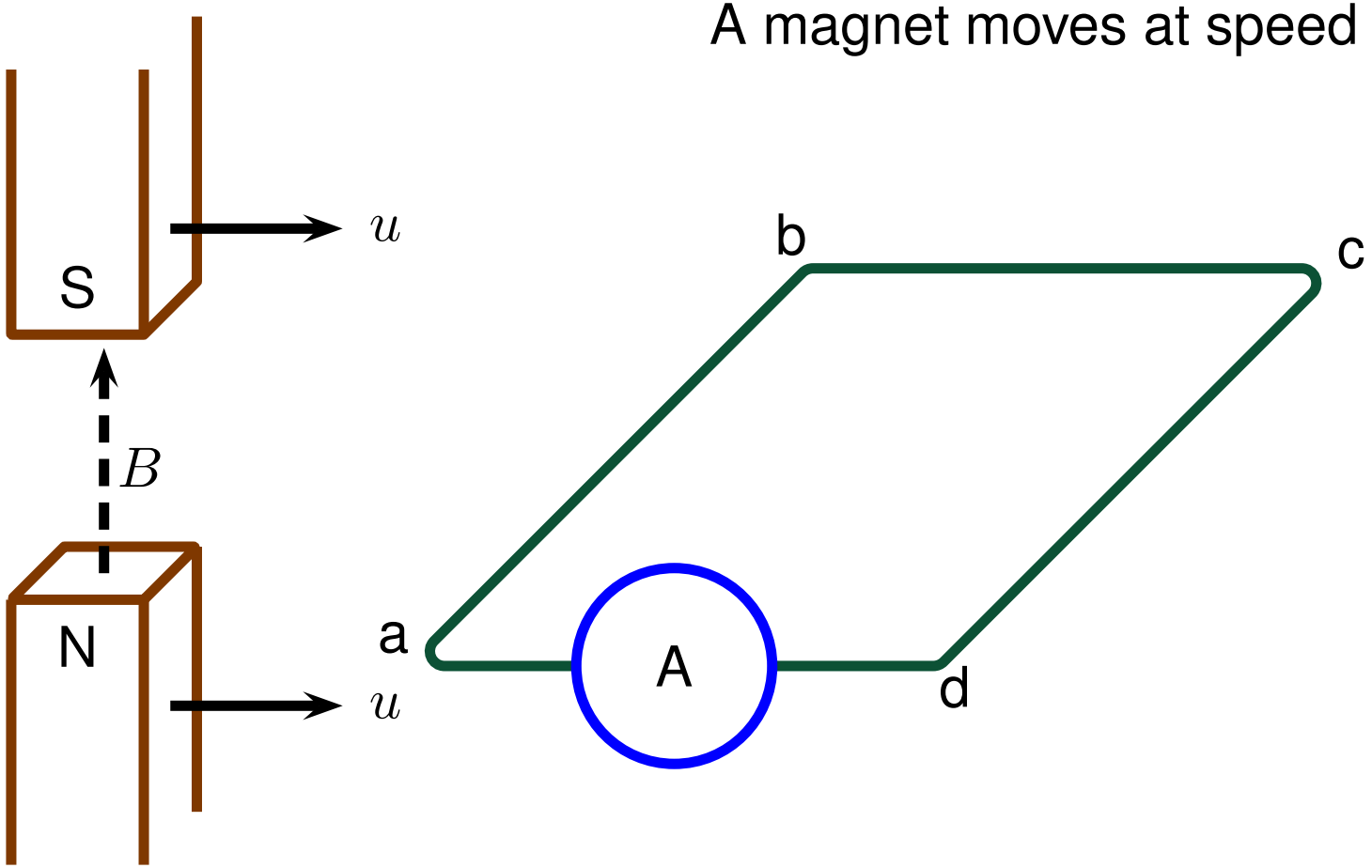


Charges out of B field $\rightarrow$ No current

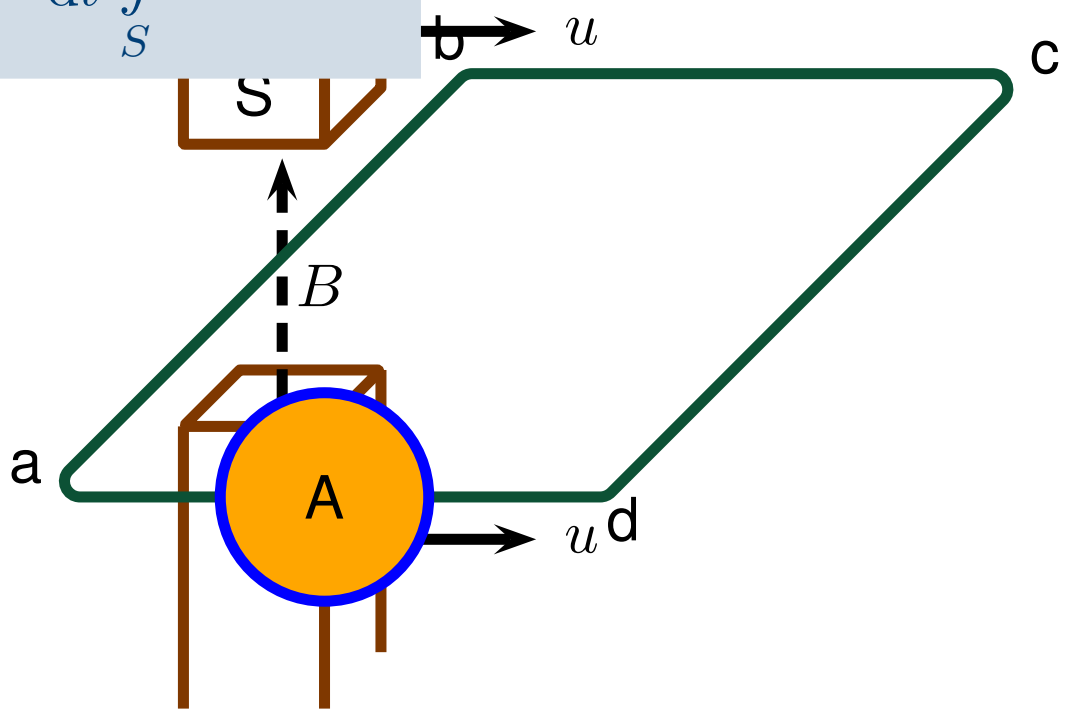
A Moving Magnet

A magnet moves at speed u towards a coil.



A Moving Magnet

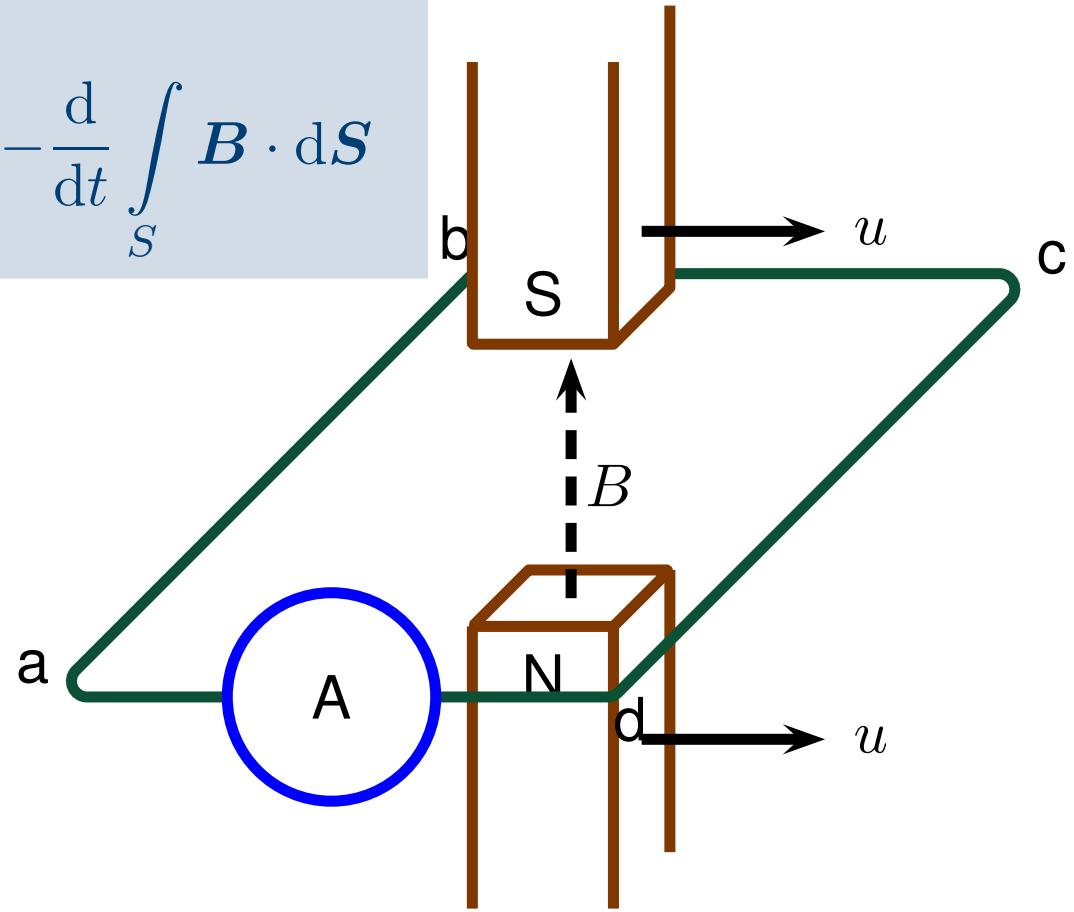
$$\int_C \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \int_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$



Increase of B flux $\rightarrow$ E $\rightarrow$ Current

A Moving Magnet

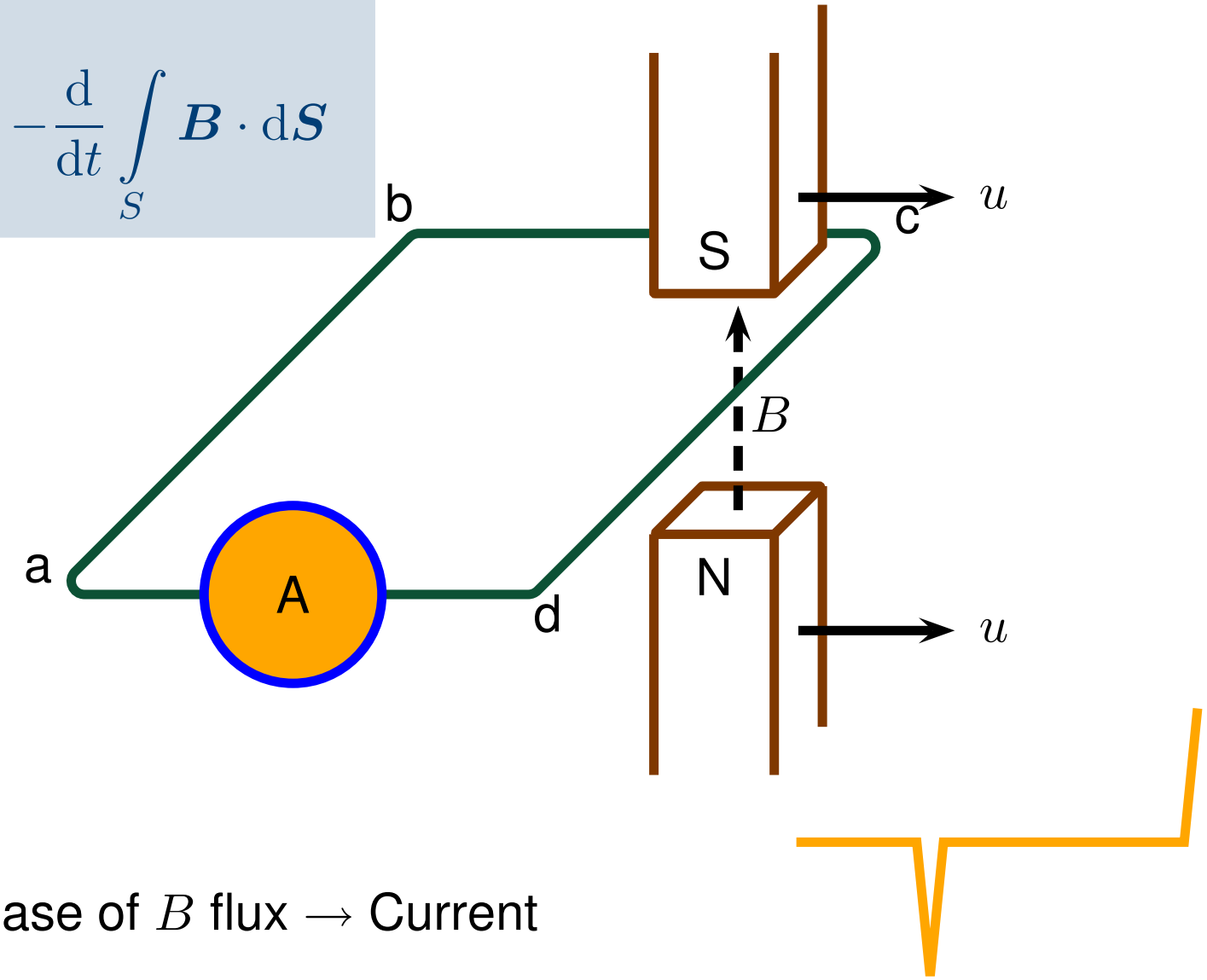
$$\int_C \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \int_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$



Constant B flux $\rightarrow$ no current

A Moving Magnet

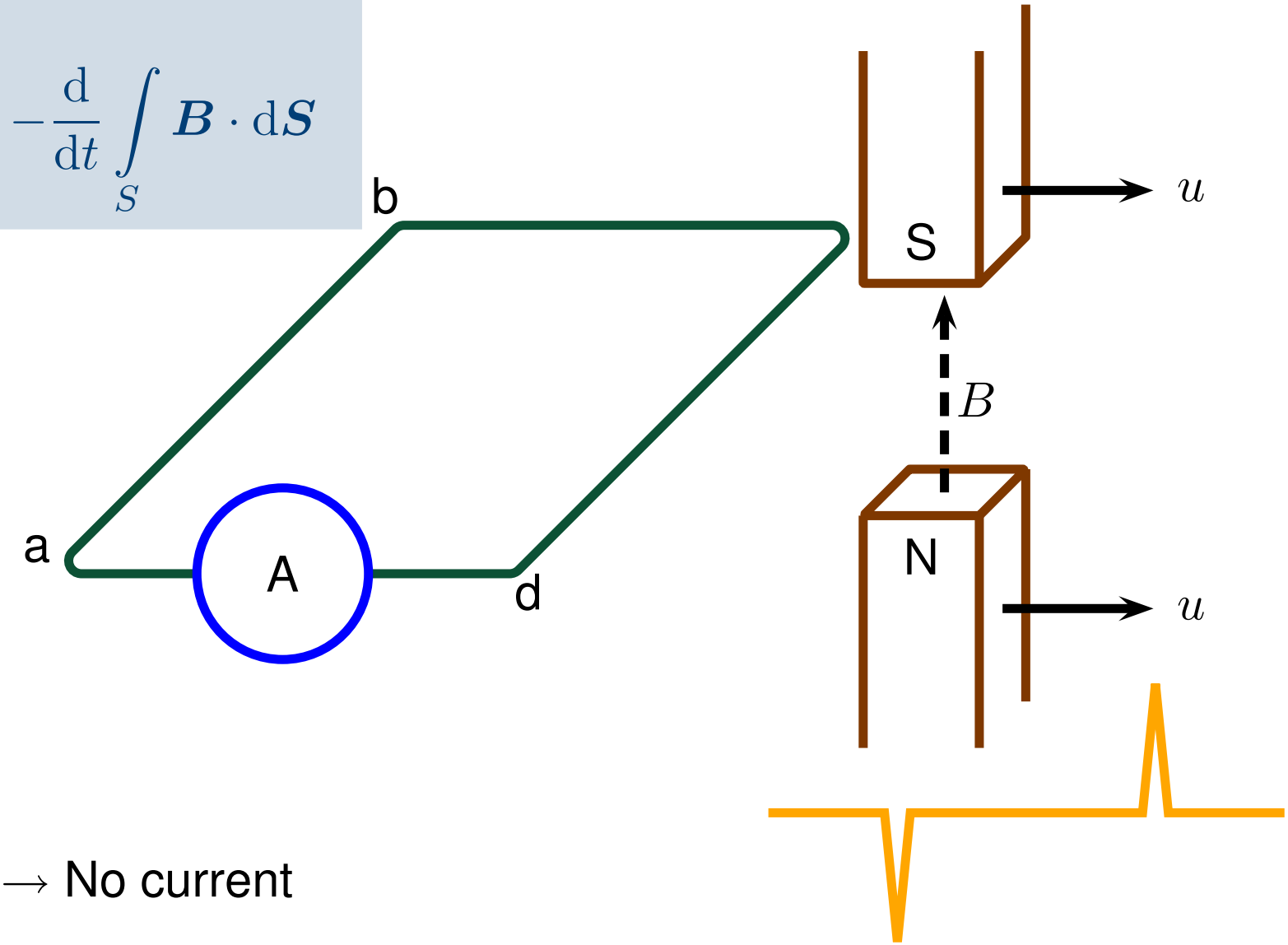
$$\int_C \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \int_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$



Decrease of B flux $\rightarrow$ Current

A Moving Magnet

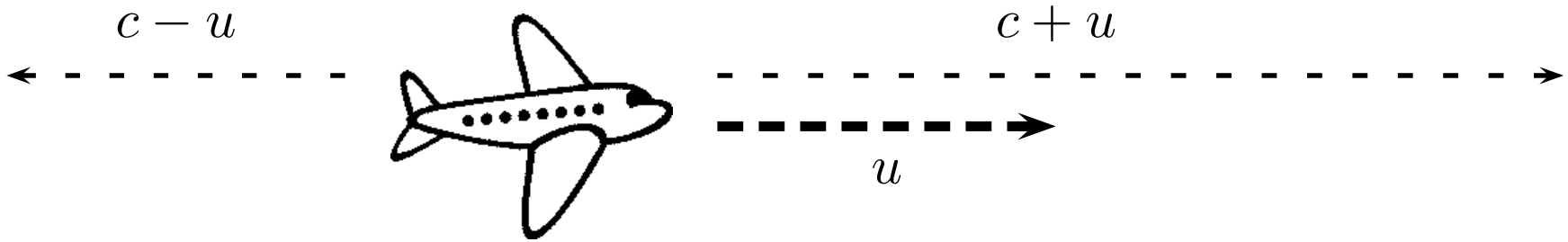
$$\int_C \boldsymbol{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \int_S \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$



No $B \rightarrow$ No current

Measurement of the Speed of Light

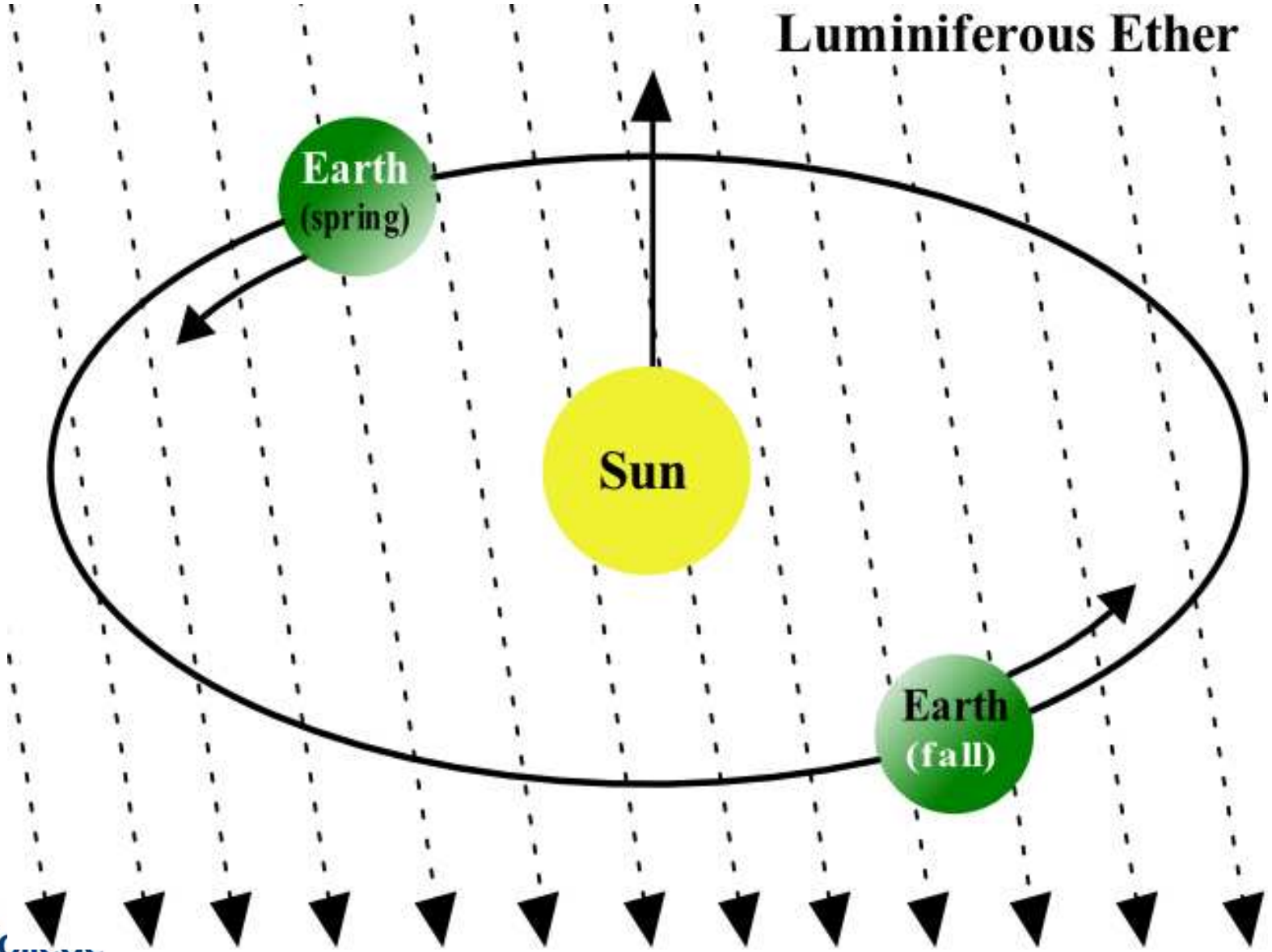
Can one infer the speed of a plane by measuring the speed of the light it emits?



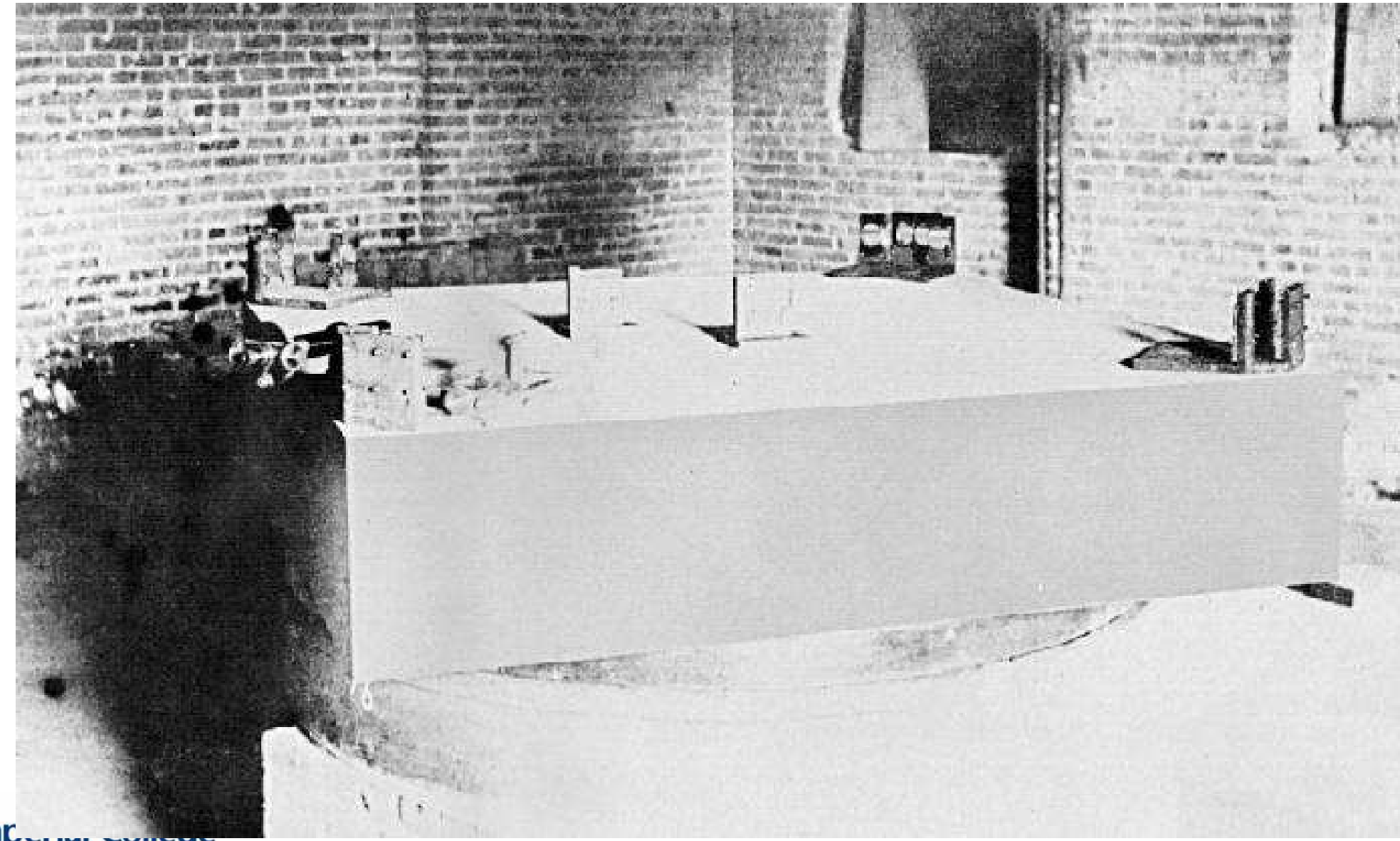
Is the speed of light constant relative to the emitting body, or to the medium?

Lecture 2

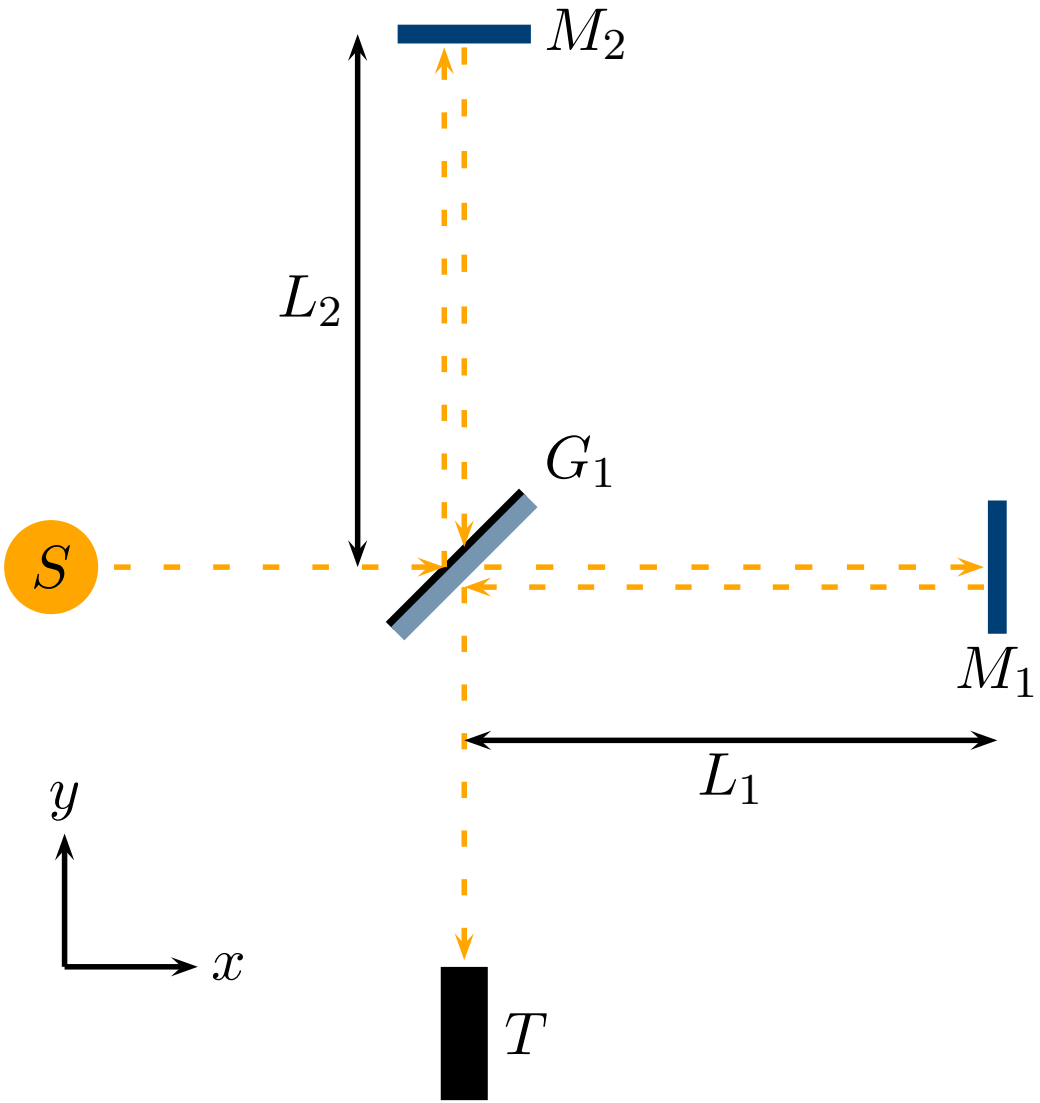
Luminiferous Æther



The Michelson-Morley experiment

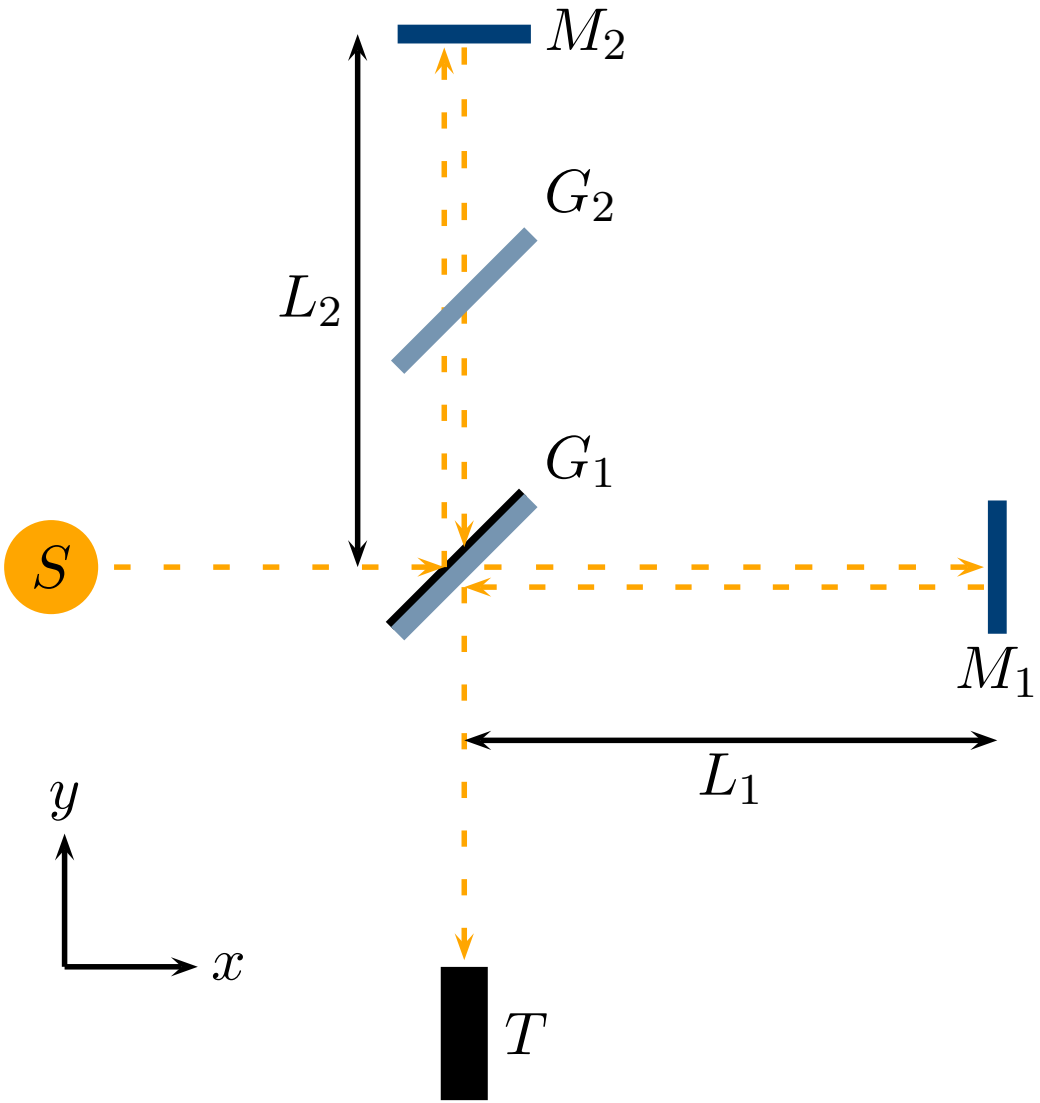


The Michelson-Morley experiment



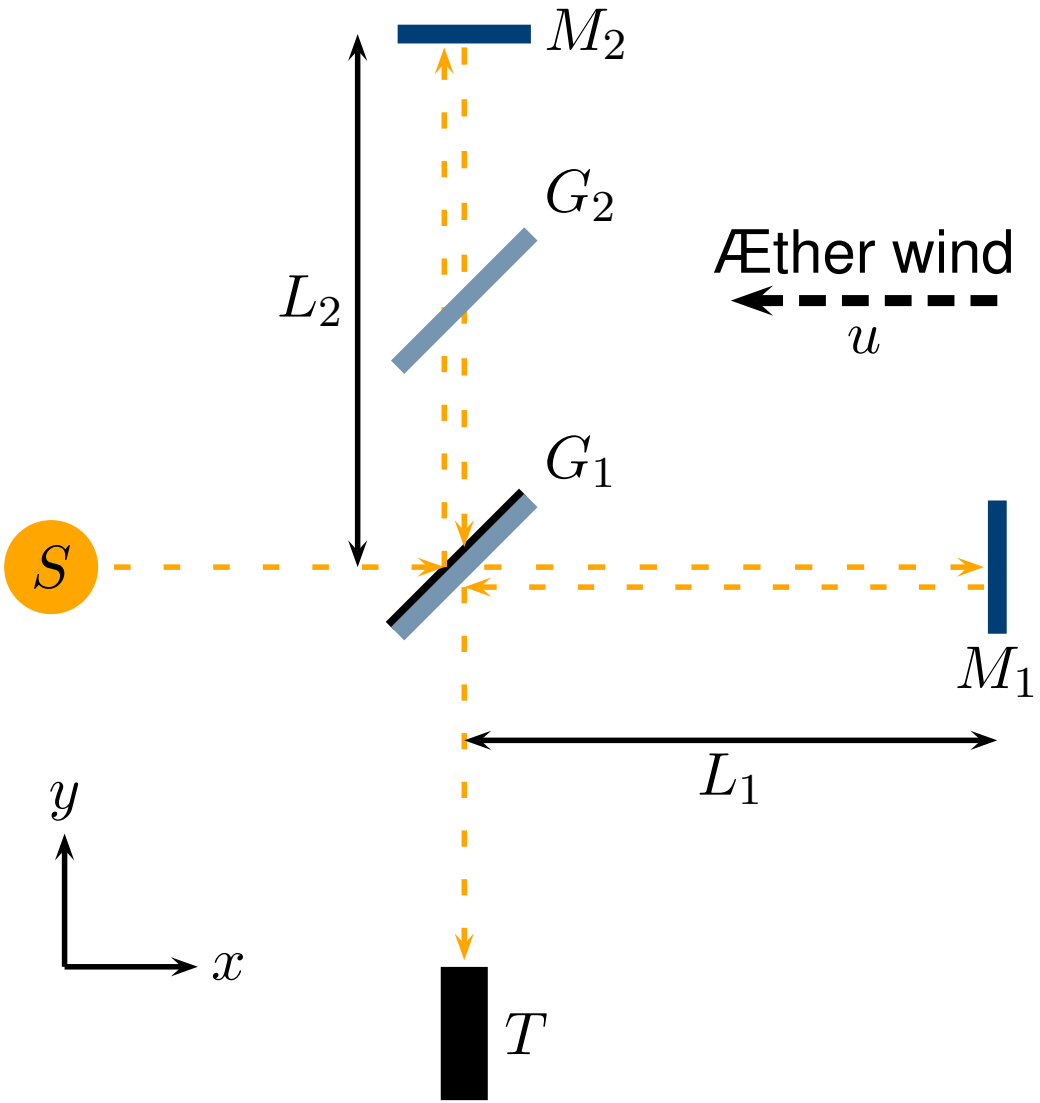
- Experiment to measure differences in speed of light due to æther wind

The Michelson-Morley experiment



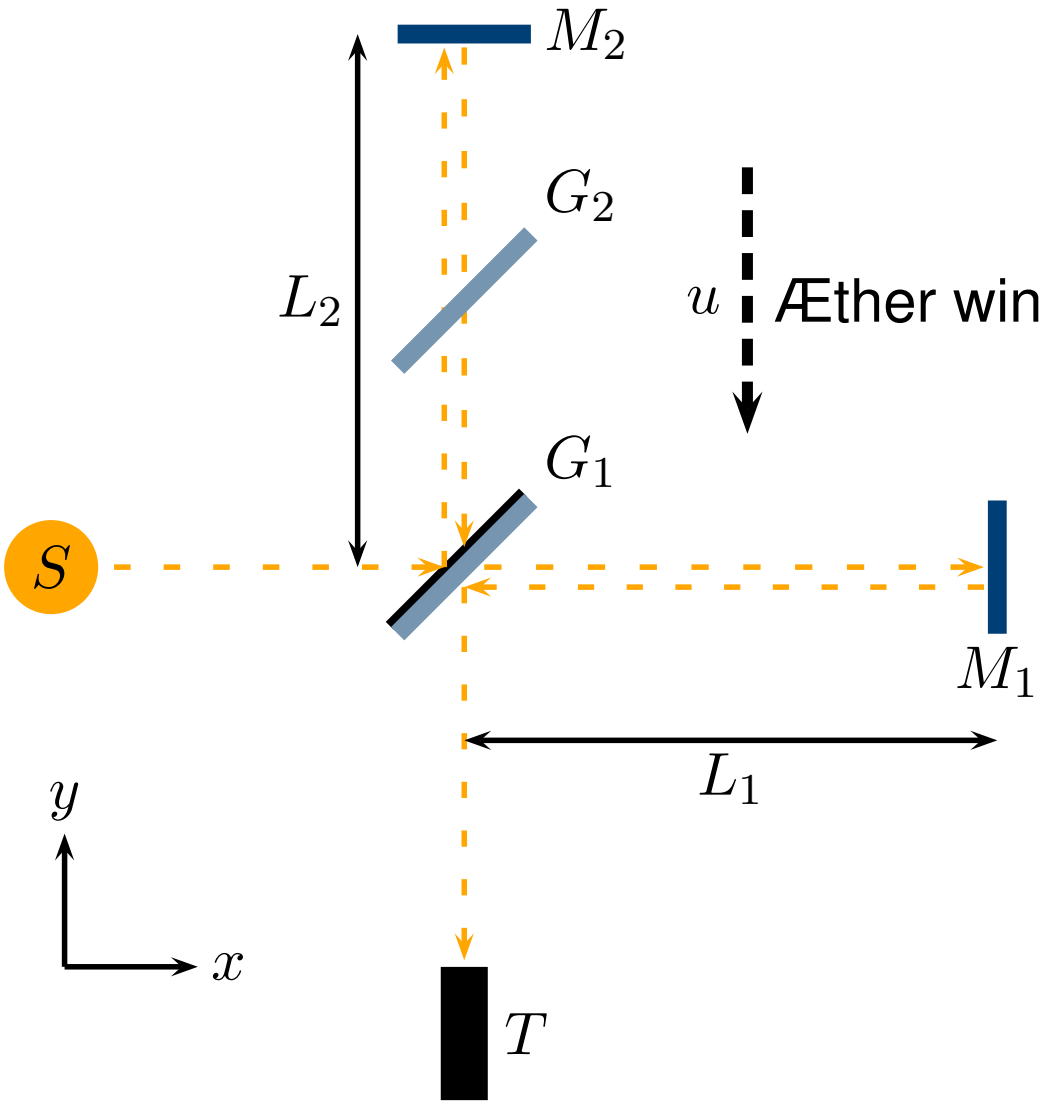
- Experiment to measure differences in speed of light due to æther wind
- Need to make sure all optical paths are of same lengths

The Michelson-Morley experiment



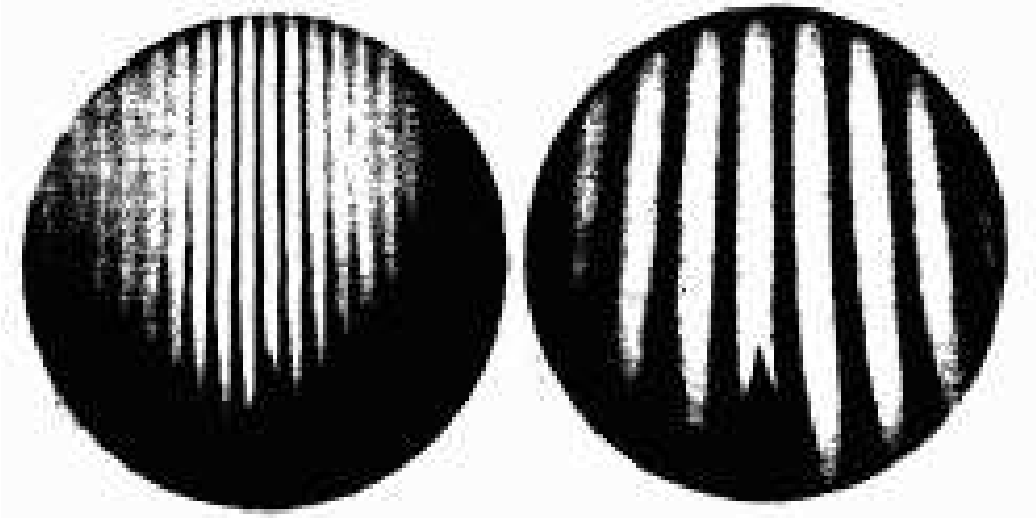
- Experiment to measure differences in speed of light due to æther wind
- Need to make sure all optical paths are of same lengths
- When wind blows from right, horizontal path takes more time

The Michelson-Morley experiment



- Experiment to measure differences in speed of light due to æther wind
- Need to make sure all optical paths are of same lengths
- When wind blows from right, horizontal path takes more time
- When wind blows from top vertical path takes more time

The Michelson-Morley experiment



- Experiment to measure differences in speed of light due to æther wind
- Need to make sure all optical paths are of same lengths
- When wind blows from right, horizontal path takes more time
- When wind blows from top vertical path takes more time
- Can the difference be seen?

Conclusion

No experimental test provides any way to distinguish an inertial frame from another.

Postulates of Special Relativity

1. **The laws of physics are identical in all inertial frames.**
2. **Light is propagated in empty space with a definite velocity c that is independent of the state of motion of the emitting body.**

Postulates of Special Relativity

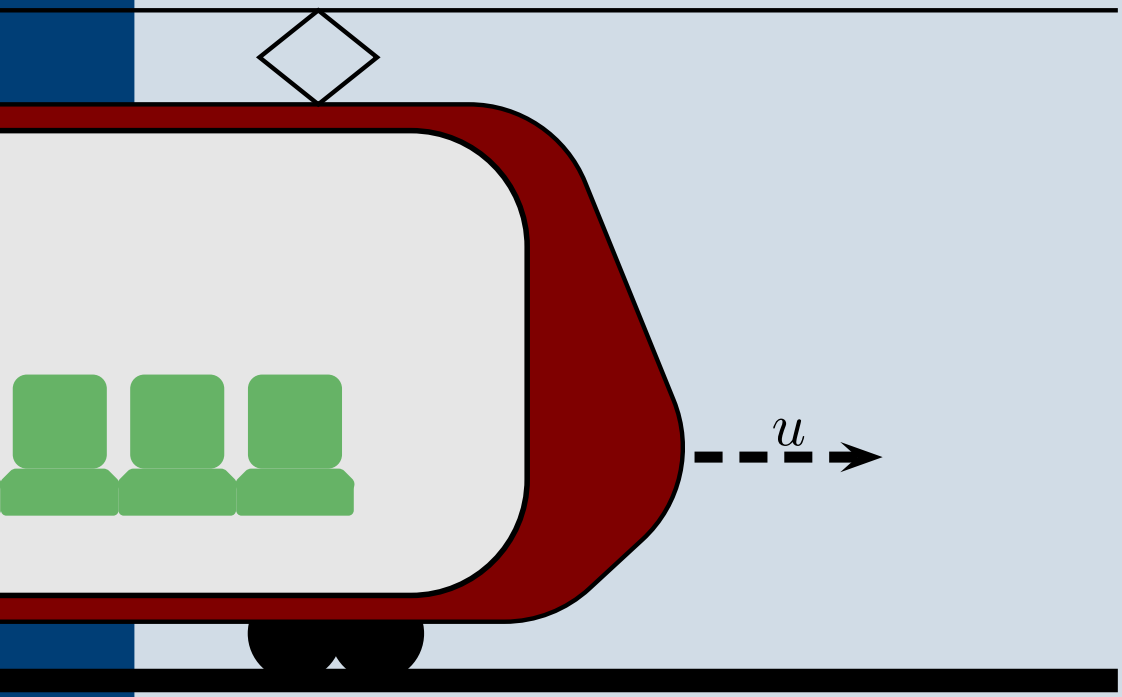
1. **The laws of physics are identical in all inertial frames.**
2. **Light is propagated in empty space with a definite velocity c that is independent of the state of motion of the emitting body.**

➜ **The speed of light in vacuum has the same value c for all inertial observers.**

$$c = 299,792,458 \text{ (exact)} \simeq 3 \cdot 10^8 \,\mathrm{m/s}.$$

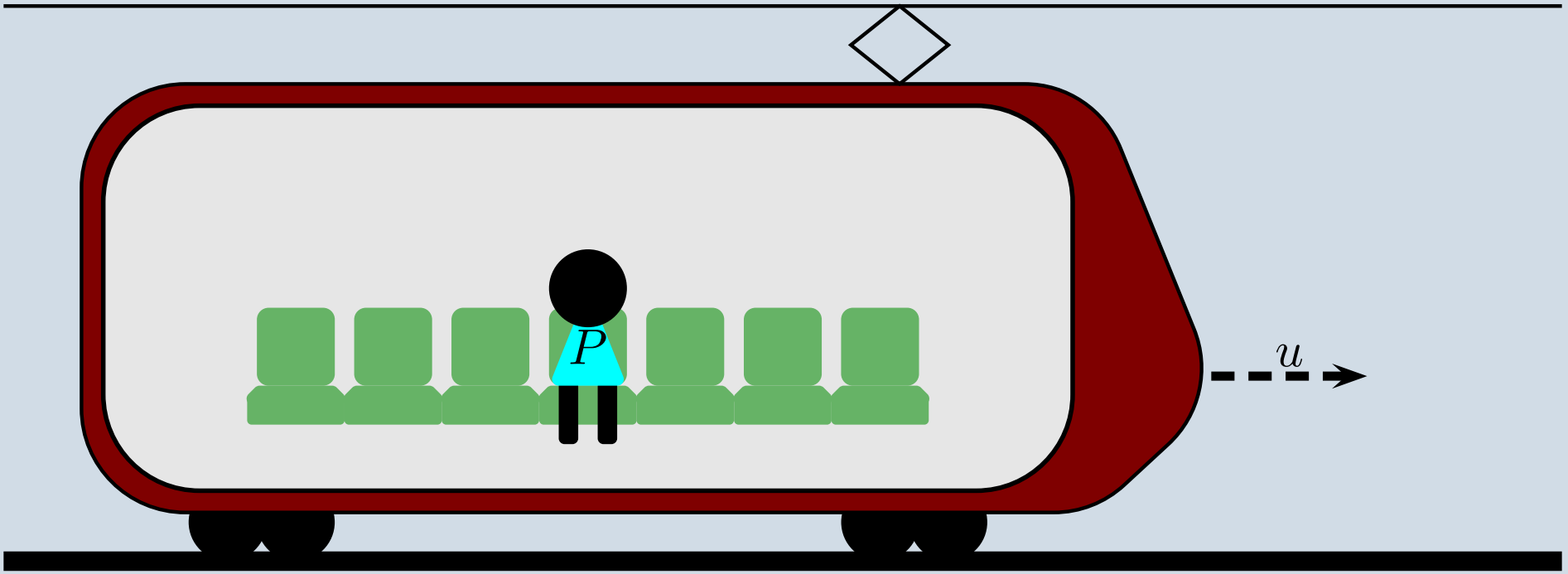
Simultaneity

Warning! Train approaching at speed close to c!



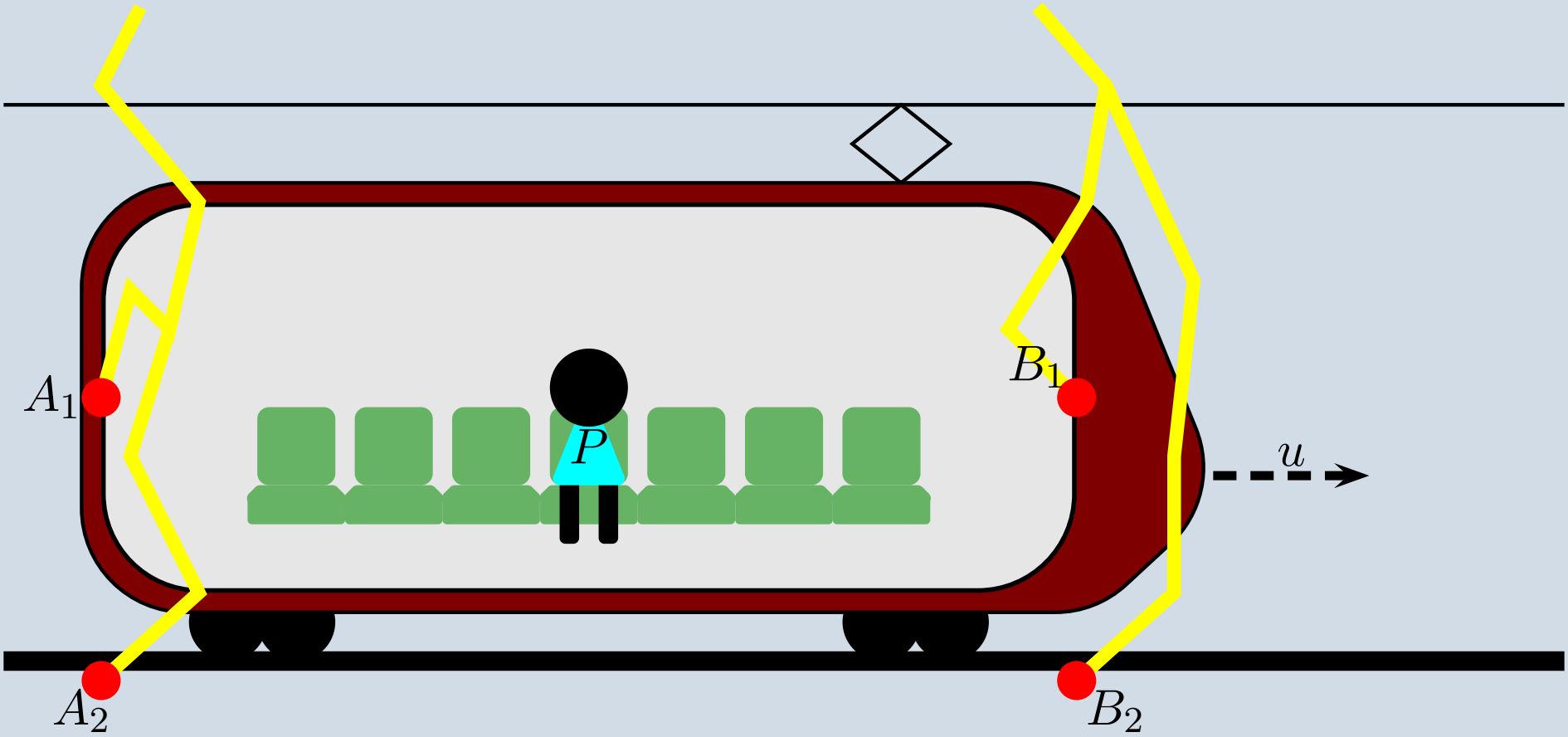
Simultaneity

A train moves at speed u close to c.



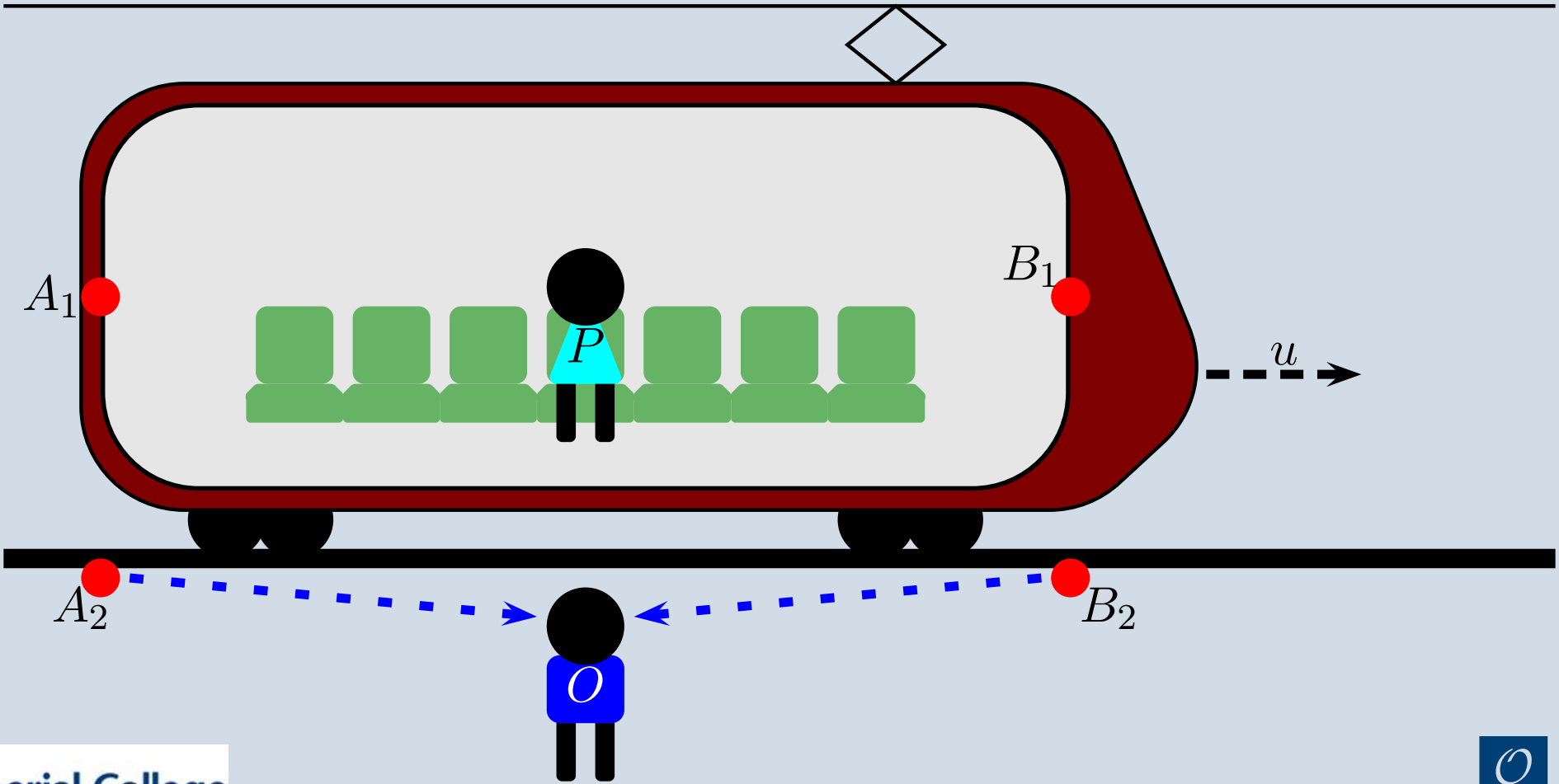
Simultaneity

It is struck by a lightning that hits simultaneously in A_1, A_2, B_1 and B_2.



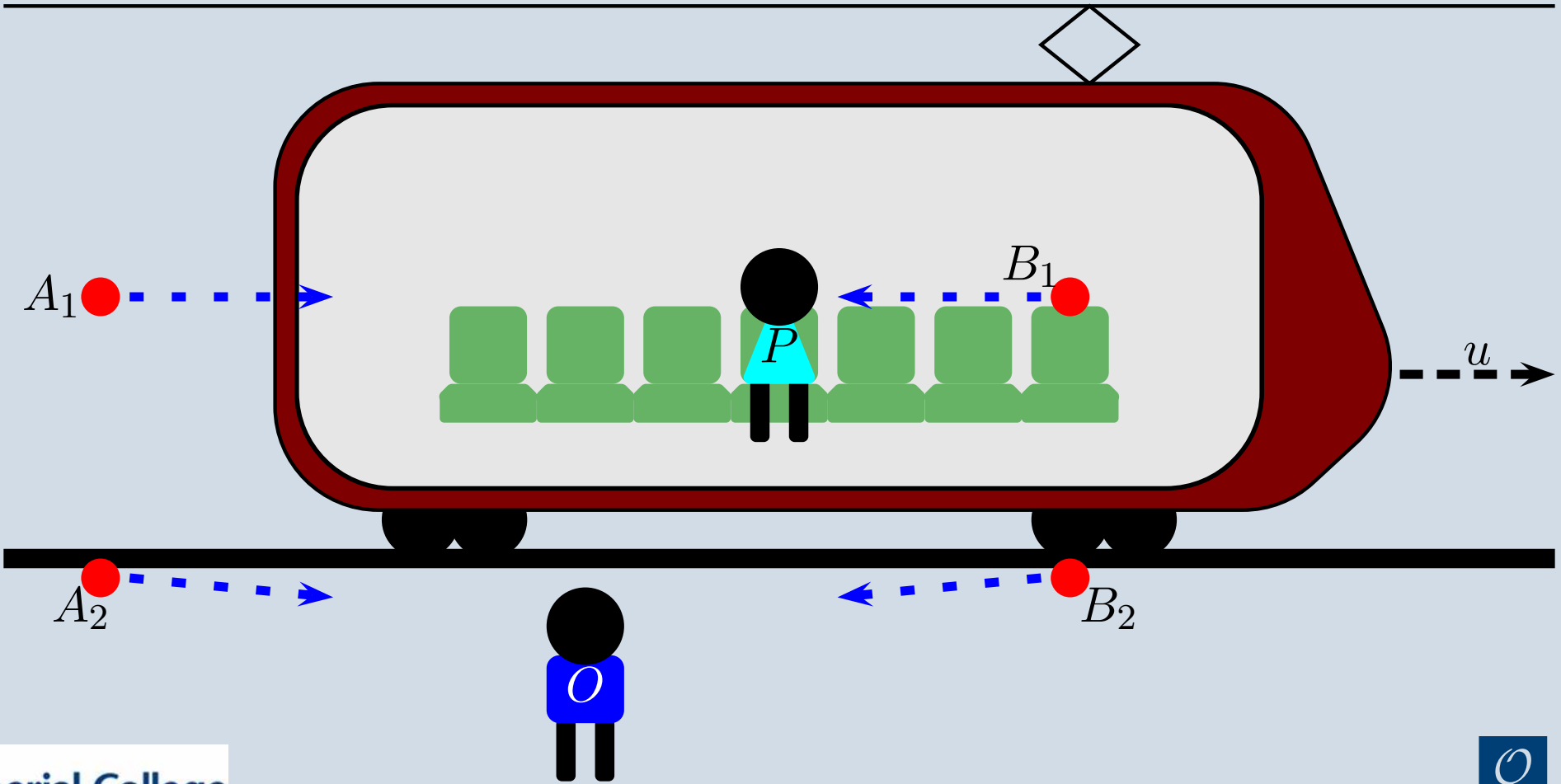
Simultaneity

Branches A **and** B **hit at the same time** because we see the flash from A_2 and B_2 arrive at the same time in O, in the middle.



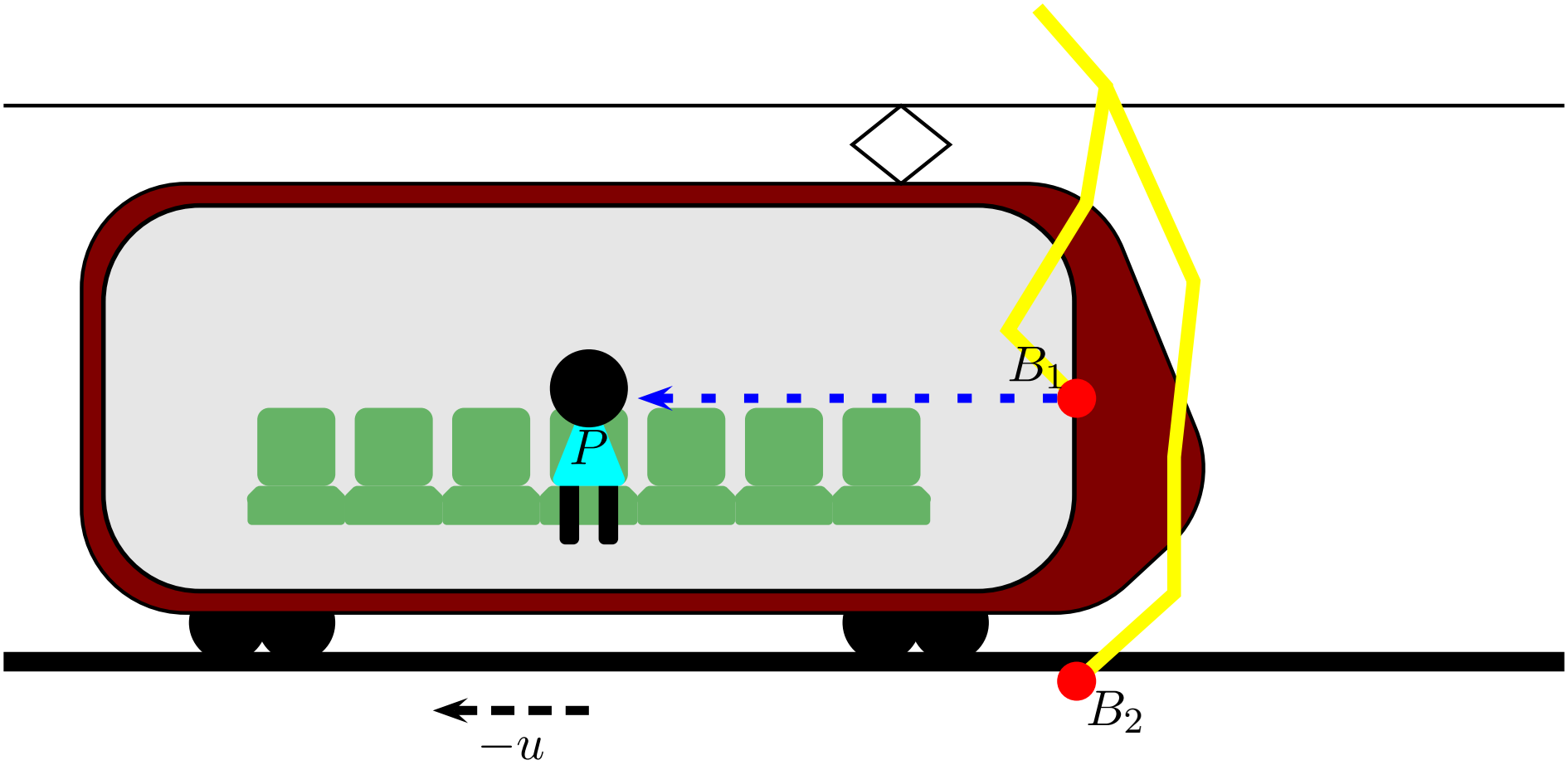
Simultaneity

The passenger sees the flash from B_1 first as she is moving to the right. She's in the middle between A_1 and B_1: $\boldsymbol{B}$ **must have struck first!**



Simultaneity

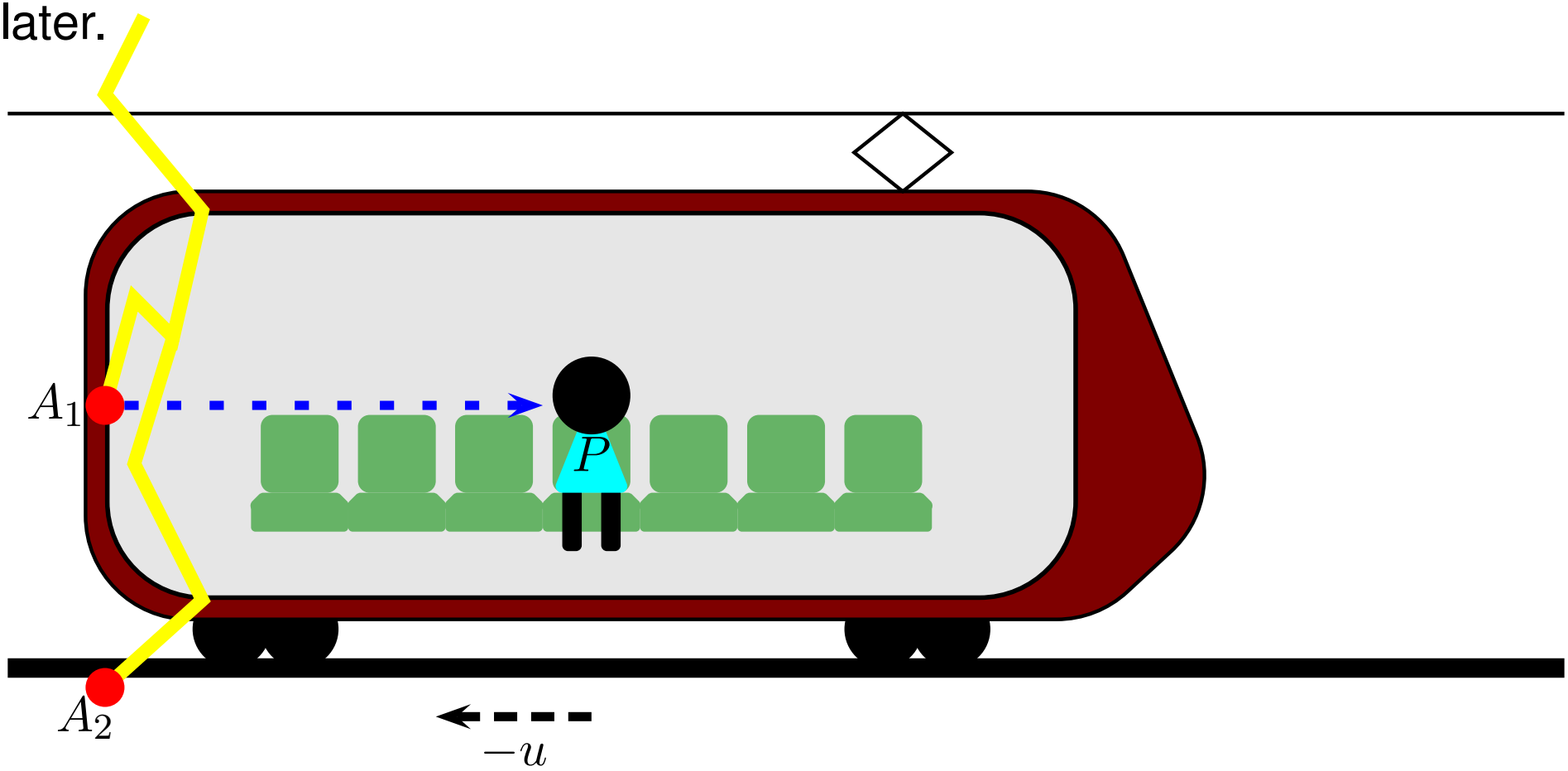
In her reference frame she sees lightning B first,



$\mathcal{O}'$

Simultaneity

In her reference frame she sees lightning B first, while lightning A strikes later.



$\mathcal{O}'$

Simultaneity — A Paradox?

Is there a paradox?

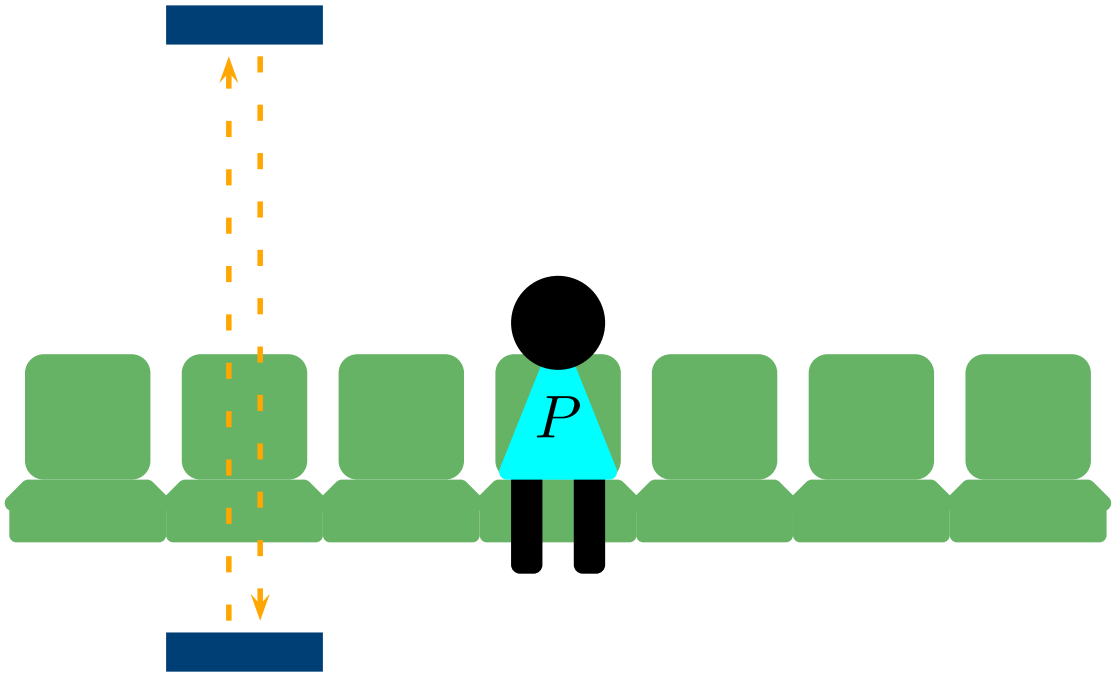
- We have used
  1. $L = ct$,
  2. c is contant

  ➜ knowing L, we conclude about t.
- But we get different results in $\mathcal{O}$ and $\mathcal{O}'$.
- "Common sense" says "*she's wrong: she's the one who's moving!*", the two lightning are *really* simultaneous.
- But that violates the principle of relativity! Both frames are inertial frames. None of them is better than the other.

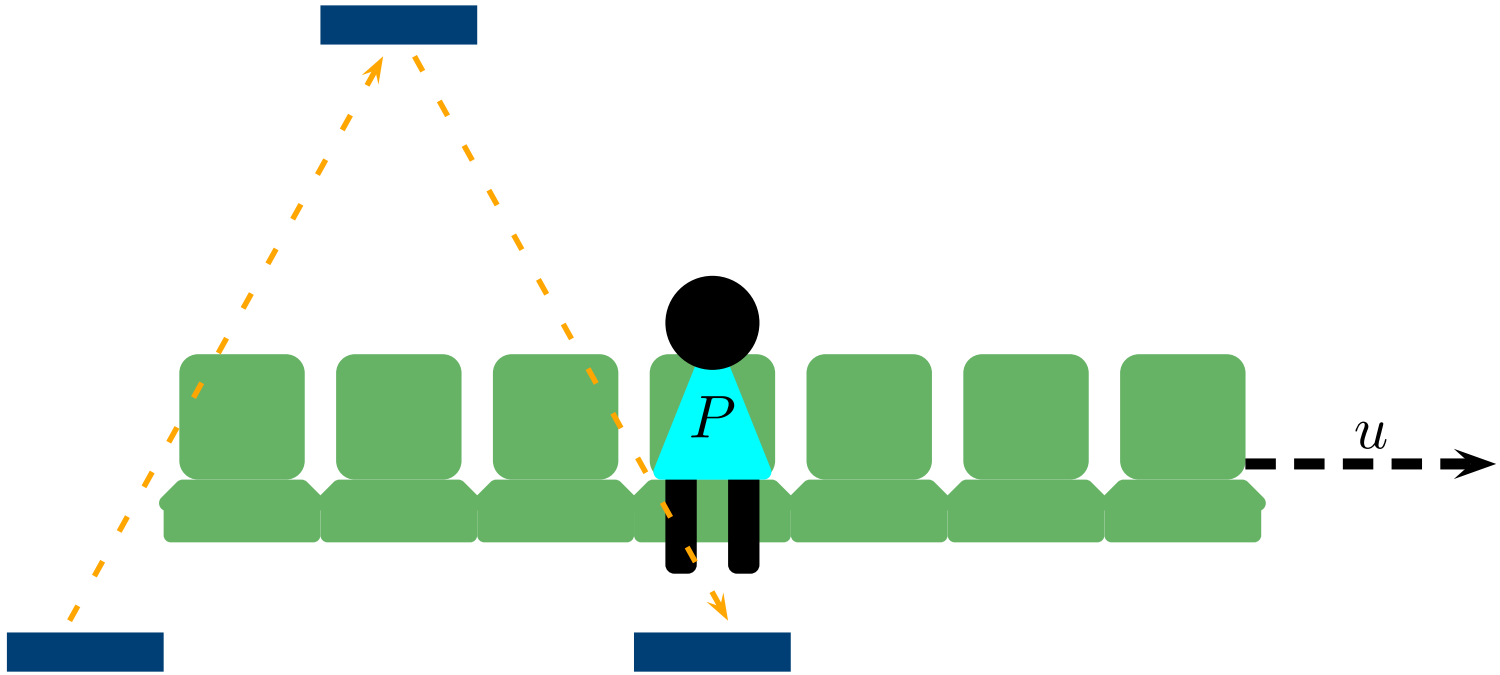
We have to abandon the concept of simultaneity!

Two events simultaneous in one frame need not be simultaneous in another frame.

Clock on a Train



Clock on a Train



Time Dilation

Moving clocks run slow.