

Galilean and special relativity

International Baccalaureate · IB Diploma · Physics · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: read the stated quantities and units, and use arithmetic and the model conditions below.

The examples are original and fictional: they are not real measurements or real student investigations.

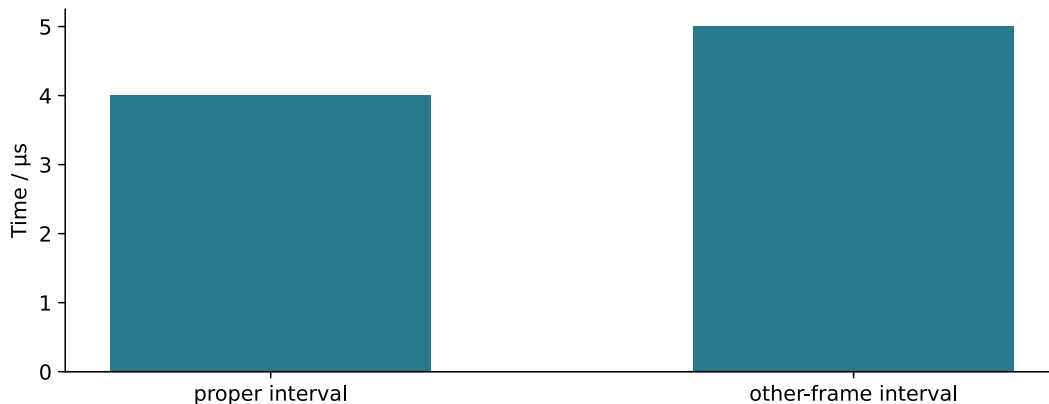
Relativity and measuring events

■ What would explain this observation?

- Two observers can assign different times between the same events. A clock reading has meaning only when the frame and events are specified.

■ Build the model

- In special relativity, inertial observers measure the same vacuum light speed.
- Time dilation compares **proper time** measured where two events occur at one place with the interval in another **inertial frame**.
- proper time: Time between events measured at one location in a frame.
- inertial frame: A frame in which a free body moves at constant velocity.



Time dilation: the proper time is shortest; here $\gamma = 5 \div 4 = 1.25$

■ Choose evidence that can test it

- The Lorentz factor is 1 divided by the square root of 1 minus speed squared over light speed squared.
- Galilean velocity addition is an approximation for speeds much smaller than light speed.

In the lab: Label which frame measures proper time or proper length before substituting. Use event coordinates consistently. Do not combine lengths from one frame with time intervals from another without transformation.

■ Work from known quantities

- Known: $v = 0.60c$ and proper time is 4.0 microseconds. $\gamma = 1/\sqrt{1-v^2/c^2} = 1/\sqrt{1-0.60^2} = 1.25$. $\Delta t = \gamma \Delta t_0 = 1.25 \times 4.0 = 5.0$ microseconds in the stated second frame.

Your turn: A proper interval is 8 microseconds and gamma is 1.25. Find the other-frame interval.

■ Check the conclusion and its limits

- Time dilation is not an instrument fault.
- Proper length is measured in the object rest frame; a contracted length is measured in a frame where it moves.

Not true: All inertial observers must measure the same time interval between any two events. Simultaneity and duration are frame-dependent: inertial observers in relative motion generally measure different time intervals between the same two events. Only the proper interval, measured in the rest frame of the events, is shared.

Key:

- In special relativity, inertial observers measure the same vacuum light speed.
- The Lorentz factor is 1 divided by the square root of 1 minus speed squared over light speed squared.
- Watch for: time dilation is not an instrument fault.

■ Write from a dilated interval of 18 microseconds

- A proper interval is 12 microseconds and gamma is 1.5.
- Find the interval in the other frame. Inertial observers need not agree on the duration.

■ **Write from a length contraction**

- A rod moves at $0.80c$; its rest length is 10 m. $\gamma = 1 \div \sqrt{1 - 0.64} = 1.67$.
- Moving length = $10 \div 1.67 = 6.0$ m – the rod contracts ALONG its motion only, never sideways.

■ **Write from a muon's clock**

- A muon's proper lifetime is 2.2 microseconds; it moves at $0.995c$ where $\gamma \approx 10$.
- Lab-frame lifetime ≈ 22 microseconds – long enough to reach the ground: time dilation is measured daily in the atmosphere.