# 5.1 Relativity and measuring events

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

**KEY WORDS** proper time • inertial frame

## Objective

Relativity and measuring events. Original classroom practice for IB HL; not an official IB paper.

## 1 Key knowledge and worked examples

### 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.

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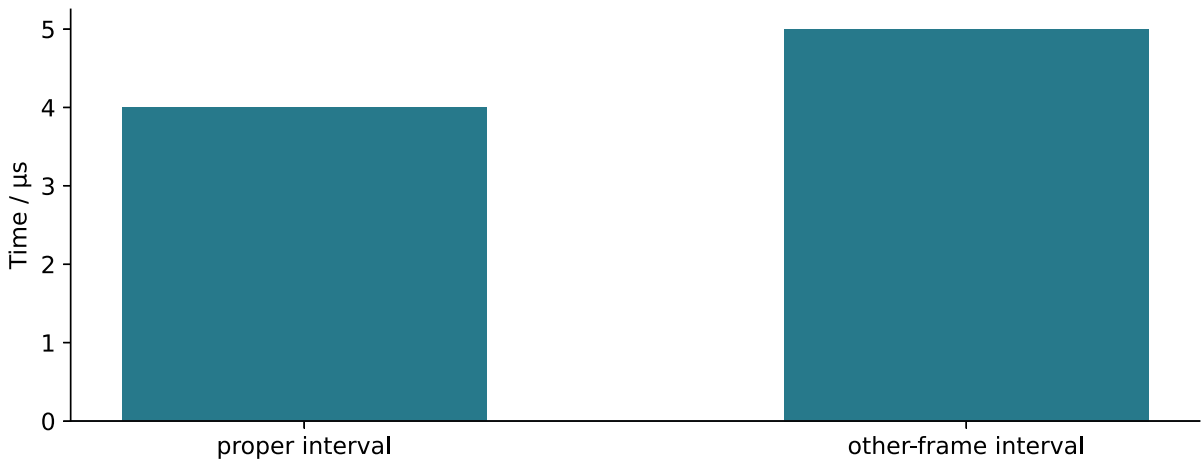
### Build the model

- 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.

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### 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.

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### 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.

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### 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.

## 2 Practice

**2.1** Where is proper length measured? Choose one answer.

- **A** In the object rest frame
- **B** Only in any fast-moving frame
- **C** In no frame at all [1]

**2.2** A proper interval is 8 microseconds and gamma is 1.25. Find the other-frame interval. Show the relation, substitution and units. [2]

**2.3** Decide whether this claim is true and justify: All inertial observers must measure the same time interval between any two events. [2]

**2.4** Time between events measured at one location in a frame: write the technical term. [1]

## 3 Exam-style questions

**3.1** At v=0.60c, lab lifetime is 10 microseconds. Find proper lifetime and lab travel distance. Identify the proper clock. [4]

## Solutions

**2.1 A** Proper length is defined in the frame where the object is at rest; every frame moving relative to the object measures a contracted length. It exists - it is simply tied to one specific frame.

**2.2** $\Delta$t=gamma$\times$proper interval=1.25$\times$8=10 microseconds.

**2.3** False. 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.

**2.4** proper time. proper time means Time between events measured at one location in a frame.

**3.1** Gamma=1.25; proper lifetime=8 microseconds. Lab distance=$0.60\times3\times10^{8}\times10^{-5}$=1,800 m. Birth and decay occur at the same particle-frame location.