INTERNATIONAL BACCALAUREATE · IB DIPLOMA · PHYSICS · HL • EXERCISE SHEET

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.

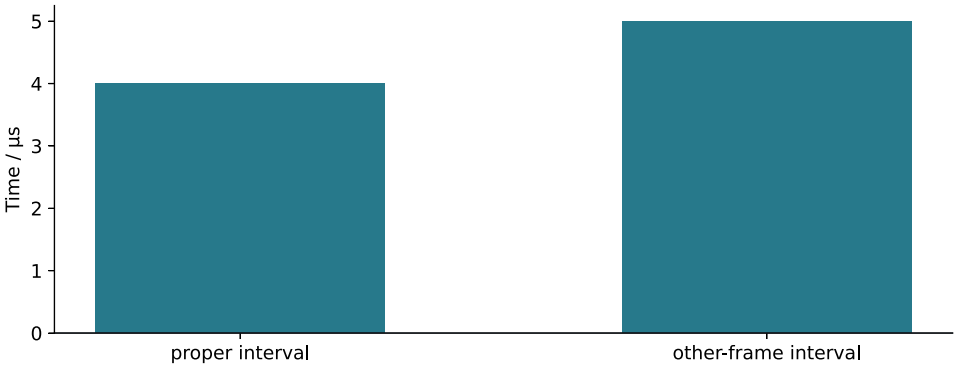
1 Key knowledge and worked examples

■ 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.

■ 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.



■ 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.

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 Δt=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.