

Exercise walk-through

# 5.1

## Relativity and measuring events

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International Baccalaureate · IB Diploma · Physics · HL

# 5.1 Relativity and measuring events

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Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_ **Total: 10 marks**

**KEY WORDS** proper time • inertial frame

## Objective

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Relativity and measuring events. Supported HL concept preparation; original classroom practice, not an official IB paper or assessed learner work.

## 1 Key knowledge and worked examples

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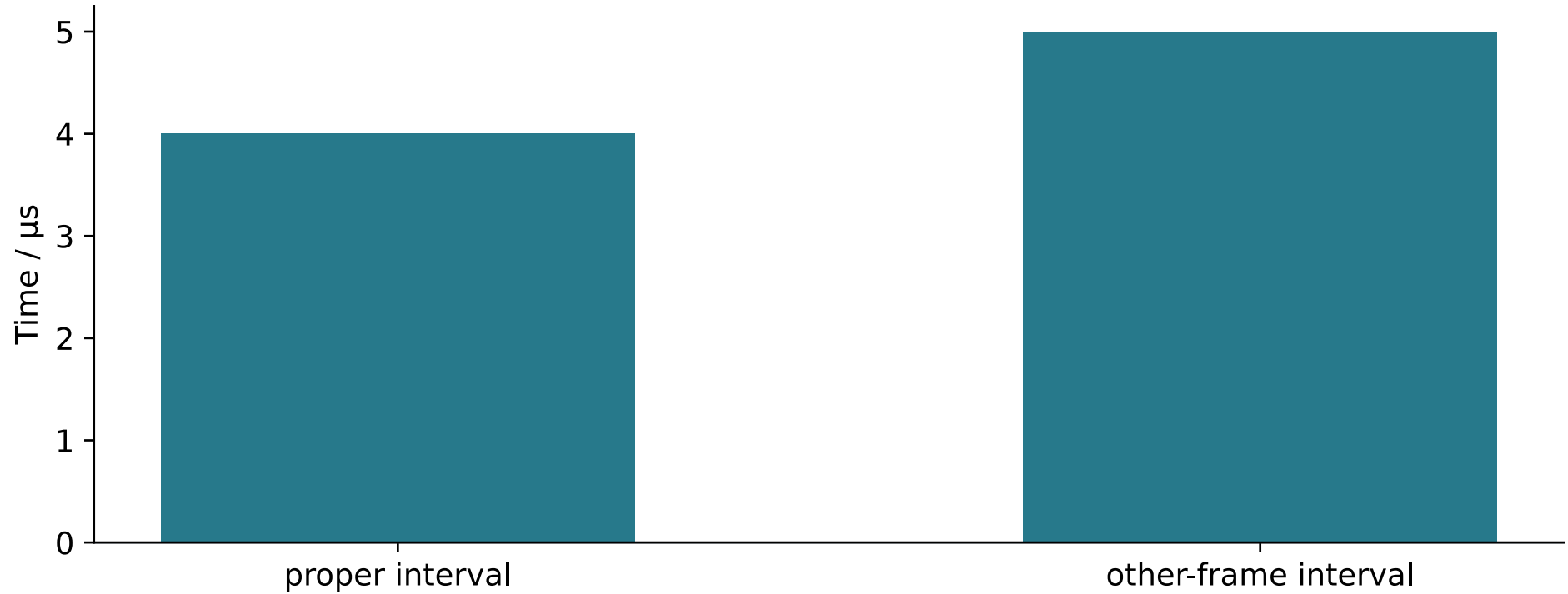
### ■ What would explain this observation?

- Two observers can assign different times between the same events. A clock reading has meaning only when the frame and events are specified.
  - Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.
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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.



■ **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.
  - 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**

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.

- 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.

### Example:

A proper interval is 8 microseconds and gamma is 1.25. Find the other-frame interval. Use the same sequence: known quantities  $\rightarrow$  model  $\rightarrow$  relation  $\rightarrow$  substitution  $\rightarrow$  unit and interpretation.

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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.
- Return to the original observation. Explain what the result supports, which conditions

it assumes, and one way to test a competing explanation.

### **Warn:**

All inertial observers must measure the same time interval between any two events. This claim is false: 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.

### **Key:**

Relativity and measuring events: 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.

## Exercises 2.1·2.3

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**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]

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**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]

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

[2]

## Exercises 2.1·2.3

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**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]

**2.1 A** 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.

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**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]

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

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

[2]

**2.3** False. 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.

## Exercises 2.4·3.1

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

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

## Exercises 2.4·3.1

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

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

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

**3.1**  $\Gamma=1.25$ ; proper lifetime=8 microseconds. Lab distance= $0.60 \times 3 \times 10^8 \times 10^{-5} = 1,800$  m. Birth and decay occur at the same particle-frame location.