

Exercise walk-through

6.1

Relativity, laboratory methods and specialised topics

GRE · GRE Subject Test · GRE Physics

6.1 Relativity, laboratory methods and specialised topics

Name: _____ Class: _____ Date: _____

Total: 10 marks

KEY WORDS precision • covariance

Objective

Apply special-relativistic energy and spacetime relations; Propagate measurement uncertainty and analyse experimental data; Recognise nuclear, particle, condensed-matter and astrophysical concepts. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

Special relativity uses $\gamma=1/\sqrt{1-v^2/c^2}$. Rest energy is mc^2 and total energy is γmc^2 .

For independent small uncertainties, combine contributions in quadrature; correlated uncertainties require covariance terms.

Random scatter affects precision ; calibration bias affects accuracy. A log plot can

reveal a power law.

Nuclear, particle, condensed-matter and astrophysics questions require undergraduate vocabulary and models. School physics alone is not a complete preparation course.

■ **Worked method**

Proper time is measured between events at one position in a frame. For a particle speed $0.60c$,

$$\gamma = (1 - v^2/c^2)^{-1/2} = (1 - 0.60^2)^{-1/2} = 1.25.$$

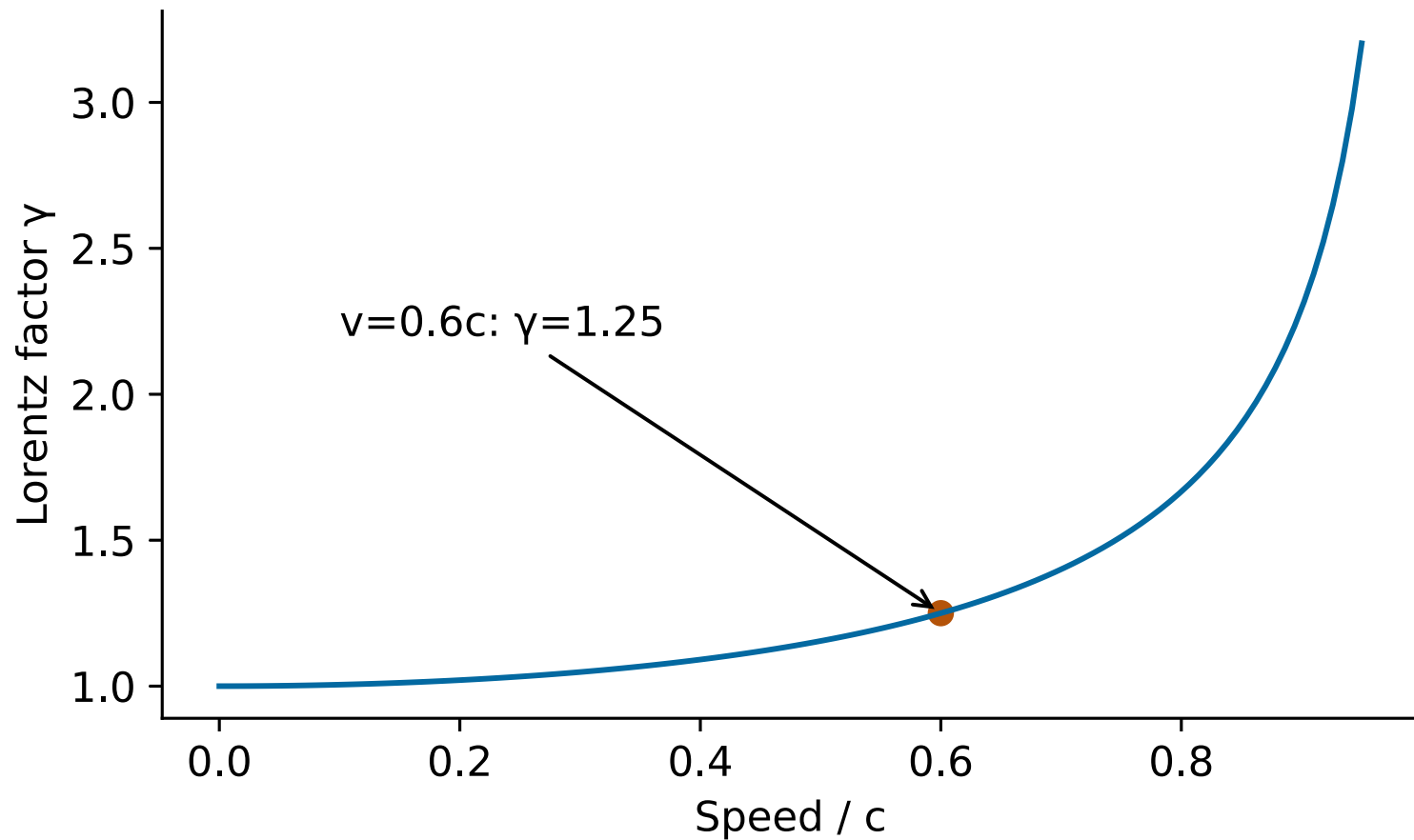
If its mean proper lifetime is 4.0 microseconds,

$$\tau = \gamma\tau_0 = 1.25(4.0\,\mu\text{s}) = 5.0\,\mu\text{s}.$$

$$\bar{d} = v\tau = (0.60)(3.00 \times 10^8\,\text{m/s})(5.0 \times 10^{-6}\,\text{s}) = 900\,\text{m}.$$

A lifetime is a mean of a distribution; it does not predict an individual decay time.

Relativistic energy grows with speed



Exercises 2.1·2.2

2.1 Choose one answer. At $v=0$, the Lorentz factor is:

[1]

- **A** 0
- **B** 1
- **C** infinite

2.2 Choose one answer. A fixed zero-offset error chiefly affects:

[1]

- **A** accuracy
- **B** sample count
- **C** the definition of velocity

Exercises 2.1·2.2

2.1 Choose one answer. At $v=0$, the Lorentz factor is:

[1]

- **A** 0
- **B** 1
- **C** infinite

2.1 B $\gamma=1/\sqrt{1}=1$.

Compare the rejected options: 0; infinite. Use the stated model and conditions.

2.2 Choose one answer. A fixed zero-offset error chiefly affects:

[1]

- **A** accuracy
- **B** sample count
- **C** the definition of velocity

2.2 A Calibration bias shifts readings from the true value.

Compare the rejected options: sample count; the definition of velocity. Use the stated model and conditions.

Exercises 2.3-3.1

2.3 Independent relative uncertainties 6% and 8% combine to _____. Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: Greater precision always guarantees greater accuracy. [2]

3.1 A detector measures 400 independent radioactive counts in a fixed interval. State the Poisson standard uncertainty. How many times longer must it count to halve relative counting uncertainty at the same stable rate? Explain whether this change removes a constant calibration bias. [4]

Exercises 2.3·3.1

2.3 Independent relative uncertainties 6% and 8% combine to _____. Show your relation and units. [2]

2.3 10. $\sqrt{6^2+8^2}=10$.

2.4 Decide whether this claim is true. Justify it: Greater precision always guarantees greater accuracy. [2]

2.4 False. A biased instrument can give tightly clustered wrong readings.

3.1 A detector measures 400 independent radioactive counts in a fixed interval. State the Poisson standard uncertainty. How many times longer must it count to halve relative counting uncertainty at the same stable rate? Explain whether this change removes a constant calibration bias. [4]

3.1 $\sigma_N = \sqrt{N} = 20$ counts, relative uncertainty $1/\sqrt{N} = 0.05$. Half that relative uncertainty needs four times N , hence four times the interval. Repetition reduces random counting uncertainty, not constant calibration bias. Award absolute uncertainty, relative uncertainty, time factor and bias distinction.