

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 $0.60c$,

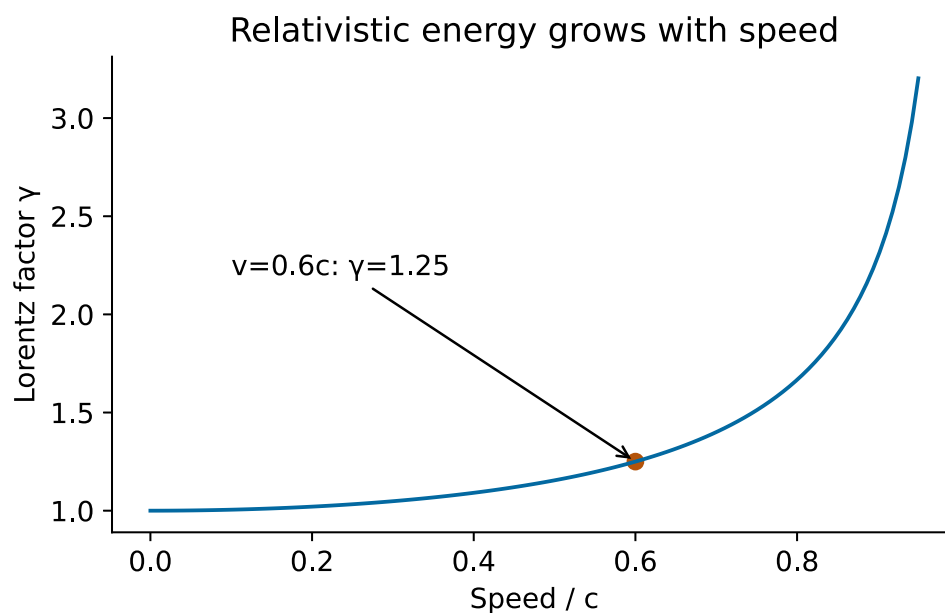
$$\gamma = (1 - v^2/c^2)^{-1/2} = (1 - 0.60^2)^{-1/2} = 1.25.$$

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.



2 Practice

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

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

[2]

Solutions

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

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

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.

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

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

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.