

Physics 203 Practice Problems - July 21st, 2022

1)

The current world record in the 100 metres for men (athletics) was set at 9.58 seconds by Usain Bolt in 2009.

- (a) From Usain Bolt's point of view there is a relativistic correction to the distance he ran. Calculate that correction assuming the entire sprint is at constant speed.

[Note: Your answer may seem small in the extreme, yet very small numbers are not always crazy; LIGO detects mirror displacements due to gravitational waves on the order of 10^{-18} m.]

[2 mark]

$$\text{His speed is } v = \frac{L}{\Delta t} = \frac{100 \text{ m}}{9.58 \text{ s}} = 10.4 \text{ m/s.}$$

In his frame he sees a contracted length $L' = \frac{L}{\gamma}$, so relativistic correction is

$$\begin{aligned} (\Delta L)_{\text{rel}} &= L - L' = (1 - \gamma^{-1})L = (1 - \sqrt{1 - \frac{v^2}{c^2}})L \\ &= (1 - (1 - \frac{1}{2} \frac{v^2}{c^2}))L \\ &= \frac{1}{2} \frac{v^2}{c^2} L = 6.0 \times 10^{-14} \text{ m} \end{aligned}$$

- (b) If relativity is considered, a clock carried by Usain Bolt would also disagree with the timing. Calculate the timing difference.

[2 mark]

His clock runs slower and records the time $\Delta t' = \gamma^{-1} \Delta t$.

Relativistic correction is

$$\begin{aligned} (\Delta t)_{\text{rel}} &= (1 - \gamma^{-1}) \Delta t \\ &= (1 - \sqrt{1 - \frac{v^2}{c^2}}) \Delta t \\ &= \frac{1}{2} \frac{v^2}{c^2} \Delta t = 5.75 \times 10^{-15} \text{ s.} \end{aligned}$$

- (c) In which frame of reference (Usain Bolt's or the stationary frame of the track) is the proper length measured (part (a)) and in which is the proper time measured (part (b))?

[1 mark]

Proper length measured in the frame of the track.

Proper time in Usain Bolt's frame (where start and finish are at the same point in space).

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