

Time Dilation and Length Contraction Problems

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Muons

A muon is a particle typically created in the upper atmosphere and has a half-life of about $1.5 \mu s$. (This means that if you take a bunch of muons and wait $1.5 \mu s$, about half of them will have decayed and about half will still be around.) A muon travels at .99 the speed of light.

So, given that a muon has been create 2,000 meters above the Earth, it would seem to have have a very small chance of reaching the ground and being detected.

Say that such a muon does reach the Earth and is detected in a laboratory. In the Lab reference frame, the muon has travelled 2,000 m. So based on its velocity that it has apparently lived for $6.73 \mu s$ in the Lab frame of reference.

Problem 1: How long has this muon lived in its own frame of reference

Problem 2: How far has it traveled in its own frame of reference

The Qzzyyxxx

Scientists on Earth detect an asteroid-sized object hurtling toward us at 80% of the speed of light. Fortunately the path of the object (an inertial one by the way) takes if a ways outside the orbit of the moon, and it actually doesn't end up presenting any danger.

But as the object passes by, it beams a message saying "Greetings people of Earth. We, the Qzzyyxxx empire, salute you and wish you well as we pass you by on our way to visit your close neighbors in the Proxima Centauri system 4 light years away."

The astounded scientists continue to track the Qzzyyxxx ship (using the new Chinese "Xiezhì" super-array telescope) until it reaches the Proxima Centauri system and disappears from view.

Problem 3: How long does it take the Qzzyyxxx to travel the 4 light years from Earth to Proxima Centauri in the Earth's frame of reference?

Problem 4: How long does it take them in the Qzzyyxxx ship's frame?

Problem 5: How far is the journey from Earth to Proxima Centauri in the Qzzyyxxx frame?

Photons

Scientists capture the very last photon of light reflected off the Qzzyyxxx ship before the ship disappears from view.

Problem 6: In the Earth's frame of reference, how long did it take the photon to travel from Proxima Centauri to Earth?

Now, you can't exactly use the dilation and contraction formulae to work out the next two questions (why not?) but see what you can come up with.

Problem 7: How long did the photon travel in its own frame of reference?

Problem 8: How far did the photon travel in its own frame of reference?