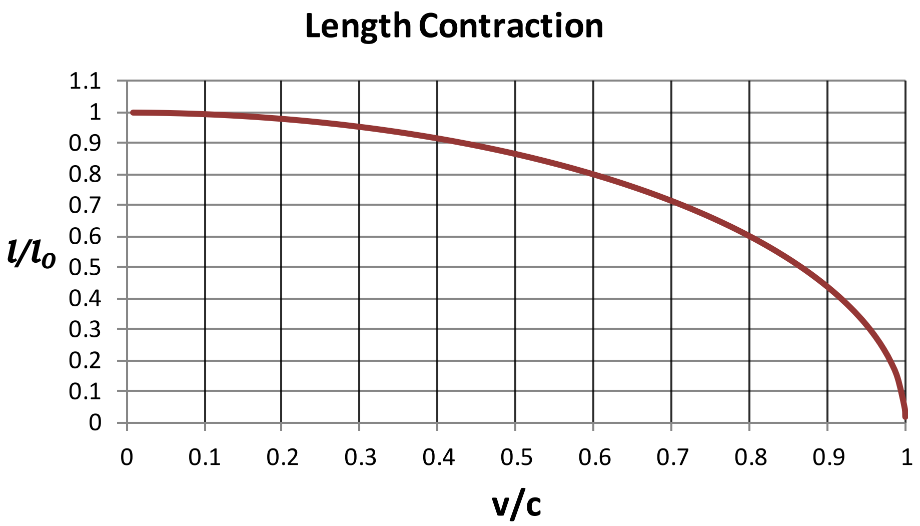
Length Contraction Problems

1. Define what the term "proper length" refers to and the conditions in which it can be measured.

2. The graph below shows how the effects of length contraction vary as the velocity of a frame of reference approaches the speed of light. Use this graph as a means to determine the answer to the following questions (no advanced formulae are required).



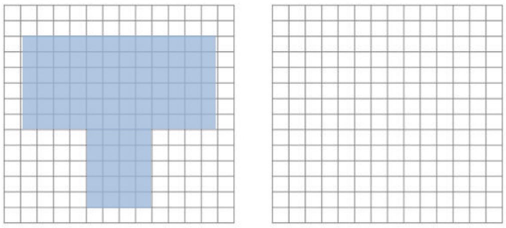
  a. Explain why length contraction is not observed when a plane flying through the air is watched by people on the ground.

  b. A metal pole is 5.00 m long as measured by an observer at rest with the pole. Another observer is moving parallel with the pole's length at 0.90c. What pole length does the moving observer see?

  c. What velocity would a spaceship need to be moving for a stationary observer to observe the spaceship as 20% shorter than its proper length along its direction of movement?

d. A photon is emitted from star A. It heads towards star B which is 8250 light years away. What distance does the photon observe between the two stars?

e. The object drawn in the grid on the left is currently at rest relative to you.



Inside the grid on the right, draw how the object would appear to you if it was moving at 2.61×10^{8} ms^{-1} towards the right of the page.

3. The Flash is 185 cm tall, 45.0 cm wide (across the hips) and 30.0 cm deep (from stomach to back). Assume The Flash keeps his body vertical while he runs.
   a. How would your observations of the appearance his three body dimensions change when The Flash is running at a high fraction of the speed of light?

   b. If The Flash can run at up to 67.5% of the speed of light, through the use of appropriate formulae, determine his body dimensions as observed by a stationary observer.

   c. The Flash is sitting down at his home when he realises he is late for work. His work place is 2.58 km from his couch while The Flash is sitting down. Calculate the distance the Flash observes when he is running at his highest speed straight toward work.

4. An alien space craft is detected by NASA observatories on the surface as it flies by Earth at 0.75c. The data reveals the space craft is 38.5 m long. Calculate the length of the alien space craft as observed by the people on Earth after it lands on the surface.

5. In the future, trips to the outer planets in our solar system will be a cheap tourist destination. A tourist spaceship has just reached the Sun and is heading towards Earth on the return trip. The distance to the Earth is 6.00×10^{10} m as observed by the passengers. Calculate the speed of the tourist spaceship from the reference frame of the Sun.

6. Peter, Sahan and Yu-ting are each carrying equivalent 1.00 m long bars while they are all at rest. Yu-ting and Sahan strap their bars along the length of some very fast cars. Sahan and Yu-ting drive off in opposite directions. Both cars move at 0.40c relative to Peter who has placed his bar on the floor, parallel with the cars' velocities.
    a. Rank the length of each bar (Peter's bar, Sahan's bar, Yu-ting's bar) from longest to shortest as observed by Peter. If any bars appear the same length, clearly state this.

    b. Rank the length of each bar (Peter's bar, Sahan's bar, Yu-ting's bar) from longest to shortest as observed by Sahan. If any bars appear the same length, clearly state this.

c. Calculate the length of Peter's bar as observed by Sahan.

d. Explain why no observed bar length can be greater than 1.00 m.

7. A muon is an unstable particle with a half life of 2.20 μs in the reference frame of the muon. Even though they move very quickly, the muons created in the upper atmosphere should not be able to reach the surface before they decay. Never the less, observers on the surface detect many muons and record a 15.6 μs half life.
   a. Explain, using relevant relativistic effects, why the muons have a large enough half life for the surface observers to detect muons.

   b. How fast are the muons moving relative to the surface observers?

c. Your answer to part (a) should suffice to explain why surface observers can detect muons much closer to the surface than what Newtonian Physics predicts. However, this does not explain why the muons themselves can reach the surface with only a 2.20 μs half life. Explain, in the context of the muon frame of reference, why the muons are able to reach the surface of the Earth before they decay.

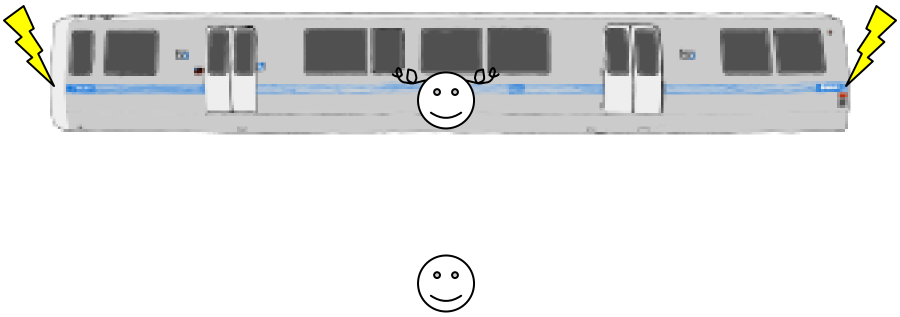
d. Surface observers detect a muon is formed 4750 m above sea level and heads directly for the ground. What distance does the muon observe between its creation point and sea level? Justify your answer.

e. Surface observers detect a muon is formed 4750 m above sea level and heads parallel with the Earth's surface. What distance does the muon observe between its creation point and sea level? Justify your answer.

f. What is the proper time for the half life of a muon? Justify your answer.

g. What is the proper length between the muon creation height and the surface? Justify your answer.

8. Hao is 100 m from a train track as he observes a train passing by at 0.80 c which appears to be 500 m long according to Hao. Sookie is in the middle of the train. As the middle of the train passes Hao, two lightning bolts strike the front and rear of the train which Hao observes to occur have occurred simultaneously.



a. Sookie tells Hao the lightning strikes did not occur at the same time. Explain why she has a different interpretation compared to Hao.

b. How long does Hao wait (in his own frame) to observe **each** lightning strike after it happens?

c. From Hao's perspective, how much time does it take for the photons of the rear lightning to reach Sookie?

d. How long does Sookie wait (in her own frame) to observe **each** lightning strike after it happens?