

PHY 116 From Newton to Einstein
Coursework Sheet 9: Length Contraction

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Hand in by 4pm, 3rd December 2012

- 1) A muon is created 55.0 km above the surface of the Earth (as measured in the Earth's frame). The average lifetime of a muon, measured in its own rest frame, is 2.20×10^{-6} s. In the frame of the muon the Earth is moving towards the muon with a speed of $0.9860c$. a) In the muon's frame, what is its initial height above the surface of the Earth? b) In the muon's frame, how much closer does the Earth get during the lifetime of the muon? What fraction is this of the muon's original height as measured in the muon's frame? c) In the Earth's frame, what is the lifetime of the muon? In the Earth's frame, how far does the muon travel during its lifetime? What fraction is this of the muon's original height in the Earth's frame? [5]

- 2) An unstable particle is created in the upper atmosphere from a cosmic ray and travels straight down toward the surface of the earth with a speed of $0.99540c$ relative to the Earth. A scientist at rest on the Earth's surface measures that the particle is created at an altitude of 45.0 km. a) As measured by the scientist, how much time does it take the particle to travel the 45.0 km to the surface of the Earth? b) Use the length contraction formula to calculate the distance from where the particle is created to the surface of the Earth as measured in the particle's frame. c) In the particle's frame, how much time does it take the particle to travel from where it is created to the surface of the Earth? Calculate this time both by the time dilation formula and also from the distance calculated in part (b). Do the two results agree? [5]

- 3) As measured by an observer on the Earth, a spacecraft runway on Earth has a length of 3600m. a). What is the length of the runway as measured by a pilot of a spacecraft flying past at a speed of $4.00 \times 10^7 \text{ ms}^{-1}$ relative to the Earth? b). An observer on Earth measures the time interval from when the spacecraft is directly over one end of the runway until it is directly over the other end. What result does she get? c). The pilot of the spacecraft measures the time it takes him to travel from one end of the runway to the other. What value does he get? [3]

- 4) A metre stick moves past you at great speed. Its motion relative to you is parallel to its long axis. If you measure the length of the moving stick to be 0.3048m, at what speed is the stick moving relative to you? [2]

- 5) A spacecraft flies past a planet at a speed of $0.6c$. A scientist on the planet measures the length of the spacecraft to be 74 m. The spacecraft lands on the planet and the scientist measures the length of the now stationary spacecraft. What value does he get? [2]