

Relativity Test  
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1. At what speed does a clock move if it runs at a rate which is one-half the rate of a clock at rest?
2. At what speed does a meter stick move if its length is observed to shrink to 0.5 m?
3. The average lifetime of a  $\pi$  meson in its own frame of reference is 26.0 ns. (this is its proper lifetime)
  - if the  $\pi$  meson moves with speed  $0.95c$  with respect to the Earth, what is its lifetime as measured by an observer at rest on Earth?
  - What is the average distance it travels before decaying as measured by an observer at rest on Earth?
4. An atomic clock is placed in a jet airplane. The clock measures a time interval of 3600s when the jet moves with speed 500 m/s. How much larger a time interval does an identical clock held by an observer at rest on the ground measure?
5. A rod of length  $L_0$  moves with speed  $v$  along the horizontal direction. The rod makes an angle  $\theta_0$  with respect to the  $x'$  axis.
  - Determine the length of the rod as measured by a stationary observer.
  - Determine the angle  $\theta$  the rod makes with the  $x$  axis.
6. Relativistic Doppler Shift
  - How fast and in what direction must galaxy  $A$  be moving if an absorption line found at wavelength 550nm (green) for a stationary galaxy is shifted to 450 nm (blue) ("blue shift")?
  - How fast and in what direction is galaxy  $B$  moving if it shows the same line shifted to 700nm (red) ("red shift")?
7. A stationary observer on Earth observes spaceships  $A$  and  $B$  moving in the same direction toward the Earth. Spaceship  $A$  has speed  $0.5c$  and spaceship  $B$  has speed  $0.8c$ . Determine the velocity of spaceship  $A$  as measured by an observer at rest in spaceship  $B$ .
8. Two rockets of rest length  $L_0$  are approaching the earth from opposite directions at velocities  $\pm c/2$ . How long does one appear to the other?
9. A person comes to you claiming that he/she has invented a microchip 1 cm square in size which can run at a clock speed of 300,000GHz. Would you invest in this person's company so that he/she can manufacture and market his/her new invention? Explain your answer.
10. Two spaceships approach each other. They are each viewed from Earth as having a speed half that of light. What is their speed relative to each other?
11. If you move toward an emitter of yellow light ( $\lambda = 580nm$ ) at half the speed of light, what wavelength would you observe? What would be the answer if the emitter moved toward you?
12. A beam of muons is injected in a storage ring, a device that uses electromagnetic fields to maintain the muons in uniform circular motion. The ring's radius is 60m, and the muons are injected with a velocity such that  $\gamma = 15$ . How many revolutions of the ring will an "average" muon make before it decays? The proper lifetime of a muon is  $2.2 \times 10^{-6}s$ .