Special Theory of Relativity – Problems

Name: _____ Date: _____

Time Dilation:

1. A tau (τ) particle has a lifetime measured at rest in the laboratory of $1.5\times10^{-13}s$. If it is accelerated to *0.950 c*, what will be its lifetime as measured in a) the laboratory frame of reference, and b) the τ particle's frame of reference?
   [a) $2.8\times10^{-13}s$ b) $1.5\times10^{-13}s$]

2. A rocket passes by Earth at a speed of *0.3000 c*. If a person on the rocket takes 245 s to drink a cup of coffee, according to his watch, how long would the same event take according to an observer watching from Earth?
   [257 s]

3. A kaon particle (κ) has a lifetime at rest in a laboratory of $1.2\times10^{-8}s$. At what speed must it travel to have its lifetime measured as $3.6\times10^{-8}s$.
   [*0.94 c*]

4. An astronaut who was 20 years old left to explore the galaxy in 1980, on a spaceship travelling at $2.5\times10^{8}m/s$. He returns in 2020. How old will he appear to be?
   [42 years old]

Length Contraction:

5. A spaceship passes you at the speed of 0.90 c. You measure its length to be 50.0 m. What is the length when at rest?
   [115 m]

6. A spacecraft travels along a space station platform at 0.65 c relative to the platform. An astronaut on the spacecraft determines the platform to be 300 m long. What is the length of the platform as measured by the observer on the platform?
   [395 m]

7. An asteroid has a long axis of 725 km. A rocket passes by parallel to the long axis at a speed of 0.250 c. What will the length of the long axis as measured by observers in the rocket?
   [702 km]

8. An electron is moving a 0.95 c parallel to a metre stick. How long will the metre stick be in the electron's frame of reference?
   [31 cm]

9. A spacecraft passes a spherical space station. Observers in the spacecraft see the station's minimum diameter as 265 m and the maximum diameter as 325 m. a) How fast is the spacecraft travelling relative to the space station? b) Why does the station not look like a sphere to the observers in the spacecraft?
   [a) *0.58 c*]

Mass Increase:

10. What is the relativistic mass of an electron moving at 0.999c in a linear accelerator? ($m_e = 9.11\times10^{-31} kg$) [$6.11\times10^{-21} kg$]

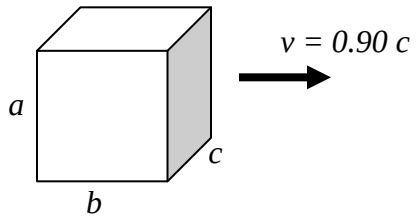
11. What would the mass of a 80 kg person be if they were travelling at 0.9 c?
    [184 kg]

12. A proton is moving at 0.6 c with respect to some inertial reference frame. Determine its relativistic momentum in that system. ($m_p = 1.67\times10^{-27} kg$) [$3.76\times10^{-19} kg\cdot m/s$]

Interesting Problems:

13. A spaceship goes past a planet at a speed of 0.80 c relative to the planet. An observer on the planet measures the length of the moving spaceship to be 40.0 m. The observer also finds that the planet has a diameter of $2.0\times10^{6} m$.
    a) The astronaut in the spaceship determines the length of the ship. What is the length?
    b) The astronaut, looks out and by some indirect method measures the diameter of the planet. What does he measure it to be?
    c) According to the observer on the planet, the spaceship takes 8.0 s to reach the next planet in the solar system. How long does the astronaut consider the journey to take?

14. A cube of aluminum 1.00 m by 1.00 m by 1.00 m is moving at *0.90 c*, in an orientation as shown. The rest density of aluminum is $2.70\times10^{3} kg/m^3$.



    a) Which of the three dimensions, *a*, *b*, or *c*, is affected b its motion?
    b) Calculate the relativistic volume.
    c) Calculate the relativistic mass.
    d) What is the density at *v = 0.90 c*?
    [*b*, 0.436 m^3, $6.18\times10^{3} kg$, $1.42\times10^{4} kg/m^3$]