Student #: _____ Student Name: _____

TOPIC 17: SPECIAL RELATIVITY

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. An atomic clock is placed in a jet airplane. The clock measures a time interval of 3600 s when the jet moves with speed 400 m/s. How much larger a time interval does an identical clock held by an observer at rest on the ground measure?

3. The muon is an unstable particle that spontaneously decays into an electron and two neutrinos. If the number of muons at $t = 0$ is N_0, the number N at time t is

$$N = N_0 e^{-t/\tau}$$

where $\tau = 2.20\,\mu s$ is the mean lifetime of the muon. Suppose the muons move at speed $0.95c$.

   (a) What is the observed lifetime of the muons?

   (b) How many muons remain after traveling a distance of 3.0 km? (The answer should be expressed in terms of N_0)

4. A muon has a lifetime of 2×10^{-6} s in its rest frame. It is created 100 km above the earth and moves toward it at a speed of 2.97×10^{8} m/s. At what altitude does it decay? According to the muon, how far did it travel in its brief life?

5. Two rockets of rest length L_0 are approaching the Earth from opposite directions at velocities $\pm c/2$, relative to Earth. How long does one of them appear to the other?

6. A body quadruples its momentum when its speed doubles. What was the initial speed in units of c, i.e. what was v/c?

7. A body of rest mass m_0 moving at speed v collides with and sticks to an identical body at rest. What is the mass M and momentum p' of the final clump?

8. The Starship Enterprise goes to a planet in a star system far away with a speed of $0.9c$, spends 6 months on the planet, and comes back with a speed of $0.95c$. The entire trip takes 5 years for the crew.
   (a) How far is the planet according to Earth observers?
   (b) How long did it take the crew to get to the planet?
   (c) How long did the entire trip take for the Earth observers?

   (Hints: For this kind of problems, instead of using SI units, it is much easier to scale the problem based on the speed of light: speed is measured in fraction of the speed of light (i.e. use $v = 0.95$ if Enterprise is travelling at $0.95c$), time is measured in *years*, and distance is measured in *light-years*.

9. A rocket ship leaves the Earth at a speed of $0.8c$. When a clock on the rocket says 1 hour has elapsed, the rocket ship sends a light signal back to Earth.
   (a) According to Earth clocks, when was the signal sent?
   (b) According to Earth clocks, how long after the rocket left did the signal arrive back on Earth?
   (c) According to the rocket clock, how long after the rocket left did the signal arrive back on Earth?

10. The spaceship Viking goes to a planet in a star system 30 light years away from Earth with a speed of $0.99c$, spends 1 year on the planet, and then returns home. The entire trip takes 10 years for the crew.
    (a) How far is the planet according to crew?
    (b) How long does it take the crew to get to the planet?
    (c) How long does it take the crew to return to Earth?
    (d) What is the speed of the crew on return? Warning! The distance for the crew is not the same as the distance on their way to the planet.
    (e) How far is the Earth from the planet according to crew on their return?
    (f) How long did the entire trip take for the Earth observers?