Worksheet 26.1 - Special Relativity – Chapter 26

Objective C: Time and mass dilation, length contraction:

Moving clocks run slowly, gain mass, and shrink in the dimension parallel to their velocity:

$$\gamma = \frac{1}{\sqrt{1 - \dfrac{v^2}{c^2}}} \qquad \Delta t = \gamma \Delta t_o \qquad L = \frac{L_o}{\gamma} \qquad \text{Not in the data packet:} \quad m = \gamma m_o$$

Problems for:
1. A clock flies by us at 0.780c. How much time will it take that clock to register 60.0 seconds? (95.9 s)
2. A clock flies by us at 0.780c. When a clock in our reference frame has registered 60.0 seconds, how much time has registered on the moving clock? (37.5 s)
3. A moving clock takes 61.0 s to register 60.0 s. How fast is it moving? (0.180 c)
4. A bus is 45.0 feet long at rest. If it is going by at 0.450c, what is its length as we observe it? What is its length as observed by people on the bus? If the bus goes through a tunnel that has a proper length of 45 feet, what length do the people in the bus observe it to be? Why is there not a single answer to the question "Does the bus fit inside the tunnel? (40.2 feet, 45.0 feet, 40.2 feet, depends which reference frame)
5. A car going 0.470c has a length of 14.0 feet. What is its length at rest? (15.9 feet)
6. What speed does a 45 foot long bus need to go to fit exactly into a tunnel that is 40. feet long? (0.46c)
7. What is the mass of a 0.142 kg baseball that is pitched by Optimus Prime at 2.89×10^8 m/s? By how much does the mass increase? Where does this mass come from? (0.529 kg, 0.387 kg, from the KE)
8. A particle going 0.740c has a mass of 2.49×10^{-27} kg. What is its rest mass? (1.67×10^{-27} kg)
9. An electron has a rest mass of 0.511 MeV, and a moving mass of 1.511 MeV. (This means it has 1.00 MeV of kinetic energy – it has been accelerated through 1.00 Million volts.) What is its speed ? (0.941c)
10. Particles that take 1.56×10^{-6} seconds to decay on the average at rest, are sped up so the average lifetime is now 2.31×10^{-6} seconds. What is the speed of the particles? How far do they travel before decaying? (0.738c, 511 m)
11. Easy from Chapter 26: 1(42.6 m), 2(2.07×10^{-6} s), 3(1.00, 0.9998, 0.980, 0.312, 0.199, 0.0447), 4(69.1 Ly)
12. Moderate from Chapter 26: 5(0.773c), 6(0.90c), 8(0.436c)
13. Challenging from Chapter 26: 7(26 y), 10(0.141c), 11(2.7 y, 9.2 y), 12(11.0 y, 3.09 y, 2.97 y, 0.96c), 13(6.39 m, 1.25 m, 15.0 s, 0.660c, 15.0 s), **14(0.887c)**

Objective I: Relativistic addition of velocities

$$u' = \frac{u - v}{1 - \dfrac{uv}{c^2}} \qquad\qquad u' = \frac{u + v}{1 + \dfrac{uv}{c^2}}$$

When you would subtract: **When you would add (Not in data packet):**

Questions:
14. Why can't you just add relativistic velocities like you do low velocities?

Problems:
15. Rob the hamster rides to the right on a cart going 0.360 c. He throws a baseball at 0.680 c relative to him to the right. What is the velocity of the baseball in the earth frame? (0.835 c right)
16. Rob rides to the right on a cart going 0.490c. He throws a baseball. We observe the baseball going 0.980c to the right relative to the earth frame. With what velocity did Rob throw the ball in his frame? (0.943c right)
17. Rob the hamster is riding a flatbed rail car to the right at 0.870c, and throws a baseball to the left at 0.560c. What is the velocity of the ball in the earth frame of reference? (0.605c to the right)
18. Rob rides to the right on a cart going 0.360 c. He throws a baseball at 0.720c to the left. What is the velocity of the ball in the earth frame? (-0.486c (left))
19. Goldy the goldfish is riding in a van going to the right at 0.820c, and throws a baseball so that we see it going 0.350c to the right in our frame of reference. What velocity did Goldy give the ball in his frame of reference? (0.659c to the left)
20. Rob rides to the right on a cart going 0.710c. He shines a torch in the direction he is going. How fast do we see the photons from the torch moving in the earth frame. What if he shines if backwards? (c, -c)
21. Problems from chapter 26: 43(0.80c), 44(0.80c, -0.80c), 45(0.98c, -0.42c), 46(0.65c), 47(0.92c), 48(0.70c)