**Worksheet 26 - Special Relativity – Chapter 26**

**Objective A: Ether and Michelson Morley**

Questions:

1. What was “Ether” supposed to be?
2. Why should their apparatus have detected the Earth’s motion in the ether? Why didn’t it?
3. What were a couple of ways people tried to explain the “null result” of the Michelson-Morley experiment?

**Objective B: Einstein’s gedanken and the postulates of relativity**

Questions:

1. What did Einstein imagine you would observe if you could catch up with a light wave? Why was this not possible
2. What are the 2 postulates of special relativity, and why are they really the same thing?

**Objective C: Time dilation – fast clocks run slowly**

**Objective D: Length contraction – objects shorten in the direction they are moving**

**Objective E: Mass dilation – moving objects gain mass as they gain energy**

**   Not in data packet: **

Questions:

1. Mass dilation is usually used to illustrate why an object with rest mass cannot exceed the speed of light. Outline this argument. (What would happen to the mass as you approached the speed of light, and what must be true about the energy needed to reach the speed of light?)

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 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)
4. What is the mass of a 0.142 kg baseball that is pitched by Optimus Prime at 2.89x108 m/s? By how much does the mass increase? Where does this mass come from? (0.529 kg, 0.387 kg, from the KE)
5. 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)
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. Particles that take 1.56x10-6 seconds to decay on the average at rest, are sped up so the average lifetime is now 2.31x10-6 seconds. What is the speed of the particles? How far do they travel before decaying? (0.738c, 511 m)
8. Easy from Chapter 26: 1(42.6 m), 2(2.07x10-6 s), 3(1.00, 0.9998, 0.980, 0.312, 0.199, 0.0447), 4(69.1 Ly)
9. Moderate from Chapter 26: 5(0.773c), 6(0.90c), 8(0.436c)
10. 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 F: The twin paradox**

Questions:

1. Describe the twin paradox.
2. Why might the twin paradox be construed to violate the postulates of special relativity?
3. Why does special relativity not apply to what the “there and back” twin does?

**Objective G: Simultaneity**

Questions:

1. Use length contraction to explain how a 15 foot pole can fit entirely within a 12 foot barn if someone runs fast enough. Explain what the runner sees, explain what we see. What does this have to do with simultaneity?

**Objective H: Relativistic kinetic energy**

**Kinetic Energy: Rest Energy:  Total or Moving energy: **

Questions:

1. Where does the mass come from when it dilates (increases) with velocity.

Problems:

1. A 1.2 kg object (rest mass) is moving at 2.85x108 m/s. What is its new mass, and what is its kinetic energy? (3.84 kg, 2.4x1017 J)
2. What velocity must an electron have when it is accelerated through 340. kV? mo = 9.11x10-31 kg = 0.511 MeV (0.800c)
3. A 0.00612 kg (rest mass) bullet is going so fast it has a (dilated) mass of 0.00645 kg. What is its kinetic energy, and what is its velocity (2.97x1013 J, 0.32c)
4. The LHC will accelerate protons to about 7 TeV. If a proton has a rest mass of 938 MeV, what is the velocity of the protons in the LHC? (0.999999991c)
5. Problems from chapter 26: 24(9x102 kg), 26(0.866c), 28(2.23×10-9 J, 6.46 × 10-18 kg m/s), 29(1.51×10-10 J, 8.70×10-19 kg m/s), 31(0.437c), 32(0.941c), 33(0.30c), 37(5.5×1019 J), 35(0.866c, 0.745c)

**Objective I: Relativistic addition of velocities**

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

Questions:

1. Why can’t you just add relativistic velocities like you do low velocities?

Problems:

1. Rob the hamster rides to the right on a cart going 0.36c. He throws a baseball at 0.68c relative to him in the direction he is going. How fast is the baseball going in the earth frame? (0.84c)
2. Rob rides to the right on a cart going 0.36c. He throws a baseball in the direction he is already going. We observe the baseball going 0.98c relative to the earth frame. How fast did Rob throw the ball in his frame? (0.96c)
3. Rob rides to the right on a cart going 0.36c. He throws a baseball at 0.68c to the left. What is the velocity of the ball in the earth frame? (Make right negative) (-0.42c)
4. Rob rides to the right on a cart going 0.36c. 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)
5. 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)

**Objective J: Relativistic Momentum p = γmou, **

Problems:

1. Problems from chapter 26: 15(8.1x10-19 kg), 17(0.38c), 30(7.48×10-19 kgm/s)
2. A particle has a momentum with magnitude 2.242x10-22 kg m/s and total energy 1.059x10-13 Joules. What is its rest mass? (9.09x10-31 kg)