Test: Relativity

Some equations you may need:

$$\beta = \frac{v}{c} \qquad \gamma = \frac{1}{\sqrt{1-\beta^2}} \qquad t = \gamma t_0 \qquad L = \frac{L_0}{\gamma} \qquad p = \gamma mv \qquad K = (\gamma - 1)E_0 \qquad E_0 = mc^2$$

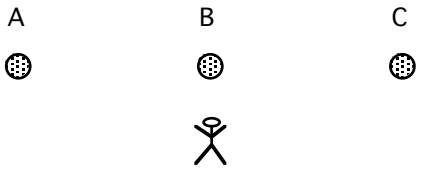
Some constants you may need:

$c = 3 \times 10^8$ m/s $\quad m_{electron} = 9.1 \times 10^{-31}$ kg $\quad m_{proton} = 1.7 \times 10^{-27}$ kg $\quad 1$ eV $= 1.6 \times 10^{-19}$ J

$\mu = 10^{-6}$ $\quad n = 10^{-9}$ $\quad p = 10^{-12}$ $\quad M = 10^{6}$ $\quad u = 1.66054 \times 10^{-27}$ kg

Multiple Choice*: Choose the letter of the best answer. 3 points each.*

Questions 1 to 2 refer to the following diagram:



1. _____ The lights are at rest and you travel by the three lights at very high speed to the right. In your reference frame, the lights all blink at the same time. In what order do they blink in their reference frame?
   a. ABC. b. CBA. c. BAC. d. at the same time.

2. _____ You are at rest and the lights travel by at very high speed to the right. In the light's reference frame, the lights all blink at the same time. In what order do they blink in your reference frame?
   a. ABC. b. CBA. c. BAC. d. at the same time.

Questions 3 to 8 refer to the following:

Particle X is traveling so fast that the Lorentz factor (γ) is equal to 4 and has a rest energy of 0.8 MeV.

3. _____ What is the mass of particle X?
   a. 0.36×10^{-30} kg. b. 1.42×10^{-30} kg. c. 4.26×10^{-30} kg. d. 5.68×10^{-30} kg.

4. _____ How fast is particle X going?
   a. 0.25c. b. 0.75c. c. 0.866c d. 0.968c

5. _____ What is the kinetic energy of particle X?
   a. 0.77 MeV. b. 0.80 MeV. c. 2.4 MeV. d. 3.2 MeV.

6. _____ If it were to speed up so that its Lorentz factor were to double, what would happen to its rest energy?
   a. It would also double.
   b. It would be cut in half.
   c. It would increase by a factor of 4.
   d. It would remain the same.

7. _____ Particle X flies across a lab table and measures the time it took to cross the table to be 2.4 ps. How long did it take in the lab table reference frame?
   a. 0.6 ps. b. 2.4 ps. c. 7.2 ps. d. 9.6 ps.

8. _____ Particle X flies down a hallway and measures the hallway to be 10 meters long. How long is the hallway for someone standing in the hallway?
   a. 40 m. b. 12 m. c. 10 m. d. 2.5 m.

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9. _____ The famous equation $E_0 = mc^2$ means that
   a. If you travel at the speed of light you explode into a massive burst of energy.
   b. The terms "mass" and "energy" are fundamentally the same thing.
   c. Light is actually energy.
   d. Everything is a lie.

10. _____ If you were to travel extremely close to the speed of light, you could reach stars thousands of light years away and only age a few years yourself. This is because
   a. Due to time dilation, your time would slow down.
   b. Due to length contraction, the distance doesn't seem as long to you.
   c. Both a and b are correct.
   d. Neither a or b are correct.

11. _____ A 100 m long ship flies by you at 0.88c. What do you measure the length of the ship to be?
   a. 47.5 m. b. 88 m. c. 114 m. d. 211 m.

Questions 12 and 13 refer to the following:
You and a friend go by each other at very high speed. You observe that your friends clocks are running slow and that your friend is shortened in the direction of travel.

12. _____ Which of the following statements are correct?
   a. Your friend agrees with you that their time is running slow.
   b. Your friend thinks that your time is running fast and theirs is normal.
   c. Your friend insists that your time is running slow and theirs is normal.
   d. Your friend says that both your clocks are running slow.

13. _____ Which of the following statements are correct?
   a. Your friend would be killed or maimed by the length contraction.
   b. Your friend would see you stretched out.
   c. You would be squeezed and killed by your length contraction.
   d. Your friend would think they are fine, but see you shortened in the direction of travel.

14. _____ A spaceship is coming at you with a speed of 0.95c. If the ship turns on a laser and fires the laser right at you, then
   a. Both you and the ship somehow measure the laser to travel with a speed c.
   b. The ship measures the laser to travel at speed c, but you measure it to something greater than c.
   c. You measure the laser to travel with speed c, but the ship measures it to be less than c.
   d. None of the above are correct.

15. _____ What is the Correspondance Principle?
   a. The laws of physics are the same in all reference frames.
   b. All "new" physics must reduce to the classical equations under the right circumstances.
   c. Two events cannot be simultaneous in two reference frames.
   d. Foreign journalists are always the first ones attacked by an angry mob.

16. _____ You watch two space ships fly by you – one traveling to the right with speed 0.6c and the other traveling to the left at 0.9c. How fast do the ships think they are traveling with respect to each other?
   a. Between 0.6c and 0.9c. b. Between 0.9c and 1.0c. c. 1.5c
   d. The answer depends on if the ships are approaching each other or going away from each other.
   e. None of the above are correct.

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Problem Solving: *Show all work. 8 points each.*

17. What are the two postulates of special relativity? *(2 points each.)*
    1.

    2.

18. Derive the expression for time dilation or length contraction. Make sure to explain what you are doing.

19. How fast is a particle going that has a total energy that is 5 times its rest energy?

20. A ship flies by a field at 0.9c. According to the ship, it takes 1.6 μs for the length of the ship to pass an observer on the field. How long does the observer on the field measure the ship to be?

Test: Relativity

21. How fast is a particle going that has a momentum equal to 2mc?

22. Imagine an atom that has a mass of 220 u. It somehow splits into two identical smaller atoms, releasing 300 MeV of energy in the process. What are the masses of the smaller atoms?

23. How fast, relative to earth, would a person have to travel so that they reach a star 8 light years away but only age 3 years?