Test: Relativity

Some equations you may need:

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

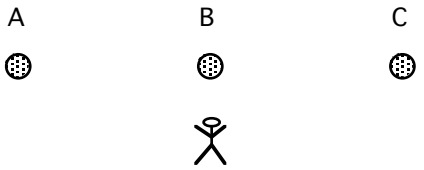
Some constants you may need:

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

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

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

Questions 1 to 3 refer to the following diagram:



1. _____ You are at rest and the lights travel by at very high speed to the left. 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.

2. _____ 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.

3. _____ In the lights reference frame, they blink in the order ABC. Which way do you have to travel in order to for you to conclude that the lights all blink at the same time?
   a. to the right. b. to the left. c. it depends on where to stand.
   d. it can't be done under any circumstances.

4. _____ Can an object of mass *m* have a momentum equal to *mc*?
   a. No, because it can't travel at the speed of light.
   b. No, because that is not the right equation.
   c. Yes, but only if it is a photon.
   d. Why not? It is just a number.

Questions 5 to 9 refer to the following:

Imagine a desk and a particle are moving with respect to each other such that the Lorentz factor is 3.1. The rest energy of the particle is also 500 MeV.

5. _____ If the particle crosses the desk in 1.65 x 10^{-9} seconds (particle time) how long did it take according to the desk?
   a. 1.58 x 10^{-8} s. b. 1.65 x 10^{-9} s. c. 5.12 x 10^{-9} s. d. 5.32 x 10^{-10} s.

6. _____ If the particle measures the desk to be 0.47 meters long, how long does the desk measure itself to be?
   a. 0.22 m. b. 1.46 m. c. 0.15 m. d. 0.99 m.

7. _____ What is the relative speed of the desk and the particle?
   a. 2.85 x 10^8 m/s. b. 2.69 x 10^8 m/s. c. 2.41 x 10^8 m/s. d. 2.03 x 10^8 m/s.

8. _____ What is the mass of the particle in kg?
   a. 8.9 x 10^{-28} kg. b. 3.5 x 10^{-28} kg. c. 2.8 x 10^{-27} kg. d. 2.9 x 10^{-28} kg.

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9. _____ What is the kinetic energy of the particle according to the desk?
   a. 1550 MeV. b. 1050 MeV. c. 550 MeV. d. 500 MeV.

10. _____ Imagine an atom with a mass of M is broken into 2 pieces of masses m and n. If $M > m+n$, which of the following must be true?
   a. It required energy to split the atom apart.
   b. Energy was released when the atom was split.
   c. There has to be third little piece of the atom somewhere (maybe it fell under the couch?)
   d. It can't have happened because of the Law of Conservation of Mass, and surely Ms. Marsh did not lie about that in chemistry.

11. _____ A rocket ship goes by you at 0.75c when it turns on its headlights. How fast do you measure the beams from the headlights to travel?
   a. 0.75c. b. between 0.75c and c. c. c. d. duh, 1.75c.

12. _____ A 4 meter long car goes by at such a high speed that you measure it to be 3 meters long. How fast was the car going?
   a. 0.44c. b. 0.87c. c. 0.75c. d. 0.66c

13. _____ What is the momentum (in kgm/s) of an electron moving at 0.6c?
   a. 2.73×10^{-22}. b. 1.64×10^{-22}. c. 2.05×10^{-22}. d. 3.41×10^{-22}.

14. _____ What is the rest energy of a particle with a mass of 1.2×10^{-29} kg?
   a. 4.22 MeV. b. 6.75 MeV. c. 10.8 MeV. d. 17.3 MeV.

15. _____ If an object's total energy is three times its kinetic energy, what is its Lorentz factor?
   a. 1.5. b. 2. c. 3. d. 4.

16. _____ In a lab, one electron is moving to the left at 0.7c while a second electron is moving to the right at 0.7c. The speed of one electron as measured from the other is
   a. 0.35c. b. 0.70c. c. 0.94c. d. 1.00c. e. 1.40c.

17. _____ A proton has a rest energy of 940 MeV while an electron has a rest energy of 510 keV. This means that
   a. The proton is moving faster than the electron.
   b. The electron is moving faster than the proton.
   c. The proton is hotter than the electron.
   d. The proton has more mass than the electron.

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Problem Solving: *Show all work.*

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

    2.

19. A ship flies by a field with a speed of 2.75×10^8 m/s. According to people standing on the field, the field is 1200 meters long. How long does it take the ship to cross the field, according to the ship?

20. How much work would it take to speed up a proton from 0.9c to 0.95c?

21. The mass of a particle is m. In order for its total energy to be twice its rest energy, what must be its momentum?

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22. Imagine you travel to a nearby star. According to the earth, your trip takes 10 years. According to you, the star was only 5 ly away. How fast were you going?

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