 $\beta = \sqrt{\frac{\gamma^2-1}{\gamma^2}}$ 2014 NAME: KEY

Test: Relativity

Some equations you may need:

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

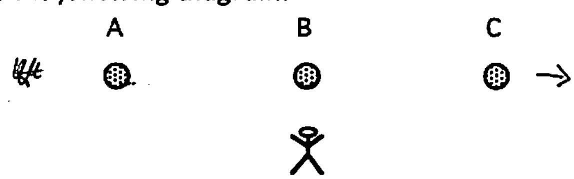
Some constants you may need:

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

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

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

Questions 1 and 2 refer to the following diagram:



$\gamma^2 = \frac{1}{1-\beta^2}$

$1-\beta^2 = \frac{1}{\gamma^2}$

$\beta^2 = 1 - \frac{1}{\gamma^2} = \frac{\gamma^2-1}{\gamma^2}$

1. __A__ You move to the right. The lights all blink at the same time in your reference frame. In what order to they blink in their reference frame?
   a. ABC. b. CBA. c. BCA. d. ACB.

2. __A__ You are at rest and the lights move to the right. The lights all blink at the same time in their reference frame. In what order to they blink in your reference frame?
   a. ABC. b. CBA. c. BCA. d. ACB.

3. __C__ A meson when at rest decays 2μs after it is created. If moving in the laboratory at 0.99c, its lifetime according to laboratory clocks would be: $\gamma = 7.09$
   a. 2 μs. b. 0.28 μs. c. 14 μs. d. 4.6 μs. e. None of those.

4. __E__ You somehow run to the right by your friend at 0.4c. You both have flashlights pointing to the right, which you both turn on. According to your friend, which of the following is true?
   a. Her flashlight beam moves at c and yours moves at 1.4c.
   b. Her flashlight beam moves at c and yours moves at something between c and 1.4c.
   c. Your flashlight beam moves at c and hers moves at something between 0.6c and c.
   d. Your flashlight beam moves at c and hers moves at 0.6c.
   e. Her flashlight beam moves at c and yours moves at c.

5. __E__ The special theory of relativity predicts that there is an upper limit to the speed of a particle. Therefor, there must also be an upper limit to a particle's
   a. total energy. b. kinetic energy. c. momentum.
   d. more than one of the above. e. there are no limits to any of those.

6. __B__ What is the kinetic energy of an electron moving with a speed of 0.95c? $\gamma = 3.2$
   a. 8.2×10^{-14} J. b. 1.8×10^{-13} J. c. 2.0×10^{-13} J. d. 2.2×10^{-13} J. e. 2.6×10^{-13} J.

7. __B__ What is the rest energy of a 65 kg person?
   a. 3.7×10^{37} J. b. 5.9×10^{18} J. c. 2.0×10^{10} J.
   d. Can't tell because you need to know how fast they are going.
   e. Can't tell because the object is too big; rest energy only matters for particles.

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Questions 8 to 11 refer to the following:

A particle flies by you so fast that its Lorentz factor (γ) is 2.5. It also has a kinetic energy equal to 2000 MeV. $2000 = (2.5-1)E_0 = 1.5 E_0$

8. C What is the rest energy of the particle?
a. 571 MeV. b. 800 MeV. c. 1333 MeV. d. 2000 MeV. e. 3000 MeV.

9. A How fast is the particle moving?
a. 0.92c. b. 0.84c. c. 0.75c d. 0.60c. e. 0.56c.

10. A You measure the room you are in to be 10 m wide. How wide does the particle measure the room to be? $L = \frac{1}{2.5} 10$
a. 4 m. b. 6.7 m. c. 10 m. d. 15 m. e. 25 m.

11. A According to you, the particle takes 5 ~~ps~~ ns to cross by your desk. How long does it take according to the particle? $5 = 2.5\,t$
a. 2 ns. b. 3.3 ns. c. 5 ns. d. 7.5 ns. e. 12.5 ns.

12. D If you were to drive by the classroom at close to the speed of light, what would you experience because of time dilation and length contraction?
a. You would feel your pulse to be really slow and see your car shortened.
b. You would feel your pulse to be really slow, but see your car as normal.
c. Your pulse would be normal, but you would see your car shortened.
d. You wouldn't notice anything strange about you or your car.
e. The monitors would get you for speeding through the parking lot. $\gamma = 2.29$

* 13. B What is the momentum (in kg•m/s) of a ~~proton~~ electron that is moving at 2.7×10^8 m/s?
a. 6.26×10^{-22}. b. 5.64×10^{-22}. c. 5.07×10^{-22}. d. 2.46×10^{-22}.

14. A Two smaller atoms can be combined to form a single larger atom. If the total mass of the smaller atoms is less than the mass of the single larger atom, then which of the following is true?
a. It takes energy to combine the two smaller atoms.
b. Energy is released when the two smaller atoms combine.
c. Need more information to tell which way the energy goes.
d. Huh?! The masses have to add up - it's called the Law of Conservation of Mass!

15. A Which of the following was one of Einstein's Postulates of Special Relativity?
a. The laws of physics are the same in all inertial reference frames.
b. Energy and mass are actually interchangeable.
c. Time is relative.
d. Classic physics is wrong.
e. All of the above.

$2.29\,(1.7 \times 10^{-27})(2.7 \times 10^{8})$

1.05×10^{-18}

15 @ 3 = 45
~~4 @ 5 =~~
4 @ 14 = 56
= 101

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Problem Solving: *Show all work.* 13 @ is 4

16. The length of a ship passes by you at 0.85c in 12 μs. How long do people on the ship measure the ship to be?

$\beta = .85 \rightarrow \gamma = 1.90$

$t_o = 12\ \mu s$

$L_o = ?$

or $t = \gamma t_o = 22.8\ \mu s$

$L_o = vt$

$L = v t_o$

$= (.85)(3\times10^8)(12\times10^{-6})$

$L = 3060\ m$

$L = \frac{1}{\gamma} L_o$

$L_o = \gamma L = (1.9)(3060) =$

$L_o = 5814\ m$

no 1/4

17. If we intercept an electron having total energy 2533 MeV that came from Vega, which is 26 ly from us, how far in light-years was the trip according to the electron?

$\hookrightarrow L_o = 26\ ly$

$E = \gamma E_o = \gamma mc^2$

$(2533\times10^6) = \gamma \dfrac{(9.1\times10^{-31})(3\times10^8)^2}{(1.6\times10^{-19}\ J/eV)}$

$\gamma = 4949 = \dfrac{1}{\sqrt{1-\beta^2}} \dashrightarrow \beta = \sqrt{\dfrac{\gamma^2-1}{\gamma^2}}$

don't need!

$\beta = .999999979$

$L = \frac{1}{\gamma} L_o = \frac{1}{4949} \cdot 26$

$L = .00525\ ly$

18. Imagine a proton is moving so fast that its actual momentum were four times what its "classical" momentum would be. How much work would it take to accelerate a proton from rest to that speed?

$\gamma mv = 4mv \rightarrow \gamma = 4$

$W = K \rightarrow K = (\gamma - 1)E_o = (\gamma - 1)mc^2$

$= (4-1)(1.7\times10^{-27})(3\times10^8)^2$

$= 4.59\times10^{-10}\ J$

$(= 2870\ MeV)$

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