University of Alabama
Department of Physics and Astronomy

PH 102-1 / LeClair Summer II 2008

Problem Set 1: Relativity

Instructions:

1. Answer all questions below. Show your work for full credit.
2. Due before 3pm, 14 July 2008
3. Email submission: pleclair@ua.edu
4. Hard copies: Gallalee 206 or Bevill 228; at the *beginning* of the lab period.
5. You may collaborate, but everyone must turn in their own work

1. 5 points. Neutrons have an average lifetime of 15 minutes when at rest in the laboratory. What is the average lifetime (measured in the lab) of a neutron moving at a speed of **(a)** 25% of the speed of light? **(b)** 50%? **(c)** 95%?

2. 5 points. If a moving clock has a time dilation factor of 10, what is its speed?

3. 10 points. A bassist taps the lowest E on his bass at 140 beats per minute during one portion of a song. What tempo would an observer on a ship moving *toward* the bassist at $0.70c$ hear?

4. 10 points. Two identical spaceships are traveling in the same direction. An observer on earth measures the first to have a speed of $0.80c$, and observes the second to be 1.50 times as long as the first one. What is the speed of the second spaceship, relative to the earth?

5. 10 points. A radioactive atom in a beam produced by an accelerator has a speed of $0.80c$ relative to the laboratory. The atom decays and ejects an electron of speed $0.50c$ relative to itself. What is the speed of the electron relative to the laboratory if ejected in **(a)** the forward direction? **(a)** The backward direction?

6. 10 points. Show that the velocity of a relativistic particle can be expressed as follows:

$$\vec{\mathbf{v}} = \frac{c\,\vec{\mathbf{p}}}{\sqrt{m^2c^2 + p^2}}$$

7. 15 points. Suppose that a spaceship traveling at $0.80c$ through our solar system suffers a totally inelastic collision with a small meteoroid of mass 2.0 kg. **(a)** What is the kinetic energy of the meteoroid in the reference frame of the spaceship? **(b)** In the collision all of this kinetic energy suddenly becomes available for inelastic processes that damage the spaceship. The effect on the spaceship is similar to an explosion. How many tons of TNT will release the same explosive energy? One ton of TNT releases $\approx 4.2\times10^9$ J.

8. 10 points. Given $\vec{\mathbf{p}} = \gamma m \vec{\mathbf{v}}$ and $E = \gamma mc^2$, derive the relationship $E^2 = c^2p^2 + m^2c^4$.

9. 10 points. Combustion of gasoline releases 1.3×10^8 J of energy. **(a)** How much mass is converted to energy? **(b)** Compare this with 2.8 kg, the mass of one gallon of gasoline.

10. 15 points. *Research Problem: one page, double spaced, 1 inch margins.* According to special relativity, the time order of events can be reversed under certain conditions. Does this violate causality? That is, could a ball hit the ground before it had been thrown?