PS303 Modern Physics Exam 1

February 12, 2015

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Name

Guidelines: This is a 50-minute closed-book, closed-notes exam. You can use a calculator.

Problems 1-6: **Each problem is worth 5 points,**
3 points for selecting the correct answer, 2 points for showing sufficient work to justify your answer.

Problems 7-8: **Each problem is worth 10 points**

5 points

1. A certain particle at rest lives for 1.25 ns. When the particle moves through the laboratory at a speed of $0.91c$, what is its lifetime according to an observer in the laboratory?

   (a) 0.52 ns
   (b) 3.01 ns
   (c) 1.25 ns
   (d) 7.27 ns

5 points

2. Two electrons, each with a kinetic energy of 2.52 MeV, collide head-on to produce a new particle what is the rest energy of this new particle?

   (a) Zero
   (b) 5.04 MeV
   (c) 6.06 MeV
   (d) 9.54 MeV

5 points

3. An unstable particle moving through the laboratory leaves a track of length 3.52 mm. The particle is moving at a speed of 0.943c. How long would the particle's track appear to someone moving with the particle?

   (a) 1.17 mm
   (b) 10.6 mm
   (c) 3.52 mm
   (d) 0.390 mm
   (e) None of these

5 points

4. A certain particle has a proper lifetime of 1.00×10^{-8} s. It is moving through the laboratory at a speed of $0.85c$. What distance does the particle travel in the laboratory?

   (a) 2.55 *m*
   (b) 4.84 *m*
   (c) 1.34 *m*
   (d) 9.19 *m*

5 points

5. Two particles each of mass *m* are each moving with a speed of $1/\sqrt{2}\ c$ directly toward one another. After the head-on collision, all that remains is a new particle of mas *M*. What is the mass of this new particle?

   (a) $0.5m$
   (b) $1.0m$
   (c) $2.0m$
   (d) $2.8m$
   (e) $4.0m$

5 points

6. An unstable particle is moving with a speed of 0.80c in the laboratory. It decays in flight with one of the "daughter" particles moving in the same direction at a speed of 0.60c as measured in the unstable particle's frame. How fast is the "daughter particle moving in the laboratory frame?

   (a) $0.521c$
   (b) $0.755c$
   (c) $0.830c$
   (d) $0.917c$
   (e) $0.946c$

10 points **Show your work**

7. Particle A has a rest energy of 1192 MeV and is moving through the laboratory in the positive x direction with a speed of $0.45c$. It decays into particle B (rest energy=1116 MeV) and a photon; particle A disappears in the decay process. Particle B moves at a speed of $0.40c$ at an angle of 3.03° with respect to the positive x axis.

   a. Find the energy of the photon (E_γ).

E_γ = _____ MeV

   b. Find the direction of the scattered photon.

θ = _____ degrees

10 points **Show your work**

8. A star is at rest relative to the Earth and at a distance of 1500 light-years. An astronaut wishes to travel from Earth to the star and age no more than 30 years during the entire round-trip journey.

   a. Assuming that the journey is made at constant speed and that the acceleration and deceleration intervals are very short compared with the rest of the journey, what speed is necessary for the trip?

v = _____ c

   b. According to the astronaut, what is the distance between the Earth and the star?

L_o = _____ light-years

   c. According to someone on Earth, how long does it take the astronaut to make the round trip?

τ = _____ years

d. It takes light 1500 years to travel from Earth to the star, but the astronaut only ages 15 years. Does this mean that the astronaut travels faster than light?

Circle one: Yes No

Explain your answer:

Useful Constants: $m_{proton} = 938.3$ MeV $m_{electron} = 0.511$ MeV
$m_{photon} = 0$ MeV