MidTerm I - Modern Physics for Engineers

October 11, 1999

Test No. ____________________

Name: ____________________

S.S. No.: ____________________

Do all work in this exam booklet. Use the backs of the sheets if necessary. The equation sheet is reproduced below. Please compute all numerical answers using your calculator if necessary. If the problem requires an integration, leave the answer as an integral. It is not necessary to evaluate the integral.

Good luck.

EQUATION SHEET

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \qquad \beta = \frac{v}{c} \qquad f\lambda = c$$

$$x' = \gamma(x + \beta ct) \qquad p' = \gamma(p + \beta E/c)$$

$$t' = \gamma(t + \beta x/c) \qquad E' = \gamma(E + \beta cp)$$

$$E^2 = p^2c^2 + m^2c^4 \qquad KE = E - mc^2$$

$$\vec{p}_i = \vec{p}_f \qquad f' = f\sqrt{\frac{1-\beta}{1+\beta}}$$

$$E_i = E_f \qquad v' = \frac{v+u}{1+uv/c^2}$$

Problem I Short Answers - 5 points each

1. What did the Michelson-Morley experiment show about the aether?

The Michelson-Morley experiment showed that the aether (the medium inwhich light waves travelled) was stationary with respect to the surface of the earth. Since that would be hard to believe with respect to a rotating earth, it was inferred that the aether did not exist.

2. How much energy (in joules) is released when a gram of Am^{241} nuclei alpha decays into into Np^{237} and He^4. The atomic weights of Am^{241}, Np^{237}, and He^4 are 243.061372 u, 239.052933 u, 4.002603 u respectively. 1 u = 1.66054×10^{-27} kg and Avogadro's number is 6.02×10^{23}.

Mass difference = 243.061372 u - 239.052933 u - 4.002603 u = .005836 u. Energy difference/atom = Δmc^2 = .005836 u * 1.66054×10^{-27} kg/u * $(3 \times 10^8 \text{ m/sec})^2$ = 8.72×10^{-13} joules/atom. 1 gm Am = 1 gm/243.06 gm/mole * 6.02×10^{23} atoms/mole = 2.48×10^{21} atoms. Total energy released = 8.72×10^{-13} joules/atom * 2.48×10^{21} atoms = 2.16×10^9 joules.

3. A neutron takes about 10.6 minutes to decay when at rest in the laboratory. If the neutron is flying by at a velocity of 99.99% of the speed of light, how far will it travel before it decays?

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} = 7.07$$

$$\begin{aligned} x_{lab} &= vt_{lab} = \beta c t_{lab} \\ &= \beta c \gamma t_{rest} \\ &= .9999 * 3 \times 10^8 \ m/sec * 7.07 * 636 \ sec \\ &= 1.35 \times 10^{12} \ m \end{aligned}$$

4. A deep space probe is moving away from earth at a velocity of .9c. It sends us its findings via flashes of a ruby laser (wave length = 670 nm). At what wave length must we look to see the signal?

$$\lambda = \lambda_0 \sqrt{\frac{1+\beta}{1-\beta}} = 670\sqrt{\frac{1.9}{.1}} = 2920\ nm$$

Problem II - 20 points

A kaon (rest mass = 498 MeV/c^2) is moving in the laboratory with a momentum of 5000 MeV/c. As it is moving, it decays into two pions (rest mass = 139 MeV/c^2) each of which moves in the same direction as the original kaon. What are the momenta of each of the pions? Note that the pion momenta are not the same.

See Mathematica solution at:

http://www.physics.uc.edu/ johnson/Modern.Physics/mt1_f99.nb