Solutions to Problems in Goldstein, *Classical Mechanics*, Second Edition

Homer Reid

August 22, 2000

Chapter 1

Problem 1.1

A nucleus, originally at rest, decays radioactively by emitting an electron of momentum 1.73 MeV/c, and at right angles to the direction of the electron a neutrino with momentum 1.00 MeV/c. (The MeV (million electron volt) is a unit of energy, used in modern physics, equal to 1.60×10^{-6} erg. Correspondingly, MeV/c is a unit of linear momentum equal to 5.34×10^{-17} gm-cm/sec.) In what direction does the nucleus recoil? What is its momentum in MeV/c? If the mass of the residual nucleus is 3.90×10^{-22} gm, what is its kinetic energy, in electron volts?

Place the nucleus at the origin, and suppose the electron is emitted in the positive y direction, and the neutrino in the positive x direction. Then the resultant of the electron and neutrino momenta has magnitude

$$|\mathbf{P}_{e+\nu}| = \sqrt{(1.73)^2 + 1^2} = 2 \text{ MeV}/c,$$

and its direction makes an angle

$$\theta = \tan^{-1} \frac{1.73}{1} = 60^\circ$$

with the x axis. The nucleus must acquire a momentum of equal magnitude and directed in the opposite direction. The kinetic energy of the nucleus is

$$T = \frac{p^2}{2m} = \frac{4 \text{ MeV}^2 \ c^{-2}}{2 \cdot 3.9 \cdot 10^{-22} \text{ gm}} \cdot \frac{1.78 \cdot 10^{-27} \text{ gm}}{1 \text{ MeV} \ c^{-2}} = 9.1 \text{ ev}$$

This is much smaller than the nucleus rest energy of several hundred GeV, so the non-relativistic approximation is justified.

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