Solutions to Problems in Goldstein, Classical Mechanics, Second Edition

Homer Reid

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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^{-29} 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

$$|\mathbf{p}_{\mathbf{e}+\nu}| = \sqrt{(1.73)^3 + 1^2} = 2 \text{ MeV/c},$$

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

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

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

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 - Advantages of eBooks Over Traditional Books
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 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
- 3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Goldstein Classical Mechanics Solutions Manual Scribd
 - User-Friendly Interface
- 4. Exploring eBook Recommendations from Goldstein Classical Mechanics Solutions Manual Scribd
 - Personalized Recommendations
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 - Participating in Virtual Book Clubs
 - o Following Authors and Publishers Goldstein Classical Mechanics Solutions Manual Scribd
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 - Benefits of a Digital Library
 - o Creating a Diverse Reading Collection Goldstein Classical Mechanics Solutions Manual Scribd
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Goldstein Classical Mechanics Solutions Manual Scribd
 - Setting Reading Goals Goldstein Classical Mechanics Solutions Manual Scribd
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Goldstein Classical Mechanics Solutions Manual Scribd
 - Fact-Checking eBook Content of Goldstein Classical Mechanics Solutions Manual Scribd
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development

- Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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