

Chapter 1

Neutron-Nucleus Interactions and Fission

The central problem in nuclear-reactor kinetics is to predict the evolution in time of the neutron population in a multiplying medium. Point kinetics allows the study of the global behaviour of the neutron population from the average properties of the medium. Before tackling, in the following chapters, the equations governing the time variation of the reactor power (proportional to the total neutron population), we shall discuss briefly the properties of a neutron-multiplying medium. After recalling a number of definitions, we shall give a qualitative description of the principal nuclear reactions at play in a self-sustaining chain reaction, and dwell on the source of fission neutrons. Since delayed neutrons play a crucial role in reactor kinetics, we shall describe in greater detail their production in a reactor.

1.1 Neutron-Nucleus Interactions

A neutron is an elementary particle. It is stable when bound to a nucleus by the nuclear force. In its free state, a neutron decays, with a time constant of 12 minutes, to a proton, accompanied by the emission of a β^- particle and an antineutrino. In view of the fact that free neutrons in a reactor either are absorbed in matter or escape, on a time scale of less than 10^{-5} s, it is clear that neutron instability is completely negligible in reactor physics.

The power generated in a reactor comes from neutron-induced fissions. It results from the interaction between the neutrons and the nuclei of the physical medium. It is generally possible to neglect neutron-neutron interactions, because the density of neutrons is much smaller than that of nuclei. Free neutrons have a certain speed relative to nuclei. If one neglects the energy of thermal motion of the nuclei, the kinetic energy E of a neutron represents the energy available to a nuclear reaction between it and a nucleus. If we denote the relative speed of a neutron by v and its mass by m , then

$$E = \frac{1}{2}mv^2 \quad (1-1)$$

The energy is generally given in units of electron-volts ($1 \text{ eV} = 1.6021 \times 10^{-19} \text{ J}$).

1.1.1 Cross Sections

Interactions of neutrons with matter are described in terms of quantities called cross sections, which can be defined in the following fashion. Imagine a unidirectional neutron beam with a density of n neutrons per cm^2 , of speed v , impinging perpendicularly on a thin slice of a target with a density of N identical nuclei per cm^2 . Define the neutron flux ϕ by

$$\phi = nv \quad (1-2)$$

¹ The speed of neutrons in a reactor is sufficiently low that one can neglect relativistic effects. Therefore $m = m_0$, the neutron rest mass ($1.6748 \times 10^{-27} \text{ kg}$).

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Mohanakrishnan,Om Pal Singh,K. Umasankari,2021-05-19 Physics of Nuclear Reactors presents a comprehensive analysis of nuclear reactor physics Editors P Mohanakrishnan Om Pal Singh and Kannan Umasankari and a team of expert contributors combine their knowledge to guide the reader through a toolkit of methods for solving transport equations understanding the physics of reactor design principles and developing reactor safety strategies The inclusion of experimental and operational reactor physics makes this a unique reference for those working and researching nuclear power and the fuel cycle in existing power generation sites and experimental facilities The book also includes radiation physics shielding techniques and an analysis of shield design neutron monitoring and core operations Those involved in the development and operation of nuclear reactors and the fuel cycle will gain a thorough understanding of all elements of nuclear reactor physics thus enabling them to apply the analysis and solution methods provided to their own work and research This book looks to future reactors in development and analyzes their status and challenges before providing possible worked through solutions Cover image Kaiga Atomic Power Station Units 1 4 Karnataka India In 2018 Unit 1 of the Kaiga Station surpassed the world record of continuous operation at 962 days Image courtesy of DAE India Includes methods for solving neutron transport problems nuclear cross section data and solutions of transport theory Dedicates a chapter to reactor safety that covers mitigation probabilistic safety assessment and uncertainty analysis Covers experimental and operational physics with details on noise analysis and failed fuel detection U.S. Government Research & Development Reports ,1965-12 *The Physics of Nuclear Reactors* Serge

Marguet,2018-02-26 This comprehensive volume offers readers a progressive and highly detailed introduction to the complex behavior of neutrons in general and in the context of nuclear power generation A compendium and handbook for nuclear engineers a source of teaching material for academic lecturers as well as a graduate text for advanced students and other non experts wishing to enter this field it is based on the author s teaching and research experience and his recognized expertise in nuclear safety After recapping a number of points in nuclear physics placing the theoretical notions in their historical context the book successively reveals the latest quantitative theories concerning The slowing down of neutrons in matter The charged particles and electromagnetic rays The calculation scheme especially the simplification hypothesis The concept of criticality based on chain reactions The theory of homogeneous and heterogeneous reactors The problem of self shielding The theory of the nuclear reflector a subject largely ignored in literature The computational methods in transport

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Table of Contents Solution Manual Fundamentals Of Nuclear Reactor Physics

1. Understanding the eBook Solution Manual Fundamentals Of Nuclear Reactor Physics
 - The Rise of Digital Reading Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Advantages of eBooks Over Traditional Books
2. Identifying Solution Manual Fundamentals Of Nuclear Reactor Physics
 - 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 Solution Manual Fundamentals Of Nuclear Reactor Physics
 - User-Friendly Interface
4. Exploring eBook Recommendations from Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Personalized Recommendations
 - Solution Manual Fundamentals Of Nuclear Reactor Physics User Reviews and Ratings
 - Solution Manual Fundamentals Of Nuclear Reactor Physics and Bestseller Lists

5. Accessing Solution Manual Fundamentals Of Nuclear Reactor Physics Free and Paid eBooks
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 - Solution Manual Fundamentals Of Nuclear Reactor Physics Budget-Friendly Options
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 - Solution Manual Fundamentals Of Nuclear Reactor Physics Compatibility with Devices
 - Solution Manual Fundamentals Of Nuclear Reactor Physics Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Highlighting and Note-Taking Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Interactive Elements Solution Manual Fundamentals Of Nuclear Reactor Physics
8. Staying Engaged with Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Solution Manual Fundamentals Of Nuclear Reactor Physics
9. Balancing eBooks and Physical Books Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Solution Manual Fundamentals Of Nuclear Reactor Physics
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Setting Reading Goals Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Solution Manual Fundamentals Of Nuclear Reactor Physics
 - Fact-Checking eBook Content of Solution Manual Fundamentals Of Nuclear Reactor Physics
 - 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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