

The corresponding homogeneous integral equation

$$u(x) = \mu \int_0^\pi \mathcal{G}(x, y) u(y) dy, \quad 0 \leq x \leq \pi,$$

is equivalent to (29*). In particular, we get

$$u_n(x) = \mu_n \int_0^\pi \mathcal{G}(x, y) u_n(y) dy, \quad 0 \leq x \leq \pi, \quad n = 1, 2, \dots \quad (31)$$

Finally, recall that the inner product on $L_2(0, \pi)$ is given by

$$(f | g) := \int_0^\pi f(x) g(x) dx.$$

Ad (i). This follows from Proposition 4(i) in Section 4.4.

Ad (ii). It follows from Proposition 4(ii) in Section 4.4 that (30) has a solution iff

$$(b | u_n) = 0.$$

By (31),

$$\begin{aligned} (b | u_n) &= \int_0^\pi \left(\int_0^\pi \mathcal{G}(x, y) f(y) dy \right) u_n(x) dx \\ &= \int_0^\pi \left(\int_0^\pi \mathcal{G}(x, y) u_n(x) dx \right) f(y) dy = \int_0^\pi \mu_n^{-1} u_n(y) f(y) dy \\ &= \mu_n^{-1} (f | u_n), \end{aligned}$$

since $\mathcal{G}(x, y) = \mathcal{G}(y, x)$ for all $x, y \in [a, b]$. Therefore, $(b | u_n) = 0 \Leftrightarrow (f | u_n) = 0$.

Observe that $u \in D(A)$. By (iii), there exists a function $w \in \text{span}\{u_1, u_2, \dots\}$ such that

$$\Delta := \max_{0 \leq x \leq \pi} |u(x) - w(x)| < \varepsilon.$$

Hence

$$\|u - w\| = \left(\int_0^\pi (u(x) - w(x))^2 dx \right)^{\frac{1}{2}} \leq \pi^{\frac{1}{2}} \Delta < \pi^{\frac{1}{2}} \varepsilon.$$

This implies

$$\|v - w\| \leq \|v - u\| + \|u - w\| < \varepsilon + \pi^{\frac{1}{2}} \varepsilon.$$

Thus, the set $\text{span}\{u_1, u_2, \dots\}$ is dense in $L_2(0, \pi)$.

Applied Functional Analysis Applied Functional Analysis

A. V. Balakrishnan



Applied Functional Analysis Applied Functional Analysis:

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Table of Contents Applied Functional Analysis Applied Functional Analysis

1. Understanding the eBook Applied Functional Analysis Applied Functional Analysis
 - The Rise of Digital Reading Applied Functional Analysis Applied Functional Analysis
 - Advantages of eBooks Over Traditional Books
2. Identifying Applied Functional Analysis Applied Functional Analysis
 - 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 Applied Functional Analysis Applied Functional Analysis
 - User-Friendly Interface
4. Exploring eBook Recommendations from Applied Functional Analysis Applied Functional Analysis
 - Personalized Recommendations
 - Applied Functional Analysis Applied Functional Analysis User Reviews and Ratings
 - Applied Functional Analysis Applied Functional Analysis and Bestseller Lists
5. Accessing Applied Functional Analysis Applied Functional Analysis Free and Paid eBooks
 - Applied Functional Analysis Applied Functional Analysis Public Domain eBooks
 - Applied Functional Analysis Applied Functional Analysis eBook Subscription Services
 - Applied Functional Analysis Applied Functional Analysis Budget-Friendly Options
6. Navigating Applied Functional Analysis Applied Functional Analysis eBook Formats

- ePub, PDF, MOBI, and More
- Applied Functional Analysis Applied Functional Analysis Compatibility with Devices
- Applied Functional Analysis Applied Functional Analysis Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Applied Functional Analysis Applied Functional Analysis
 - Highlighting and Note-Taking Applied Functional Analysis Applied Functional Analysis
 - Interactive Elements Applied Functional Analysis Applied Functional Analysis
- 8. Staying Engaged with Applied Functional Analysis Applied Functional Analysis
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Applied Functional Analysis Applied Functional Analysis
- 9. Balancing eBooks and Physical Books Applied Functional Analysis Applied Functional Analysis
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Applied Functional Analysis Applied Functional Analysis
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Applied Functional Analysis Applied Functional Analysis
 - Setting Reading Goals Applied Functional Analysis Applied Functional Analysis
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Applied Functional Analysis Applied Functional Analysis
 - Fact-Checking eBook Content of Applied Functional Analysis Applied Functional Analysis
 - 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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