

REAL ANALYSIS QUALIFYING EXAMS

MINH KHA

ABSTRACT. Here are some of my own solutions of recent qualifying exams of Real Analysis in TAMU. For three exams Jan 2013, August 2012 and January 2012, I type all full solutions. For previous exams before 2012, I type solutions of some selected problems. Sometimes, there are some comments and similar exercises after some problems. This is written for my Real Analysis Qualifying Exam Preparation Course in Summer 2013 at TAMU.

1. JANUARY 2013

Problem 1: Let f be a Lebesgue integrable, real valued function on $(0, 1)$ and for $x \in (0, 1)$ define

$$g(x) = \int_x^1 t^{-1} f(t) dt \quad (1)$$

Show that g is Lebesgue integrable and $\int_0^1 g(x) dx = \int_0^1 f(x) dx$.

Proof. Since $f(t)/t$ is measurable, we could approximate it by a sequence of simple functions on $(0, 1)$. Hence, g is Lebesgue measurable. Applying Fubini theorem for $t^{-1}|f(t)|$,

$$\int_0^1 |g(x)| dx \leq \int_0^1 \int_x^1 |t^{-1} f(t)| dt dx = \int_0^1 t^{-1} |f(t)| \int_0^t dx dt = \|f\|_1 < \infty \quad (2)$$

Thus g is Lebesgue integrable.

The identity (1) is proved by Fubini theorem again since g is integrable now. \square

Problem 2: Let $f_n \in C[0, 1]$. Show that $f_n \rightarrow 0$ weakly if and only if the sequence $(\|f_n\|)_{n=1}^{\infty}$ is bounded and f_n converges pointwise to 0.

Proof. $f_n \rightarrow 0$ weakly iff for any nonnegative Borel measure μ on $[0, 1]$, then

$$\int_0^1 f_n d\mu \rightarrow 0 \quad (3)$$

Moreover, f_n converges pointwise to 0 iff for any $x_0 \in [0, 1]$, (3) is satisfied for $\mu = \delta_{x_0}$.

Assume (3). Since $L^1[0, 1]^* = L^\infty[0, 1]$, $\|f_n\| = \sup_{\|g\|_1 \leq 1} |\int_0^1 f_n g dx|$. If we view each f_n as a linear functional on $L^1[0, 1]$ and since $\sup_n |\int_0^1 f_n g dx| < \infty$ for each

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Michael Seilmaier



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Table of Contents Real Analysis Qualifying Exam Solutions

1. Understanding the eBook Real Analysis Qualifying Exam Solutions
 - The Rise of Digital Reading Real Analysis Qualifying Exam Solutions
 - Advantages of eBooks Over Traditional Books
2. Identifying Real Analysis Qualifying Exam Solutions
 - 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 Real Analysis Qualifying Exam Solutions
 - User-Friendly Interface
4. Exploring eBook Recommendations from Real Analysis Qualifying Exam Solutions
 - Personalized Recommendations
 - Real Analysis Qualifying Exam Solutions User Reviews and Ratings
 - Real Analysis Qualifying Exam Solutions and Bestseller Lists
5. Accessing Real Analysis Qualifying Exam Solutions Free and Paid eBooks

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