

# Abstract Algebra MAT02B3 / MAT3B20

Solutions to the Exam - November 2021

Marks: 39 ..... total time 3 hours

## Question 1

[0.5+2+ 1.5+2=6]

(a) Define what is meant by a group.

*A: A group is a non-empty set  $G$  with a binary operation on  $G$  that satisfies:*

*(1) for all  $a, b, c \in G$ :  $a(bc) = (ab)c$  (associativity),*

*(2) there exists an element  $e \in G$  such that for all  $a \in G$ :  $ae = ea = a$ ,*

*(3) for all  $a \in G$  there exists an element  $b$  with  $ab = ba = e$  (inverse element).*

(b) Let  $G$  be the set of all  $2 \times 2$ -matrices of the form

$$\begin{pmatrix} 0 & a \\ b & 0 \end{pmatrix},$$

where  $a$  and  $b$  are real numbers. Is  $G$  a group under matrix addition? Prove your answer.

*A:  $G$  is a group. Clearly  $G \neq \emptyset$ . If  $A = \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix}$  and  $B = \begin{pmatrix} 0 & b_1 \\ b_2 & 0 \end{pmatrix}$  are matrices in  $G$ , then clearly*

$$A + B = \begin{pmatrix} 0 & a_1 + b_1 \\ a_2 + b_2 & 0 \end{pmatrix}$$

*is an element of  $G$ . Hence  $G$  is closed under matrix addition.*

*(1) Since matrix addition is associative for all  $2 \times 2$  matrices, it is also associative for all matrices in  $G$ .*

*(2) The matrix  $\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$  is an identity element for matrix addition since*

$$\begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix} + \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix}, \quad \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} + \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix} = \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix}.$$

*Moreover,  $\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix} \in G$ .*

*(3) For a given  $A \in G$ ,  $A = \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix}$ , define  $-A = \begin{pmatrix} 0 & -a_1 \\ -a_2 & 0 \end{pmatrix}$ . Then*

$$A + -A = \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix} + \begin{pmatrix} 0 & -a_1 \\ -a_2 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix},$$

$$-A + A = \begin{pmatrix} 0 & -a_1 \\ -a_2 & 0 \end{pmatrix} + \begin{pmatrix} 0 & a_1 \\ a_2 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}.$$

*hence  $-A$  is the inverse of  $A$ . Moreover,  $-A$  is clearly in  $G$ .*

*Since  $G$  satisfies all group axioms,  $G$  is a group.*

(c) Let the set  $G$  be defined by

$$G = \{2^k \mid k \in \mathbb{Z}\} \cup \{0\}.$$

Prove that  $G$  is not a group under the usual addition.

*A: The set  $G$  is not closed under addition. For example  $2^1 + 2^0 = 3 \notin G$ . Hence  $G$  is not a group.*

(d) State what is meant by the "socks-shoes property", and prove that every group has this property.

*A: The socks-shoes property states that for elements  $a, b$  of a group  $G$ , the inverse of  $ab$  is  $b^{-1}a^{-1}$ .*

# Abstract Algebra Exam Solutions

**A Gutmann**



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*Library of Congress Subject Headings* Library of Congress,2010      **United States Air Force Academy** United States Air Force Academy,1968      *Innovations in Teaching Abstract Algebra* Allen C. Hibbard, Ellen J. Maycock,2002      *Cracking the GRE Math Subject Test* Steven A. Leduc,2005 Offers suggestions and techniques to help students prepare for the Graduate Record Examination subject test in mathematics and includes a full length sample test with answers and explanations      *Guided Independent Study* University of Iowa. Center for Credit Programs,2004      **Teaching and Learning Mathematics Online** James P. Howard, II, John F. Beyers,2020-05-10 Online education has become a major component of higher education worldwide In mathematics and statistics courses there exists a number of challenges that are unique to the teaching and learning of mathematics and statistics in an online environment These challenges are deeply connected to already existing difficulties related to math anxiety conceptual understanding of mathematical ideas communicating mathematically and the appropriate use of technology Teaching and Learning Mathematics Online bridges these issues by presenting meaningful and practical solutions for teaching mathematics and statistics online It focuses on the problems observed by mathematics instructors currently working in the field who strive to hone their craft and share best practices with our professional community The book provides a set of standard practices improving the quality of online teaching and the learning of mathematics Instructors will benefit from learning new techniques and approaches to delivering content Features Based on the experiences of working educators in the field Assimilates the latest technology developments for interactive distance education Focuses on mathematical education for developing early mathematics courses      *The State correspondent and higher examination journal, ed. by J. Gibson* ,1905      **The Cumulative Book Index** ,1990 A world list of books in the English language      *The Mathematical Gazette* ,2006      *Resources in Education* ,1982-10

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*Current Index to Journals in Education* ,1991      **ACM SIGPLAN Notices** ,2003-07      **American Men of Science** ,1949      *The University of Virginia Record* University of Virginia,2003      **Government Reports Announcements** ,1974

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**Table of Contents Abstract Algebra Exam Solutions**

- 1. Understanding the eBook Abstract Algebra Exam Solutions
  - The Rise of Digital Reading Abstract Algebra Exam Solutions
  - Advantages of eBooks Over Traditional Books
- 2. Identifying Abstract Algebra 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 Abstract Algebra Exam Solutions
  - User-Friendly Interface
- 4. Exploring eBook Recommendations from Abstract Algebra Exam Solutions
  - Personalized Recommendations
  - Abstract Algebra Exam Solutions User Reviews and Ratings
  - Abstract Algebra Exam Solutions and Bestseller Lists
- 5. Accessing Abstract Algebra Exam Solutions Free and Paid eBooks
  - Abstract Algebra Exam Solutions Public Domain eBooks
  - Abstract Algebra Exam Solutions eBook Subscription Services
  - Abstract Algebra Exam Solutions Budget-Friendly Options
- 6. Navigating Abstract Algebra Exam Solutions eBook Formats
  - ePub, PDF, MOBI, and More
  - Abstract Algebra Exam Solutions Compatibility with Devices
  - Abstract Algebra Exam Solutions Enhanced eBook Features
- 7. Enhancing Your Reading Experience
  - Adjustable Fonts and Text Sizes of Abstract Algebra Exam Solutions
  - Highlighting and Note-Taking Abstract Algebra Exam Solutions
  - Interactive Elements Abstract Algebra Exam Solutions
- 8. Staying Engaged with Abstract Algebra Exam Solutions

- Joining Online Reading Communities
  - Participating in Virtual Book Clubs
  - Following Authors and Publishers Abstract Algebra Exam Solutions
9. Balancing eBooks and Physical Books Abstract Algebra Exam Solutions
- Benefits of a Digital Library
  - Creating a Diverse Reading Collection Abstract Algebra Exam Solutions
10. Overcoming Reading Challenges
- Dealing with Digital Eye Strain
  - Minimizing Distractions
  - Managing Screen Time
11. Cultivating a Reading Routine Abstract Algebra Exam Solutions
- Setting Reading Goals Abstract Algebra Exam Solutions
  - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Abstract Algebra Exam Solutions
- Fact-Checking eBook Content of Abstract Algebra 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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