

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 2×2 -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 2×2 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

Thomas Griffiths



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Assessment Practices in Undergraduate Mathematics Bonnie Gold, Sandra Keith, William A. Marion,1999 The collection of 72 articles offers the mathematics teacher suggestions for assessing testing and grading teaching efficacy how departments place students into courses the effectiveness of the major and the quantitative literacy of the graduating students Lacks an index Annotation c Book New **The American Mathematical Monthly** ,1983 **General Catalog** Iowa State University,1995 **Philosophic Abstracts** ,1966 **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
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