

Chapter 6, Problem 10. Let G be a group. Prove that the mapping $\alpha(g) = g^{-1} \forall g \in G$ is an automorphism if and only if G is Abelian.

Solution:(\Rightarrow) Let G be a group and let a and $b \in G$. Assume that the map α such that $\alpha(g) = g^{-1} \forall g \in G$ is an automorphism. Then we know $\alpha(ab) = \alpha(a)\alpha(b)$. But since $ab \in G$, we can write $\alpha(ab) = (ab)^{-1} = b^{-1}a^{-1} = \alpha(b)\alpha(a)$. Hence, $\alpha(a)\alpha(b) = \alpha(b)\alpha(a)$, so by Theorem 6.2 (part 3), G is Abelian.

(\Leftarrow) Let G be an Abelian group and let a and $b \in G$. Let $\alpha : G \rightarrow G$ be the map $\alpha(g) = g^{-1} \forall g \in G$. The existence property of inverses in a group guarantees that the map α is onto and the uniqueness property guarantees that the map α is one-to-one. Now, consider $\alpha(ab)$. Since G is Abelian, $ab = ba$ so $\alpha(ab) = \alpha(ba) = (ba)^{-1} = a^{-1}b^{-1} = \alpha(a)\alpha(b)$. So we have $\alpha(ab) = \alpha(a)\alpha(b)$. Hence, α is an automorphism.

Chapter 6, Problem 12. Find two groups G and H such that $G \not\cong H$, but $\text{Aut}(G) \cong \text{Aut}(H)$.

Solution: Consider the groups Z (the integers under addition) and Z_3 . We see immediately that $Z \not\cong Z_3$ since Z has an infinite number of elements while Z_3 has only 3. However, since these are both cyclic groups, we know that generators must be mapped to generators, and each of these groups has exactly two generators, hence there are exactly two automorphisms on each. Under addition, $Z = \langle 1 \rangle = \langle -1 \rangle$, and under addition modulo 3, $Z_3 = \langle 1 \rangle = \langle 2 \rangle$. So the automorphisms on Z are the maps

$\alpha_1 : Z \rightarrow Z : x \mapsto x$ and $\alpha_2 : Z \rightarrow Z : x \mapsto -x$ for $x \in Z$.

The automorphisms on Z_3 are the maps

$\beta_1 : Z_3 \rightarrow Z_3 : y \mapsto y$ and $\beta_2 : Z_3 \rightarrow Z_3 : y \mapsto -y$ for $y \in Z_3$ (that is, $0 \mapsto 0; 1 \mapsto 2; 2 \mapsto 1$).

So we can compare the Cayley tables of the automorphism groups:

\circ	α_1	α_2
α_1	α_1	α_2
α_2	α_2	α_1

\circ	β_1	β_2
β_1	β_1	β_2
β_2	β_2	β_1

We can see from these that $\text{Aut}(G) \cong \text{Aut}(H)$.

Chapter 6, Problem 22. Prove or disprove that $U(20)$ and $U(24)$ are isomorphic.

Solution: These groups are **not** isomorphic. In $U(24)$ every element other than the identity has order 2 (since $5^2 = 25 = 1 \pmod{24}$, etc.). However, in $U(20)$, the order of the element 3 is 8. Since Theorem 6.2 part 5, tells us that isomorphisms preserve order, there cannot be an isomorphism between these two groups.

Chapter 7, Problem 22. Suppose that G is a group with more than one element and G has no proper, nontrivial subgroups. Prove that $|G|$ is prime. Do not assume at the outset that G is finite.

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Table of Contents Abstract Algebra Manual Problems Solutions

1. Understanding the eBook Abstract Algebra Manual Problems Solutions
 - The Rise of Digital Reading Abstract Algebra Manual Problems Solutions
 - Advantages of eBooks Over Traditional Books
2. Identifying Abstract Algebra Manual Problems 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 Manual Problems Solutions
 - User-Friendly Interface
4. Exploring eBook Recommendations from Abstract Algebra Manual Problems Solutions
 - Personalized Recommendations
 - Abstract Algebra Manual Problems Solutions User Reviews and Ratings
 - Abstract Algebra Manual Problems Solutions and Bestseller Lists

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