

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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