GroupRepresentation 5

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PROBLEM I K is a field, A is algebra on K, $\emptyset \neq A_1 \subset A$, we call A_1 is a subalgebra of A, if A_1 is a subring of A which contains 1 of A and A_1 is a subspace of A on K and is also an algebra on K. Let $Z(A) := \{c \in A : ca = ac, \forall a \in A\}$. Prove: $Z(A)$ is a subalgebra of A, we call $Z(A)$ is the center of algebra A.

SOLUTION. 1. $Z(A)$ is a subring of A which contains 1 of A: Since $\forall a \in A$, A is a ring, then $1a = a1$. So $1 \in Z(A)$. $\forall c_1, c_2 \in Z(A)$, $\forall a \in A$, $(c_1 - c_2)a = (c_1 + (-c_2))a = c_1a + (-1)c_2a = ac_1 + (-1)ac_2 = ac_1 + a(-1)c_2 = a(c_1 + (-1)c_2) = a(c_1 - c_2)$, then $c_1 - c_2 \in Z(A)$. $(c_1c_2)a = c_1(c_2a) = c_1(ac_2) = (c_1a)c_2 = (ac_1)c_2 = a(c_1c_2)$, then $c_1c_2 \in A$.

2. $Z(A)$ is a subspace of A on K:$\forall k \in K$, $\forall c, c_1, c_2 \in Z(A)$, $\forall a \in A$, since A is an algebra on K, then $(kc)a = k(ca) = k(ac) = a(kc)$, then $kc \in Z(A)$. And by Item 1, we get $c_1 + c_2 \in Z(A)$.

3. By Item 1, Item 2, we get $Z(A)$ is also an algebra on K.
   So $Z(A)$ is a subalgebra of A. □

PROBLEM II Let G is infinite group, K is a field. Prove:

1. $\sum_{g\in G} g \in Z(K[G])$;

2. $C_a := \{gag^{-1} : g \in G\}$, $\sum_{x\in C_a} x \in Z(K[G])$.

SOLUTION. 1. $\forall \sum_{h\in G} a_h h \in K([G])$, then $\sum_{g\in G} g \sum_{h\in G} a_h h = \sum_{g\in G}\sum_{x\in G} x a_{x^{-1}g} x^{-1} g = \sum_{g\in G}\sum_{x\in G} a_{x^{-1}g} g = \sum_{g\in G}\sum_{x\in G} a_x g = \sum_{g\in G}\sum_{x\in G} a_x x x^{-1} g = \sum_{x\in G}\sum_{g\in G} a_x x x^{-1} g = \sum_{h\in G} a_h h \sum_{g\in G} g$.

2. $\forall \sum_{h\in G} a_h h \in K([G])$, then $\sum_{x\in C_a} x \sum_{g\in G} a_g g = \sum_{x\in C_a}\sum_{g\in G} x a_g g = \sum_{x\in C_a}\sum_{g\in G} a_g x g = \sum_{g\in G} a_g \sum_{x\in C_a} xg$, $\sum_{g\in G} a_g g \sum_{x\in C_a} x = \sum_{g\in G}\sum_{x\in C_a} a_g g x = \sum_{g\in G}\sum_{x\in C_a} a_g g x = \sum_{g\in G} a_g \sum_{x\in C_a} gx$. Since $\forall g \in G$, then $\{hah^{-1}g : h \in G\} = \{g(g^{-1}h)a(h^{-1}g) : h \in G\} = \{ghah^{-1} : h \in G\}$, then, $\sum_{x\in C_a} x \sum_{g\in G} a_g g = \sum_{g\in G} a_g g \sum_{x\in C_a} x$.

□