

Algebra Ph.D. Qualifying Exams, January 2013

Answer all questions. Partial credit will be given.

1. Let p be prime and let P be a group of prime power order p^α for some $\alpha \geq 1$. Prove that the center $Z(P)$ is nontrivial.
2. Prove that $x^4 + 4x^3 + 6x^2 + 2x + 1$ is irreducible in $\mathbb{Z}[x]$.
3. Let p be a prime. Compute the Galois group over \mathbb{Q} for the splitting field of the polynomial $x^p - 2$, by describing the action of the elements of the group on generators of the extension.
4. Let F be a field and let V_F be a (possibly infinite-dimensional) vector space over F . Let $V^* = \text{Hom}(V, F)$ denote the dual space of V . Consider the map
$$\Phi : V \rightarrow (V^*)^*, \quad v \mapsto E_v,$$
where $E_v \in (V^*)^* = \text{Hom}(V^*, F)$ is the evaluation map defined by the rule $E_v(f) = f(v)$ (for each $f \in V^*$). Prove that Φ is an injective linear transformation.

5. Show that the alternating group A_5 is simple.
6. Part A: Describe all ring homomorphisms (not necessarily sending $1 \mapsto 1$) from $\mathbb{Z} \rightarrow \mathbb{Q}$.
Part B: Describe all \mathbb{Z} -module homomorphisms from $\mathbb{Z} \rightarrow \mathbb{Q}$.
7. Prove the existence of a non-abelian group of order 20 not isomorphic to D_{20} .
8. Let I be an indexing set and let R be a (commutative) ring with $1 \neq 0$. For each $i \in I$ let M_i be an R -module. Also let N be an R -module. Prove that there exists an isomorphism:

$$\text{Hom}_R\left(\bigoplus_{i \in I} M_i, N\right) \cong \prod_{i \in I} \text{Hom}(M_i, N).$$

9. Let R be a noncommutative ring with 1. Assume $ab = 1$ but $ba \neq 1$. Prove that a has at least two distinct right inverses.
10. Let F be a field and assume α, β are both algebraic over F . Prove that $\alpha + \beta$ is algebraic over F .

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