Math 301 **Homework 10** **Fall 2014**

Exercises: Judson 10.1abe, 10.5, 10.10, 10.11, 10.13acd, and Problem 6 below.
Due date: Wednesday, 11/05

10.1 For each of the following groups G, determine whether H is a normal subgroup of G. If H is a normal subgroup, write out a Cayley table for the factor group G/H.

(a) $G = S_4$ and $H = A_4$

(b) $G = A_5$ and $H = \{(1), (123), (132)\}$

(e) $G = \mathbb{Z}$ and $H = 5\mathbb{Z}$

10.5. Show that the intersection of two normal subgroups is a normal subgroup.

10.10. Let H be a subgroup of index 2 of a group G. Prove that H must be a normal subgroup of G. Conclude that S_n is not simple for $n \geq 3$.

10.11. If a group G has exactly one subgroup H of order k, prove that H is normal in G.

10.13. Recall that the **center** of a group G is the set

$$Z(G) = \{x \in G : xg = gx \text{ for all } g \in G\ \}.$$

(a) Calculate the center of S_3.

(c) Show that the center of any group G is a normal subgroup of G.

(d) If $G/Z(G)$ is cyclic, show that G is abelian.[1]

Problem 6. Let $\mathbf{G} = \langle G, \cdot, ^{-1}, e\rangle$ be a finite group of order n. Take the set G (the elements of $\mathbf{G}$) and consider the group of all permutations of these elements. This group is sometimes denoted by $\mathrm{Sym}(G)$; note that it is isomorphic to the symmetric group S_n of permutations of an n-element set. Now fix an element $a \in G$ and recall that the function $\lambda_a : G \to G$, defined by $\lambda_a(g) = a \cdot g$, is a permutation of the set G. That is, λ_a belongs to the permutation group $\mathrm{Sym}(G)$.

(a) Prove that the function $\lambda : G \to \mathrm{Sym}(G)$ is a group homomorphism.

(b) What is the kernel of λ?[2]

(c) Let N denote the equivalence class of $\ker\lambda$ that contains the identity element e of G. Prove that N is a normal subgroup of G.

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[1] Hint: Let $Z := Z(G)$. If G/Z is cyclic then there exists $x \in G$ such that for each $a \in G$ there exists $m \in \mathbb{N}$ such that $aZ = x^m Z$. Fix $a, b \in G$ and show $ab = ba$ using the fact that $aZ = x^m Z$ and $bZ = x^n Z$ for some m and n.

[2] Recall that the kernel of a function $f : X \to Y$ is the subset of $X \times X$ defined by

$$\ker f = \{(x_1, x_2) : f(x_1) = f(x_2)\}.$$

As you have already proved, the kernel is an equivalence relation on X.