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Notes on Intuitionistic Fuzzy Subbigroup of A Bigroup

Mathematics

KEYWORDS : Bigroup, fuzzy subset, intuitionistic fuzzy subset, fuzzy subbigroup, intuitionistic fuzzy subbigroup.

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ABSTRACT

In this paper, we made an attempt to study the algebraic nature of intuitionistic fuzzy subbigroup of a bigroup.

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INTRODUCTION: In 1965, the fuzzy subset was introduced by L.A.Zadeh [9, 10], after that several researchers explored on the generalization of the concept of fuzzy sets. The concept of intuitionistic fuzzy subset was introduced by K.T.Atanassov [2, 3], as a generalization of the notion of fuzzy set. The notion of fuzzy subgroups was introduced by Azriel Rosenfeld [4]. Palaniappan.N & K.Arjunan [6] defined the intuitionistic fuzzy subgroups of a group. In this paper, we introduce the some theorems in intuitionistic fuzzy subbigroup of a bigroup.

1.PRELIMINARIES:

1.1 Definition: A set $(G, +, \bullet)$ with two binary operations $+$ and $\bullet$ is called a bigroup if there exist two proper subsets G_1 and G_2 of G such that (i) $G = G_1 \cup G_2$ (ii) $(G_1, +)$ is a group (iii) $(G_2, \bullet)$ is a group.

1.2 Definition: Let X be a non-empty set. A **fuzzy subset A** of X is a function $A: X \to [0, 1]$.

1.3 Definition: Let X be a non-empty set. A **intuitionistic fuzzy subset** A in X is defined as an object of the form $A = \{ < x, \mu_A(x), \nu_A(x) > / x \text{ in } X\}$, where $\mu_A : X \to [0, 1]$ and $\nu_A : X \to [0, 1]$ define the degree of membership and the degree of non-membership of the element $x \in X$ respectively and for every $x \in X$ satisfying $\mu_A(x) + \nu_A(x) \le 1$.

1.4 Definition: Let $(G, +)$ be a group. A fuzzy subset A of G is said to be a fuzzy subgroup of G if $\mu_A(x-y) \ge \min \{ \mu_A(x), \mu_A(y) \}$ for all x and y in G.

1.5 Definition: Let $(G, +)$ be a group. An intuitionistic fuzzy subset A of G is said to be an intuitionistic fuzzy subgroup of G if it satisfies the following axioms:

(i) $\mu_A(x-y) \ge \min \{ \mu_A(x), \mu_A(y) \}$

(ii) $\nu_A(x-y) \le \max \{ \nu_A(x), \nu_A(y) \}$ for all x and y in G.

1.6 Definition: Let $G = (G_1 \cup G_2, +, \bullet)$ be a bigroup. Then a fuzzy set A of G is said to be a fuzzy subbigroup of G if there exist two fuzzy subsets A_1 of G_1 and A_2 of G_2 such that (i) $A = A_1 \cup A_2$ (ii) A_1 is a fuzzy subgroup of $(G_1, +)$ (iii) A_2 is a fuzzy subgroup of $(G_2, \bullet)$.

1.7 Definition: Let $G = (G_1 \cup G_2, +, \bullet)$ be a bigroup. Then an intuitionistic fuzzy set A of G is said to be an intuitionistic fuzzy subbigroup of G if there exist two intuitionistic fuzzy subsets A_1 of G_1 and A_2 of G_2 such that (i) $A = A_1 \cup A_2$ (ii) A_1 is an intuitionistic fuzzy subgroup of $(G_1, +)$ (iii) A_2 is an intuitionistic fuzzy subgroup of $(G_2, \bullet)$.

2. PROPERTIES:

2.1 Theorem: If $A = M \cup N$ is an intuitionistic fuzzy subbigroup of a bigroup $G = E \cup F$, then $\mu_M(-x) = \mu_M(x)$, $\mu_M(x) \le \mu_M(e)$, $\nu_M(-x) = \nu_M(x)$, $\nu_M(x) \ge \nu_M(e)$ for all x, e in E, $\mu_N(x^{-1}) = \mu_N(x)$, $\mu_N(x) \le \mu_N(e')$, $\nu_N(x^{-1}) = \nu_N(x)$, $\nu_N(x) \ge \nu_N(e')$ for all x, e' in F.

Proof: Let x and e in E. Now $\mu_M(x) = \mu_M((-(-x))) \ge \mu_M(-x) \ge \mu_M(x)$. Therefore $\mu_M(-x) = \mu_M(x)$ for all x in E. And $\mu_M(e) = \mu_M(x-x) \ge \min \{ \mu_M(x), \mu_M(x) \} = \mu_M(x)$. Therefore $\mu_M(e) \ge \mu_M(x)$ for all x, e in E. Then $\nu_M(x) = \nu_M((-(-x))) \le \nu_M(-x) \le \nu_M(x)$. Therefore $\nu_M(-x) = \nu_M(x)$ for all x in E. And $\nu_M(e) = \nu_M(x-x) \le \max \{ \nu_M(x), \nu_M(x) \} = \nu_M(x)$. Therefore $\nu_M(e) \le \nu_M(x)$ for all x, e in

E. Also $\mu_N(x) = \mu_N((x^{-1})^{-1}) \ge \mu_N(x^{-1}) \ge \mu_N(x)$. Therefore $\mu_N(x^{-1}) = \mu_N(x)$ for all x in F. And $\mu_N(e') = \mu_N(xx^{-1}) \ge \min\{ \mu_N(x), \mu_N(x^{-1}) \} = \mu_N(x)$. Therefore $\mu_N(e') \ge \mu_N(x)$ for all x, e' in F. Also $\nu_N(x) = \nu_N((x^{-1})^{-1}) \le \nu_N(x^{-1}) \le \nu_N(x)$. Therefore $\nu_N(x^{-1}) = \nu_N(x)$ for all x in F. And $\nu_N(e') = \nu_N(xx^{-1}) \le \max\{ \nu_N(x), \nu_N(x^{-1}) \} = \nu_N(x)$. Therefore $\nu_N(e') \le \nu_N(x)$ for all x, e' in F.

2.2 Theorem: If $A = M \cup N$ is an intuitionistic fuzzy subbigroup of a bigroup $G = E \cup F$, then (i) $\mu_M(x-y) = \mu_M(e)$ gives $\mu_M(x) = \mu_M(y)$ for all x, y and e in E

(ii) $\nu_M(x-y) = \nu_M(e)$ gives $\nu_M(x) = \nu_M(y)$ for all x, y and e in E

(iii) $\mu_N(xy^{-1}) = \mu_N(e')$ gives $\mu_N(x) = \mu_N(y)$ for all x, y and e' in F.

(iv) $\nu_N(xy^{-1}) = \nu_N(e')$ gives $\nu_N(x) = \nu_N(y)$ for all x, y and e' in F.

Proof: (i) Let x, y and e in E. Then $\mu_M(x) = \mu_M(x-y+y) \ge \min \{ \mu_M(x-y), \mu_M(y) \} = \min \{ \mu_M(e), \mu_M(y) \} = \mu_M(y) = \mu_M(y-x+x) \ge \min \{ \mu_M(y-x), \mu_M(x) \} = \min \{\mu_M(e), \mu_M(x) \} = \mu_M(x)$. Therefore $\mu_M(x) = \mu_M(y)$ for all x and y in E. (ii) Let x, y and e in E. Then $\nu_M(x) =$

$\nu_M(x-y+y) \le \max\{\nu_M(x-y), \nu_M(y)\} = \max\{\nu_M(e), \nu_M(y)\} = \nu_M(y) = \nu_M(y-x+x) \le \max\{\nu_M(y-x), \nu_M(x)\} = \max\{\nu_M(e), \nu_M(x)\} = \nu_M(x)$. Therefore $\nu_M(x) = \nu_M(y)$ for all x and y in E. (iii) Let x, y and e' in F. Then $\mu_N(x) = \mu_N(xy^{-1}y) \ge \min\{\mu_N(xy^{-1}), \mu_N(y)\} = \min\{\mu_N(e'), \mu_N(y)\} = \mu_N(y) = \mu_N(yx^{-1}x) \ge \min\{\mu_N(yx^{-1}), \mu_N(x)\} = \min\{\mu_N(e'), \mu_N(x)\} = \mu_N(x)$. Therefore $\mu_N(x) = \mu_N(y)$ for all x and y in F. (iv) Let x, y and e' in F. Then $\nu_N(x) = \nu_N(xy^{-1}y) \le \max\{\nu_N(xy^{-1}), \nu_N(y)\} = \max\{\nu_N(e'), \nu_N(y)\} = \nu_N(y) = \nu_N(yx^{-1}x) \le \max\{\nu_N(yx^{-1}), \nu_N(x)\} = \max\{\nu_N(e'), \nu_N(x)\} = \nu_N(x)$. Therefore $\nu_N(x) = \nu_N(y)$ for all x and y in F.

2.3 Theorem: If A = M∪N is an intuitionistic fuzzy subbigroup of a bigroup G = E∪F,

then (i) $H_1 = \{ x / x \in E, \mu_M(x) = 1 \text{ and } \nu_M(x) = 0 \}$ is either empty or a subgroup of E.

(ii) $H_2 = \{ x / x \in F, \mu_N(x) = 1 \text{ and } \nu_N(x) = 0 \}$ is either empty or a subgroup of F.

(iii) $K = H_1 \cup H_2$ is either empty or a subbigroup of G.

Proof: If no element satisfies this condition, then H_1 and H_2 are empty. Also $K = H_1 \cup H_2$ is empty. (i) If x and y in H_1, then $\mu_M(x-y) \ge \min\{\mu_M(x), \mu_M(y)\} \ge \min\{1, 1\} = 1$. Therefore $\mu_M(x-y) = 1$. And $\nu_M(x-y) \le \max\{\nu_M(x), \nu_M(y)\} \le \max\{0, 0\} = 0$. Therefore $\nu_M(x-y) = 0$. We get x–y in H_1. Hence H_1 is a subgroup of G_1. (ii) If x and y in H_2, then $\mu_N(xy^{-1}) \ge \min\{\mu_N(x), \mu_N(y)\} = \min\{1, 1\} = 1$. Therefore $\mu_N(xy^{-1}) = 1$. And $\nu_N(xy^{-1}) \le \max\{\nu_N(x), \nu_N(y)\} = \max\{0, 0\} = 0$. Therefore $\nu_N(xy^{-1}) = 0$. We get xy^{-1} in H_2. Hence H_2 is a subgroup of G_2. (iii) From (i) and (ii) we get $K = H_1 \cup H_2$ is a subbigroup of G.

2.4 Theorem: If A = M∪N is an intuitionistic fuzzy subbigroup of a bigroup G = E∪F, then (i) $H_1 = \{ x / x \in E, \mu_M(x) = \mu_M(e) \text{ and } \nu_M(x) = \nu_M(e) \}$ is a subgroup of E

(ii) $H_2 = \{ x / x \in F, \mu_N(x) = \mu_N(e') \text{ and } \nu_N(x) = \nu_N(e') \}$ is a subgroup of F

(iii) $K = H_1 \cup H_2$ is a subbigroup of G.

Proof: (i) Clearly e in H_1 so H_1 is a non empty. Let x and y be in H_1. Then $\mu_M(x-y) \ge \min\{\mu_M(x), \mu_M(y)\} = \min\{\mu_M(e), \mu_M(e)\} = \mu_M(e)$. Therefore $\mu_M(x-y) \ge \mu_M(e)$ for all x and y in H_1. We get $\mu_M(x-y) = \mu_M(e)$ for all x and y in H_1. And $\nu_M(x-y) \le \max\{\nu_M(x), \nu_M(y)\} = \max\{\nu_M(e), \nu_M(e)\} = \nu_M(e)$. Therefore $\nu_M(x-y) \le \nu_M(e)$ for all x and y in H_1. We get $\nu_M(x-y) = \nu_M(e)$ for all x and y in H_1. Therefore x–y in H_1. Hence H_1 is a subgroup of E. (ii) Clearly e' in H_2 so H_2 is a non empty. Let x and y be in H_2. Then $\mu_N(xy^{-1}) \ge \min\{\mu_N(x), \mu_N(y)\} = \min\{\mu_N(e'), \mu_N(e')\} = \mu_N(e')$. Therefore $\mu_N(xy^{-1}) \ge \mu_N(e')$ for all x and y in H_2. We get $\mu_N(xy^{-1}) = \mu_N(e')$ for all x and y in H_2. And $\nu_N(xy^{-1}) \le \max\{\nu_N(x), \nu_N(y)\} = \max\{\nu_N(e'), \nu_N(e')\} = \nu_N(e')$. Therefore $\nu_N(xy^{-1}) \le \nu_N(e')$ for all x and y in H_2. We get $\nu_N(xy^{-1}) = \nu_N(e')$ for all x and y in H_2. Therefore xy^{-1} in H_2. Hence H_2 is a subgroup of F. (iii) From (i) and (ii) we get $K = H_1 \cup H_2$ is a subbigroup of G.

2.5 Theorem: Let A = M∪N be an intuitionistic fuzzy subbigroup of a bigroup G = E∪F.

(i) If $\mu_M(x-y) = 1$, then $\mu_M(x) = \mu_M(y)$ for all x and y in E.

(ii) If $\nu_M(x-y) = 0$, then $\nu_M(x) = \nu_M(y)$ for all x and y in E.

(iii) If $\mu_N(xy^{-1}) = 1$, then $\mu_N(x) = \mu_N(y)$ for all x and y in F.

(iv) If $\nu_N(xy^{-1}) = 0$, then $\nu_N(x) = \nu_N(y)$ for all x and y in F.

Proof: (i) Let x and y belongs to E. Then $\mu_M(x) = \mu_M(x-y+y) \ge \min\{\mu_M(x-y), \mu_M(y)\} = \min\{1, \mu_M(y)\} = \mu_M(y) = \mu_M(-y) = \mu_M(-x+x-y) \ge \min\{\mu_M(-x), \mu_M(x-y)\} = \min\{\mu_M(-x), 1\} = \mu_M(-x) = \mu_M(x)$. Therefore $\mu_M(x) = \mu_M(y)$ for all x and y in E. (ii) Let x and y belongs to E. Then $\nu_M(x) = \nu_M(x-y+y) \le \max\{\nu_M(x-y), \nu_M(y)\} = \max\{1, \nu_M(y)\} = \nu_M(y) = \nu_M(-y) = \nu_M(-x+x-y) \le \max\{\nu_M(-x), \nu_M(x-y)\} = \max\{\nu_M(-x), 1\} = \nu_M(-x) = \nu_M(x)$. Therefore $\nu_M(x) = \nu_M(y)$ for all x and y in E. (iii) Let x and y belongs to F. Then $\mu_N(x) = \mu_N(xy^{-1}y) \ge \min\{\mu_N(xy^{-1}), \mu_N(y)\} = \min\{1, \mu_N(y)\} = \mu_N(y) = \mu_N(y^{-1}) = \mu_N(x^{-1}xy^{-1}) \ge \min\{\mu_N(x^{-1}), \mu_N(xy^{-1})\} = \min\{\mu_N(x^{-1}), 1\} = \mu_N(x^{-1}) = \mu_N(x)$. Therefore $\mu_N(x) = \mu_N(y)$ for all x and y in F. (iv) Let x and y belong to F. Then $\nu_N(x) = \nu_N(xy^{-1}y) \le \max\{\nu_N(xy^{-1}), \nu_N(y)\} = \max\{1, \nu_N(y)\} = \nu_N(y) = \nu_N(y^{-1}) = \nu_N(x^{-1}xy^{-1}) \le \max\{\nu_N(x^{-1}), \nu_N(xy^{-1})\} = \max\{\nu_N(x^{-1}), 1\} = \nu_N(x^{-1}) = \nu_N(x)$. Therefore $\nu_N(x) = \nu_N(y)$ for all x and y in F.

2.6 Theorem: If A = M∪N is an intuitionistic fuzzy subbigroup of a bigroup G = E∪F, then (i) $\mu_M(x+y) = \min\{\mu_M(x), \mu_M(y)\}$ for each x and y in E with $\mu_M(x) \ne \mu_M(y)$ (ii) $\nu_M(x+y) = \max\{\nu_M(x), \nu_M(y)\}$ for each x and y in E with $\nu_M(x) \ne \nu_M(y)$ (iii) $\mu_N(xy) = \min\{\mu_N(x), \mu_N(y)\}$ for each x and y in F with $\mu_N(x) \ne \mu_N(y)$.

(iv) $\nu_N(xy) = \max\{\nu_N(x), \nu_N(y)\}$ for each x and y in F with $\nu_N(x) \ne \nu_N(y)$.

Proof: (i) Let x and y belongs to E. Assume that $\mu_M(x) > \mu_M(y)$, then $\mu_M(y) = \mu_M(-x+x+y) \ge \min\{\mu_M(-x), \mu_M(x+y)\} \ge \min\{\mu_M(x), \mu_M(x+y)\} = \mu_M(x+y) \ge \min\{\mu_M(x), \mu_M(y)\} = \mu_M(y)$. Therefore $\mu_M(x+y) = \mu_M(y) = \min\{\mu_M(x), \mu_M(y)\}$ for x and y in E. (ii) Let x and y belongs to E. Assume that $\nu_M(x) < \nu_M(y)$, then $\nu_M(y) = \nu_M(-x+x+y) \le \max\{\nu_M(-x), \nu_M(x+y)\} \le \max\{\nu_M(x), \nu_M(x+y)\} = \nu_M(x+y) \le \max\{\nu_M(x), \nu_M(y)\} = \nu_M(y)$. Therefore $\nu_M(x+y) = \nu_M(y) = \max\{\nu_M(x), \nu_M(y)\}$ for x and y in E. (iii) Let x and y belongs to F. Assume that $\mu_N(x) > \mu_N(y)$, then $\mu_N(y) = \mu_N(x^{-1}xy) \ge \min\{\mu_N(x^{-1}), \mu_N(xy)\} \ge \min\{\mu_N(x), \mu_N(xy)\} = \mu_N(xy) \ge \min\{\mu_N(x), \mu_N(y)\} = \mu_N(y)$. Therefore $\mu_N(xy) = \mu_N(y) = \min\{\mu_N(x), \mu_N(y)\}$ for x and y in F. (iv) Let x and y belongs to F. Assume that $\nu_N(x) < \nu_N(y)$, then $\nu_N(y) = \nu_N(x^{-1}xy) \le \max\{\nu_N(x^{-1}), \nu_N(xy)\} \le \max\{\nu_N(x), \nu_N(xy)\} = \nu_N(xy) \le \max\{\nu_N(x), \nu_N(y)\} = \nu_N(y)$. Therefore $\nu_N(xy) = \nu_N(y) = \max\{\nu_N(x), \nu_N(y)\}$ for x and y in F.

2.7 Theorem: If A = M∪N and B = O∪P are two intuitionistic fuzzy subbigroups of a bigroup G = E∪F, then their intersection A∩B is an intuitionistic fuzzy subbigroup of G.

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Proof: Let $A = M \cup N = \{ \langle x, \mu_A(x), \nu_A(x) \rangle / x \in G \}$ where $M = \{ \langle x, \mu_M(x), \nu_M(x) \rangle / x \in E \}$ and $N = \{ \langle x, \mu_N(x), \nu_N(x) \rangle / x \in F \}$ and $B = O \cup P = \{ \langle x, \mu_B(x), \nu_B(x) \rangle / x \in G \}$ where $O = \{ \langle x, \mu_O(x), \nu_O(x) \rangle / x \in E \}$ and $P = \{ \langle x, \mu_P(x), \nu_P(x) \rangle / x \in F \}$. Let $C = A \cap B = R \cup S$ where $C = \{ \langle x, \mu_C(x), \nu_C(x) \rangle / x \in G \}$, $R = M \cap O = \{ \langle x, \mu_R(x), \nu_R(x) \rangle / x \in E \}$ and $S = N \cap P = \{ \langle x, \mu_S(x), \nu_S(x) \rangle / x \in F \}$. Let x and y belong to E. Then $\mu_R(x-y) = \min\{\mu_M(x-y), \mu_O(x-y)\} \geq \min\{\min\{\mu_M(x), \mu_M(y)\}, \min\{\mu_O(x), \mu_O(y)\}\} \geq \min\{\min\{\mu_M(x), \mu_O(x)\}, \min\{\mu_M(y), \mu_O(y)\}\} = \min\{\mu_R(x), \mu_R(y)\}$. Therefore $\mu_R(x-y) \geq \min\{\mu_R(x), \mu_R(y)\}$ for all x and y in E. And $\nu_R(x-y) = \max\{\nu_M(x-y), \nu_O(x-y)\} \leq \max\{\max\{\nu_M(x), \nu_M(y)\}, \max\{\nu_O(x), \nu_O(y)\}\} \leq \max\{\max\{\nu_M(x), \nu_O(x)\}, \max\{\nu_M(y), \nu_O(y)\}\} = \max\{\nu_R(x), \nu_R(y)\}$. Therefore $\nu_R(x-y) \leq \max\{\nu_R(x), \nu_R(y)\}$ for all x and y in E. Let x and y belong to F. Then $\mu_S(xy^{-1}) = \min\{\mu_N(xy^{-1}), \mu_P(xy^{-1})\} \geq \min\{\min\{\mu_N(x), \mu_N(y)\}, \min\{\mu_P(x), \mu_P(y)\}\} \geq \min\{\min\{\mu_N(x), \mu_P(x)\}, \min\{\mu_N(y), \mu_P(y)\}\} = \min\{\mu_S(x), \mu_S(y)\}$. Therefore $\mu_S(xy^{-1}) \geq \min\{\mu_S(x), \mu_S(y)\}$ for all x and y in F. And $\nu_S(xy^{-1}) = \max\{\nu_N(xy^{-1}), \nu_P(xy^{-1})\} \leq \max\{\max\{\nu_N(x), \nu_N(y)\}, \max\{\nu_P(x), \nu_P(y)\}\} \leq \max\{\max\{\nu_N(x), \nu_P(x)\}, \max\{\nu_N(y), \nu_P(y)\}\} = \max\{\nu_S(x), \nu_S(y)\}$. Therefore $\nu_S(xy^{-1}) \leq \max\{\nu_S(x), \nu_S(y)\}$ for all x and y in F. Hence $A \cap B$ is an intuitionistic fuzzy subbigroup of G.

2.8 Theorem: The intersection of a family of intuitionistic fuzzy subbigroups of a bigroup G is an intuitionistic fuzzy subbigroup of G.

Proof: It is trivial.

2.9 Theorem: If $A = M \cup N$ is an intuitionistic fuzzy subbigroup of a bigroup $G = E \cup F$, then (i) $\mu_M(x+y) = \mu_M(y+x)$ if and only if $\mu_M(x) = \mu_M(-y+x+y)$ for all x and y in E (ii) $\nu_M(x+y) = \nu_M(y+x)$ if and only if $\nu_M(x) = \nu_M(-y+x+y)$ for all x and y in E (iii) $\mu_N(xy) = \mu_N(yx)$ if and only if $\mu_N(x) = \mu_N(y^{-1}xy)$ for all x and y in F.

(iv) $\nu_N(xy) = \nu_N(yx)$ if and only if $\nu_N(x) = \nu_N(y^{-1}xy)$ for all x and y in F.

Proof: (i) Let x and y be in E. Assume that $\mu_M(x+y) = \mu_M(y+x)$, then $\mu_M(-y+x+y) = \mu_M(-y+y+x) = \mu_M(e_1+x) = \mu_M(x)$. Therefore $\mu_M(x) = \mu_M(-y+x+y)$ for all x and y in E. Conversely, assume that $\mu_M(x) = \mu_M(-y+x+y)$, then $\mu_M(x+y) = \mu_M(x+y-x+x) = \mu_M(y+x)$. Therefore $\mu_M(x+y) = \mu_M(y+x)$ for all x and y in E. (ii) Let x and y be in E. Assume that $\nu_M(x+y) = \nu_M(y+x)$, then $\nu_M(-y+x+y) = \nu_M(-y+y+x) = \nu_M(e_1+x) = \nu_M(x)$. Therefore $\nu_M(x) = \nu_M(-y+x+y)$ for all x and y in E. Conversely, assume that $\nu_M(x) = \nu_M(-y+x+y)$, then $\nu_M(x+y) = \nu_M(x+y-x+x) = \nu_M(y+x)$. Therefore $\nu_M(x+y) = \nu_M(y+x)$ for all x and y in E. (iii) Let x and y be in F. Assume that $\mu_N(x+y) = \mu_N(y+x)$, then $\mu_N(y^{-1}xy) = \mu_N(y^{-1}yx) = \mu_N(e_2x) = \mu_N(x)$. Therefore $\mu_N(x) = \mu_N(y^{-1}xy)$ for all x and y in F. Conversely, assume that $\mu_N(x) = \mu_N(y^{-1}xy)$, then $\mu_N(xy) = \mu_N(xyxx^{-1}) = \mu_N(yx)$. Therefore $\mu_N(xy) = \mu_N(yx)$ for all x and y in F. (iv) Let x and y be in F. Assume that $\nu_N(x+y) = \nu_N(y+x)$, then $\nu_N(y^{-1}xy) = \nu_N(y^{-1}yx) = \nu_N(e_2x) = \nu_N(x)$. Therefore $\nu_N(x) = \nu_N(y^{-1}xy)$ for all x and y in F. Conversely, assume that $\nu_N(x) = \nu_N(y^{-1}xy)$, then $\nu_N(xy) = \nu_N(xyxx^{-1}) = \nu_N(yx)$. Therefore $\nu_N(xy) = \nu_N(yx)$ for all x and y in F.

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