ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

ON INTUITIONISTIC FUZZY REGULAR α GENERALIZED CLOSED SETS

Nivetha M *, Assistant Professor Jayanthi D
* Department of Mathematics, Avinashilingam University, Coimbatore, Tamilnadu, India.

ABSTRACT

The purpose of this paper is to introduce and study the concept of intuitionistic fuzzy regular α generalized closed set in intuitionistic fuzzy topological space. We investigate some of their properties.

KEYWORDS: Intuitionistic fuzzy set, Intuitionistic fuzzy topology, Intuitionistic fuzzy topological space, Intuitionistic fuzzy regular α generalized closed set.

INTRODUCTION

The theory of fuzzy sets was introduced by Zadeh [10] in 1965. Later, Chang [2] proposed fuzzy topology in 1967. After this, there have been several generalizations of notions of fuzzy sets and fuzzy topology. The concept of intuitionistic fuzzy sets, introduced by Atanassov [1] is a generalization of fuzzy sets. In the last 25 years various concept of fuzzy mathematics have been extended for intuitionistic fuzzy sets. Using the notion of intuitionistic fuzzy sets, Coker [3] introduced the notion of intuitionistic fuzzy topological spaces in 1997. This approach provided a wide field for investigation in the area of intuitionistic fuzzy topology.

In this paper, we introduce intuitionistic fuzzy regular α generalized closed set. We investigate some of their properties.

PRELIMINARIES

Definition 2.1:[1] An intuitionistic fuzzy set (IFS in short) A in X is an object having the form $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$ where the function $\mu_A : X \to [0,1]$ and $\nu_A : X \to [0,1]$ denote the degree of membership (namely $\mu_A(x)$) and the degree of non-membership (namely $\nu_A(x)$) of each element $x \in X$ to the set A, respectively, and $0 \le \mu_A(x) + \nu_A(x) \le 1$ for each $x \in X$.

Definition 2.2: [1] Let A and B be two IFSs of the form $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$ and $B = \{\langle x, \mu_B(x), \nu_B(x)\rangle / x \in X\}$. Then

a) $A \subseteq B$ if and only if $\mu_A(x) \le \mu_B(x)$ and $\nu_A(x) \ge \nu_B(x)$ for all $x \in X$
b) $A = B$ if and only if $A \subseteq B$ and $B \subseteq A$
c) $A^c = \{\langle x, , \nu_A(x), \mu_A(x)\rangle / x \in X\}$
d) $A \cap B = \{\langle x, \mu_A(x) \wedge \mu_B(x), \nu_A(x) \vee \nu_B(x)\rangle / x \in X\}$
e) $A \cup B = \{\langle x, \mu_A(x) \vee \mu_B(x), \nu_A(x) \wedge \nu_B(x)\rangle / x \in X\}$

For the sake of simplicity, we shall use the notation $A = \langle x, \mu_A, \nu_A\rangle$ instead of $A = \{\langle x, \mu_A(x), \nu_A(x)\rangle / x \in X\}$. The IFS $0\sim = \{\langle x, 0, 1\rangle / x \in X\}$ and $1\sim = \{\langle x, 1, 0\rangle / x \in X\}$ are respectively the empty set and the whole set of X.

Definition 2.3: [3] An intuitionistic fuzzy topology (IFT in short) on X is a family τ of IFS in X satisfying the following axioms:

a) $0\sim, 1\sim \in \tau$,
b) $G_1 \cap G_2 \in \tau$ for any $G_1, G_2 \in \tau$,
c) $\cup G_i \in \tau$ for any family $\{ G_i / i \in J\} \subseteq \tau$.

In this case the pair (X, τ) is called an intuitionistic fuzzy topological space (IFTS in short) and any IFS in τ is known as an intuitionistic fuzzy open set (IFOS in short) in X. The complement A^c of an IFOS A in (X, τ) is called an intuitionistic fuzzy closed (IFCS in short) in X.

Definition 2.4: [3] Let (X, τ) be an IFTS and $A = \langle x, \mu_A, \nu_A\rangle$ be an IFS in X. Then the intuitionistic fuzzy interior and intuitionistic fuzzy closure are defined by

$int(A) = \cup \{ G / G \text{ is an IFOS in X and } G \subseteq A\}$
$cl(A) = \cap \{K / K \text{ is an IFCS in X and } A \subseteq K\}$

Note that for any IFS A in (X, τ), we have $cl(A^c) = (int(A))^c$ and $int(A^c) = (cl(A))^c$.

Definition 2.5: [5] An IFS A in an IFTS (X, τ) is said to be an

a) intuitionistic fuzzy semi closed set (IFSCS in short) if $int(cl(A)) \subseteq A$,
b) intuitionistic fuzzy α closed set (IFαCS in short) if $cl(int(cl(A))) \subseteq A$,

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

c) intuitionistic fuzzy pre closed set (IFPCS in short) if cl(int(A)) ⊆ A.

Definition 2.6: [9] An IFS A in an IFTS (X, τ) is said to be an

a) intuitionistic fuzzy regular closed set (IFRCS in short) if A = cl(int(A)),

b) intuitionistic fuzzy generalized closed set (IFGCS in short) if cl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X,

c) intuitionistic fuzzy regular generalized closed set (IFRGCS in short) if cl(A) ⊆ U whenever A ⊆ U and U is an IFROS in X.

Definition 2.7: [7] An IFS A in an IFTS (X, τ) is intuitionistic fuzzy α generalized closed set (IFαGCS in short) if αcl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X.

Definition 2.8: [8] Two IFSs A and B are said to be q-coincident ($A\ _q\ B$ in short) if and only if there exist an element x ∈ X such that $\mu_A(x) > \nu_B(x)$ or $\nu_A(x) < \mu_B(x)$.

Definition 2.9: [8] Two IFSs A and B are said to be not q-coincident ($A\ _q{}^c\ B$ in short) if and only if $A \subseteq B^c$.

Definition 2.10:[4] An intuitionistic fuzzy point (IFP in short), written as $p_{(\alpha,\beta)}$, is defined to be an IFS of X given by

$$p_{(\alpha,\beta)}(x) = \begin{cases} (\alpha,\beta) & \text{if } x = p, \\ (0,1) & \text{otherwise.} \end{cases}$$

An IFP $p_{(\alpha,\beta)}$ is said to belong to a set A if $\alpha \leq \mu_A$ and $\beta \geq \nu_A$.

INTUITIONISTIC FUZZY REGULAR α GENERALIZED CLOSED SETS

In this section, we introduced intuitionistic fuzzy regular α generalized closed sets and studied some of their basic properties.

Definition 3.1: An IFS A of an IFTS (X, τ) is called intuitionistic fuzzy regular α generalized closed set (IFRαGCS in short) if αcl(A) ⊆ U whenever A ⊆ U and U is an IFROS in X.

Example 3.2: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.4,0.2), (0.6,0.7)⟩ where μ_a=0.4, μ_b=0.2, ν_a=0.6, ν_b=0.7 and G = ⟨x, (0.8,0.8), (0.2,0.2)⟩ where μ_a=0.8, μ_b=0.8, ν_a=0.2, ν_b=0.2. Let A = ⟨x, (0.2,0.2), (0.8,0.8)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.2,0.2), (0.8,0.8)⟩ ⊆ U. Therefore A is an IFRαGCS in (X,τ).

Theorem 3.3: Every IFCS in (X,τ) is an IFRαGCS in (X,τ) but not conversely.

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) = A∪cl(int(A)) ⊆ A∪cl(A) = A∪A = A, since by the hypothesis cl(A) = A. Therefore αcl(A) ⊆ U. Hence A is an IFRαGCS in (X,τ).

Example 3.4: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and G = ⟨x, (0.1,0.2), (0.9,0.8)⟩. Let A = ⟨x, (0.3,0.1), (0.6,0.7)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.4,0.2), (0.6,0.7)⟩ ⊆ U . Therefore A is an IFRαGCS in X but not an IFCS in X, since cl(A) = ⟨x, (0.4,0.2), (0.6,0.7)⟩ ≠ A.

Theorem 3.5: Every IFRCS in (X,τ) is an IFRαGCS in (X,τ) but not conversely.

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) = A∪cl(int(A)), since every IFRCS is an IFCS cl(A) = A, and by hypothesis A = cl(int(A)). Therefore αcl(A) = A∪A = A, and hence αcl(A) ⊆ U. Hence A is an IFRαGCS in (X,τ).

Example 3.6: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.6,0.7), (0.3,0.2)⟩ and G = ⟨x, (0.2,0.2), (0.8,0.7)⟩. Let A = ⟨x, (0.3,0.1), (0.7,0.7)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.3,0.2), (0.6,0.7)⟩⊆ U . Therefore A is an IFRαGCS in X but not an IFRCS in X, since cl(int(A)) = 0~ ≠ A.

Theorem 3.7: Every IFαCS in (X,τ) is an IFRαGCS in (X,τ) but not conversely.

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) ⊆ A∪A = A, since by the hypothesis cl(int(cl(A))) ⊆ A. Therefore αcl(A) ⊆ U. Hence A is an IFRαGCS in (X,τ).

Example 3.8: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and G = ⟨x, (0.1,0.2), (0.6,0.8)⟩. Let A = ⟨x, (0.1,0.1), (0.6,0.7)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.4,0.2), (0.6,0.7)⟩ ⊆ U. Therefore A is an IFRαGCS in X but not an IFαCS in X, since cl(int(cl(A))) =⟨x, (0.4,0.2), (0.6,0.7)⟩ ⊈ A.

Remark 3.9: Every IFRαGCSs and every IFPCSs are independent to each other.

Example 3.10: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.5,0.6), (0.4,0.2)⟩ and G = ⟨x, (0.3,0.2), (0.7,0.8)⟩. Let A = ⟨x, (0.3,0.2), (0.5,0.6)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.4,0.2), (0.5,0.6)⟩ ⊆ U. Therefore A is an IFRαGCS in X, but not an IFPCS in X, since cl(int(A)) = ⟨x, (0.4,0.2), (0.5,0.6)⟩ ⊈ A.

Example 3.11: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.2,0.3), (0.6,0.7)⟩ and

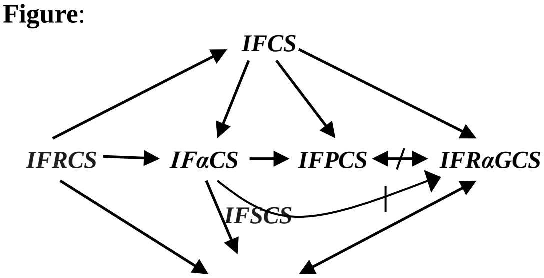
G = ⟨x, (0.8,0.7), (0.1,0)⟩. Let A = ⟨x, (0.1,0.2), (0.7,0.8)⟩ be any IFS in (X,τ). Then cl(int(A)) = 0~ ⊆ A. Therefore A is an IFPCS in X but not an IFRαGCS in X, since A ⊆ U where U is an IFROS in X but αcl(A) = ⟨x, (0.6,0.7), (0.2,0.3)⟩ ⊈ U.

Remark 3.12: Every IFRαGCSs and every IFSCSs are independent to each other.

Example 3.13: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and G = ⟨x, (0.1,0.2), (0.7,0.8)⟩. Let A = ⟨x, (0.2,0.1), (0.6,0.7)⟩ be any IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. Now αcl(A) = ⟨x, (0.4,0.2), (0.6,0.7)⟩ ⊆ U. Therefore A is an IFRαGCS in X but not an IFSCS in X, since int(cl(A)) = ⟨x, (0.1,0.2), (0.7,0.8)⟩ ⊈ A.

Example 3.14: Let X = {a,b} and let τ = {0~,U,G,1~} where U = ⟨x, (0.5,0.2), (0.5,0.8)⟩ and G = ⟨x, (0.2,0.2), (0.8,0.8)⟩. Let A = ⟨x, (0.5,0.2), (0.5,0.8)⟩ be any IFS in (X,τ). Then int(cl(A)) = ⟨x, (0.5,0.2), (0.5,0.8)⟩ = A. Therefore A is an IFSCS in X but not an IFRαGCS in X, since A = U where U is an IFROS in X, but αcl(A) = ⟨x, (0.5,0.8), (0.5,0.2)⟩ ⊈ U.

Figure:



In this diagram by " A ⟶ B " we mean A implies B but not conversely and " A ↮ B " means A and B are independent of each other.

Theorem 3.15: If an IFS A is both IFSCS and IFCS in (X,τ) then A is an IFRαGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) ⊆ A∪cl(A), since by the hypothesis int(cl(A)) ⊆ A. Also αcl(A) = A∪A, as cl(A) = A by the hypothesis. Therefore αcl(A) = A ⊆ U. Hence A is an IFRαGCS in (X,τ).

Theorem 3.16: If an IFS A is both IFPCS and IFCS in (X,τ) then A is an IFRαGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) = A∪cl(int(A)), since by the hypothesis cl(A) = A. Also αcl(A) ⊆ A∪A, as cl(int(A)) ⊆ A by the hypothesis, αcl(A) = A ⊆ U. Hence A is an IFRαGCS in (X,τ).

Theorem 3.17: If an IFS A is both IFROS and IFCS in (X,τ) then A is an IFRαGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. We have αcl(A) = A∪cl(int(cl(A))) = A∪cl(A), since by the hypothesis int(cl(A)) = A. Also αcl(A) = A∪A, as cl(A) = A by the hypothesis, αcl(A) = A ⊆ U. Hence A is an IFRαGCS in (X,τ).

Theorem 3.18: If an IFS A is both IFSCS and IFGCS in (X,τ) then A is an IFRαGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. Since every IFROS is an IFOS, U is an IFOS. We have αcl(A) = A∪cl(int(cl(A))) ⊆ A∪cl(A), since by the hypothesis int(cl(A)) ⊆ A. Also αcl(A) ⊆ cl(A), By the hypothesis cl(A) ⊆ U whenever A ⊆ U and U is an IFOS in X. Therefore αcl(A) ⊆ U. Hence A is an IFRαGCS in (X,τ).

Remark 3.19: The union of two IFRαGCS in an IFTS (X,τ) need not be IFRαGCS in general.

Example 3.20: Let X = {a,b} and let τ = {0~, U, G, H, I, J, K, 1~} is an IFT on (X,τ). Where U = ⟨x, (0.6,0.7), (0.3,0.2)⟩, G = ⟨x, (0.4,0.2), (0.4,0.8)⟩, H = ⟨x, (0.2,0.2), (0.4,0.8)⟩, I = ⟨x, (0.4,0.2), (0.4,0.7)⟩, J = ⟨x, (0.4,0.2), (0.6,0.8)⟩ and K = ⟨x, (0.2,0.2), (0.6,0.8)⟩. Let A = ⟨x, (0.6,0.7), (0.4,0.2)⟩ and B = ⟨x, (0.4,0.7), (0.3,0.2)⟩ be any two IFS in (X,τ). Then A ⊆ U where U is an IFROS in X. αcl(A) = ⟨x, (0.6,0.7), (0.4,0.2)⟩ ⊆ U and then B ⊆ U where U is an IFROS in X. αcl(B) = ⟨x, (0.4,0.7), (0.3,0.2)⟩ ⊆ U. Therefore A and B are IFRαGCS in X but A∪B = ⟨x, (0.6,0.7), (0.3,0.2)⟩ is not an IFRαGCS in X, since A∪B ⊆ U but αcl(A∪B) = ⟨x, (0.6,0.8), (0.2,0.2)⟩ ⊈ U.

Theorem 3.21: Let A be an IFRαGCS in an IFTS (X,τ) and A ⊆ B ⊆ αcl(A) then B is an IFRαGCS in (X,τ).

Proof: Let B ⊆ U and U be an IFROS in X. Then A ⊆ U, since A ⊆ B. As A is an IFRαGCS in X, αcl(A) ⊆ U. But by the hypothesis, B ⊆ αcl(A) ⟹ αcl(B) ⊆ αcl(A) ⊆ U. This implies αcl(B) ⊆ U. Hence B is an IFRαGCS in (X,τ).

Theorem 3.22: Let (X,τ) be an intuitionistic fuzzy topological space and A be an IFαCS of (X,τ). Then A is an IFRαGCS in (X,τ) if and only if $A\ {}_{q}^{c}\ F \Rightarrow \alpha cl(A)\ {}_{q}^{c}\ F$ for every IFRCS F of (X,τ).

Necessity: Let F be an IFRCS of X, and $A\ {}_{q}^{c}\ F$. Then $A \subseteq F^c$, by definition and F^c is IFROS in X. Therefore $\alpha cl(A) \subseteq F^c$ because A is an IFRαGCS in X. Hence $\alpha cl(A)\ {}_{q}^{c}\ F$.

Sufficiency: Let U be an IFROS of X such that A ⊆ U. Then $A\ {}_{q}^{c}\ (U^c)$ and U^c is an IFRCS in X. Hence by hypothesis, $\alpha cl(A)\ {}_{q}^{c}\ (U^c)$.Therefore $\alpha cl(A) \subseteq (U^c)^c = U$. Hence A is an IFRαGCS in (X,τ).

Theorem 3.23: If A is both an IFROS and IFRαGCS in (X,τ).Then A is an IFRGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. We have cl(A) = A∪cl(A), By hypothesis int(cl(A))=A as

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

A is an IFROS. This implies cl(A) = A∪cl(int(cl(A))) = αcl(A), By the hypothesis αcl(A) ⊆ U. This implies cl(A) ⊆ U. Hence A is an IFRGCS in (X,τ).

Theorem 3.24: If A is both an IFPOS and IFRαGCS in (X,τ).Then A is an IFRGCS in (X,τ).

Proof: Let A ⊆ U and U be an IFROS in X. We have cl(A) = A∪cl(A), By hypothesis A ⊆ int(cl(A)) as A is an IFPOS. This implies cl(A) ⊆ A∪cl(int(cl(A))) = αcl(A), By the hypothesis αcl(A) ⊆ U. This implies cl(A) ⊆ U. Hence A is an IFRGCS in (X,τ).

Theorem 3.25: If A is an IFROS and an IFRαGCS in (X,τ). Then A is an IFαCS in (X,τ).

Proof: As A ⊆ A, by the hypothesis, αcl(A) ⊆ A. But we have A ⊆ αcl(A). This implies αcl(A) = A. Hence A is an IFαCS in (X,τ).

Theorem 3.26: Let (X,τ) be an IFTS. Then every IFS in (X,τ) is an IFRαGCS if and only if IFαO(X) = IFαC(X).

Necessity: Suppose that every IFS in (X,τ) is an IFRαGCS. Let U ∊ IFRO(X), then U ∊ IFαO(X) and by the hypothesis, αcl(U) ⊆ U ⊆ αcl(U). This implies αcl(U) = U. Therefore U ∊ IFαC(X). Hence IFαO(X) ⊆ IFαC(X). Let A ∊ IFαC(X), then A^c ∊ IFαO(X) ⊆ IFαC(X). That is, A^c ∊ IFαC(X). Therefore A ∊ IFαO(X). Hence IFαC(X) ⊆ IFαO(X). Thus IFαO(X) = IFαC(X).

Sufficiency: Suppose that IFαO(X) = IFαC(X). Let A ⊆ U and U be an IFROS. Then U ∊ IFαO(X) and αcl(A) ⊆ αcl(U) = U, since U ∊ IFαC(X), by hypothesis. Therefore A is an IFRαGCS in (X,τ).

Theorem 3.27: Let A be an IFRαGCS in (X,τ) and p(α, β) be an IFP in X such that $int(p_{(\alpha,\beta)})\ _q\ \alpha cl(A)$, then $cl(int(p_{(\alpha,\beta)}))\ _q\ A$.

Proof: Let A be an IFRαGCS and let $int(p_{(\alpha,\beta)})\ _q\ \alpha cl(A)$. If $cl(int(p_{(\alpha,\beta)}))\ _q^c\ A$ then by Definition 2.9, A ⊆ $[cl(int(p_{(\alpha,\beta)}))]^c$ where $[cl(int(p_{(\alpha,\beta)}))]^c$ is an IFROS. Then by hypothesis, αcl(A) ⊆$[cl(int(p_{(\alpha,\beta)}))]^c$ = $int(cl(p_{(\alpha,\beta)})^c)$ ⊆ $cl(p_{(\alpha,\beta)})^c$ = $(int(p_{(\alpha,\beta)}))^c$. This implies $\alpha cl(A)\ _q^c\ int(p_{(\alpha,\beta)})$. Therefore by Definition 2.9, $int(p_{(\alpha,\beta)})\ _q^c\ \alpha cl(A)$, which is a contradiction to the hypothesis. Hence $cl(int(p_{(\alpha,\beta)}))\ _q\ A$.

Theorem 3.28: Let F ⊆ A ⊆ X where A is an IFROS and an IFRαGCS in (X,τ). Then F is an IFRαGCS in A if and only if F is an IFRαGCS in (X,τ).

Necessity: Let U be an IFROS in X and F ⊆ U. Also let F be an IFRαGCS in A. Then clearly F ⊆ A ∩ U and A ∩ U is an IFROS in A. Hence the α closure of F in A, $\alpha cl_A(F)$ ⊆ A ∩ U. By Theorem 3.25, A is an IFαCS. Therefore αcl(A) = A and the α closure of F in X, αcl(F) ⊆ αcl(F) ∩ αcl(A) = αcl(F) ∩ A = $\alpha cl_A(F)$ ⊆ A ∩ U ⊆ U. That is αcl(F) ⊆ U whenever F ⊆ U. Hence F is an IFRαGCS in A.

Sufficiency: Let V be an IFROS in A such that F ⊆ V. Since A is an IFROS in X, V is an IFROS in X. Therefore αcl(F) ⊆ V, since F is an IFRαGCS in X. Thus $\alpha cl_A(F)$ = αcl(F) ∩ A ⊆ V ∩ A ⊆ V. Hence F is an IFRαGCS in A.

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