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$\hat{\delta}\omega$ Closed Sets in Ideal Topological Space

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Abstract: In this paper the notion of $\hat{\delta}\omega$ closed sets is introduced and some of its basic properties are studied. This new class of sets is independent of semi closed and closed sets. Also the relationship with some of the known closed sets is discussed.
Keywords: $\hat{\delta}\omega$ closed sets, closed sets, ω closed sets.

I. INTRODUCTION

Levine, velicko introduced the notions of generalized closed (briefly gclosed) and δ closed sets respectively and studied their basic properties. The notion of I_g closed sets was first introduced by Dontchev in 1999. Navaneetha Krishanan and Joseph further investigated and characterized I_g closed sets. Julian Dontchev and maximilian Ganster, Yuksel, Acikgoz and Noiri introduced and studied the notions of δ generalized closed (briefly δ g closed) and δ-I-closed sets respectively. The purpose of this paper is to define a new class of sets called $\hat{\delta}\omega$ closed sets and also study some basic properties and characterizations.

Throughout this paper (X, τ ,I) represents a ideal topological space on which no separation axiom is assumed unless otherwise mentioned. For a subset A of a ideal topological space X, cl(A) and int(A) denote the closure of A and the interior of A respectively. X / A or A^c denotes the complement of A in X. We recall the following definitions and results.

II. PRELIMINARIES

A. subset A of a space X is called

pre-open set if $A \subseteq intcl(A)$ and pre-closed set if $clint(A) \subseteq A$.

semi-open set if $A \subseteq clint(A)$ and semi-closed set if $intcl(A) \subseteq A$.

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regular open set if $A = intcl(A)$ and regular closed set if $A = clint(A)$.

Π -open set if A is a finite union of regular open sets.

regular semi open if there is a regular open U such $U \subseteq A \subseteq cl(U)$

B. A subset A of (X, τ) is called

generalized closed set, if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X.

regular generalized closed set, if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is regular open in X.

weakly generalized closed set, if $clint(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X.

weakly closed set, if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi open in X.

regular weakly generalized closed set, if $clint(A) \subseteq U$, whenever $A \subseteq U$ and U is regular open in X.

regular weakly closed if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is regular semi open.

g-closed if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is w-open.

Let A and B be subsets of an ideal topological space (X, τ, I). Then, the following properties holds.

$A \subseteq \sigma cl(A)$.

If $A \subset B$, then $\sigma cl(A) \subset \sigma cl(B)$.

$\sigma cl(A) = \cap \{ F \subset x \setminus A \subset F$ and F is $\delta - I - closed \}$.

If A is δ -I-closed set of X for each $\alpha \in \Delta$, then $\cap \{A\alpha / \alpha \in \Delta\}$ is δ -I-closed.

σ cl(A) is δ-I-closed.

δ.I closure is $\{x \in X$: $int(cl^*(U)) \cap A \neq \phi$, $U \in I \}$.

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III. $\hat{\delta}\omega$ - CLOSED SETS IN IDEAL TOPOLOGICAL SPACES

Definition 3.1 : A subset A of an ideal space (X, τ, I) is called $\hat{\delta}\omega$ closed, if $\sigma cl(A) \subseteq U$, whenever $A \subseteq U$ and U is ω open.

Theorem 3.1

Every g-closed set in X is $\hat{\delta}\omega$ -closed set in X.

Proof: Let A be an arbitrary g-closed set in the space X. Suppose $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open. i.e., $A \subseteq U$ and U is open. Then by the

$\hat{\delta}\omega$ - closed sets in ideal topological space 3

definition of $\hat{\delta}\omega$ -closed set, if $\sigma cl(A) \subseteq U$, Whenever $A \subseteq U$ and U is ω open in X. Hence, the arbitrary element A of g-closed set belongs to U and also the arbitrary element A of $\hat{\delta}\omega$ -closed set belongs to U. This implies A is a $\hat{\delta}\omega$ - closed set.

The converse of the above theorem is not true, which is verified from the following example.

Example 3.1: Let $X = \{b, c, d\}$ be with topology $\tau = \{\phi, \{c\}, \{d\}, \{c, d\}, X\}$. Now if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is open in X. Then g-closed set will be $\{\phi, \{b\}, \{b, c\}, \{b, d\}, X\}$. Here, $A = \{c\}$ is a set. $\hat{\delta}\omega$ -closed set but not g-closed.

Theorem 3.2

Every closed set in X is $\hat{\delta}\omega$ -closed set in X.

Proof: Let A be an arbitrary closed set in the space X, every closed set is g-closed set and from the theorem 3.1, every g-closed set in X is $\hat{\delta}\omega$ -closed. Thus every closed set in X is $\hat{\delta}\omega$ -closed.

The converse of the above theorem is not true, which is verified from the following example.

Example 3.2: Let X = {b, c, d} be with the topology $\tau = \{\phi, \{c\}, \{d\}, \{c, d\}, X\}$ and $\tau^C = \{\phi, \{b, d\}, \{b, c\}, \{b\}, X\}$. Thus, the closed set is $\{\phi, \{b, d\}, \{b, c\}, \{b\}, X\}$. Here $A = \{c, d\}$ is $\hat{\delta}\omega$ -closed set but not closed set.Theorem 3.3

Every regular closed set in X is $\hat{\delta}\omega$ –closed

Proof: Let A be an arbitrary regular closed set in the space X , every regular closed set is closed and from the theorem 3.1, every g-closed set in X is $\hat{\delta}\omega$ –closed. This implies every regular closed set in X is $\hat{\delta}\omega$ –closed.

The converse of the above theorem is not true, which is verified from the following example.

Example 3.3: Let X = {b, c, d} be with the topology $\tau = \{\phi, \{c\}, \{d\}, \{c, d\}, X\}$ and $\tau^c = \{\phi, \{b, d\}, \{b, c\}, \{b\}, X\}$, the regular closed set, here is $\{\phi, \{b, d\}, \{b, c\}, X\}$. Then A = {c, d} is $\hat{\delta}\omega$ -closed set but not regular closed.

Theorem 3.4

Every regular generalized closed set in X is $\hat{\delta}\omega$ –closed.

Proof: Let A be an arbitrary regular generalized closed set in the space X. Suppose $cl(A) \subseteq U$. Whenever $A \subseteq U$ and U is regular open. i.e., $A \subseteq U$ and U is regular open, every regular open set in X is open. Then by the definition of $\hat{\delta}\omega$ -closed set, if $\sigma cl(A) \subseteq U$, whenever $A \subseteq U$ and U is ω open in X. Hence, the arbitrary element A of regular generalized closed set belongs to U and the arbitrary element A of $\hat{\delta}\omega$ -closed set belongs to U. This implies that A is a $\hat{\delta}\omega$ -closed set.

The converse of above theorem need not be true, which is verified from the following example.

Example 3.4: Let X = {b, c, d} be with topology $\tau = \{\phi, \{c\}, \{d\}, \{c, d\}, X\}$ and $\tau^c = \{\phi, \{b, d\}, \{b, c\}, \{b\}, X\}$. Then if $cl(A) \subseteq U$, whenever $A \subseteq U$ and U is regular open in X. Then regular generalized closed set will be $\{\phi, \{b, d\}, \{b, c\}, \{c, d\}, \{b\}, X\}$. Here A = {c} is a $\hat{\delta}\omega$ -closed set but not regular generalized closed set.

Theorem 3.5

Every weakly generalized closed set in X is $\hat{\delta}\omega$ -closed.

Proof: Let A be an arbitrary weakly generalized closed set in the space X .Then by definition of weakly generalized closed set and $\hat{\delta}\omega$ -closed set the arbitrary element A of weakly generalized closed set belongs to U and the arbitrary element A of $\hat{\delta}\omega$ –closed set belongs to U. This implies that A is a $\hat{\delta}\omega$ -closed set.

The converse of the above theorem need not to be true, which is verified from the following example.

Example 3.5: Let $X = \{b, c, d\}$ be with the topology $\tau = \{\phi, \{c\}, \{d\}, \{c, d\}, X\}$. Now, if $cl(int(A)) \subseteq U$ whenever $A \subseteq U$ and U is open in X . Then wg-closed set will be $\{\phi, \{b, c\}, \{b, d\}, \{b\}, X\}$. Here A = {c} is a $\hat{\delta}\omega$ -closed set but not weakly generalized closed.

Theorem 3.6

Every semi closed set in X , is $\hat{\delta}\omega$ –closed.

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Proof: Let A be an arbitrary semi closed set in the space X, every semi closed set is closed and from the theorem 3.1 every closed set in X is $\hat{\delta}\omega$ –closed set. This implies, every semi closed set in X is $\hat{\delta}\omega$ closedset.

The converse of the above theorem is not true, which is verified from the following example.

Example 3.6: Let $X =$ $\{b, c, d\}$ be with the topology $\boldsymbol{\tau} = \{\phi,\{c\},\{d\},\{c,d\},X\}$. Then from the definition of semi closed set $\{\phi,\{b,d\},\{b,c\},X\}$. Here $A=\{c\}$is $\hat{\delta}\omega$ -closedset, but not semi-closed.

Theorem3.7

Every weekly closed set in X is $\hat{\delta}\omega$ –closed set.

Proof: Let A be a weakly closed set in the space X. Suppose cl(A)⊆U When ever A⊆ U and U is semi open in X . i.e., when ever A⊆ U and U is semi Open, every semi open set is open in X. Then by the definition of $\hat{\delta}\omega$ –closed set. if $\sigma cl(A)\subseteq U$,whenever $A\subseteq U$ and U is ωopen in X. Hence, the arbitrary element A of weakly closed set belongs to U and the arbitrary element A of δˆω –closed set belongs to U . This implies that A is a $\hat{\delta}\omega$ –closed set in X.

The converse of the above theorem need not to be true, which is verified from the following example.

Example 3.7: Let $X = \{b,c,d\}$ be with the topology $\boldsymbol{\tau}$ = {ϕ, {c} ,{d} , {c, d} , X} . Now if cl(A) ⊆ U , whenever A ⊆ U and U is semiopen in X. Then $U= \{\phi,\{c\},\{d\},X\}$. Then weakly closed set will be {ϕ,{b},{b,d},{b,c},{c,d},X}.Here A={c}is a closed set in $\hat{\delta}\omega$ - closed set, but not Weakly X.

Theorem3.8

Every regular weakly generalized closed set in X is $\hat{\delta}\omega$ - closed.

Proof: Let A be a regular weakly generalized closed set in the space X. Suppose cl(int(A)) ⊆ U whenever A ⊆ U and U is open in X . i.e., A⊆ U and U is open, every regular open set in X is open. Then by the definition of $\hat{\delta}\omega$ closed set , if σcl(A)⊆ U , whenever A ⊆ U and U is $\hat{\delta}\omega$ open in X . Hence, the arbitrary element A of regular weakly generalized closed set belongs to U and the arbitrary element A of $\hat{\delta}\omega$ -closed set belongs to U. This implies that A is a $\hat{\delta}\omega$ -closed set in X.

example 3.8: Let X = {b, c, d} be with the topology $\boldsymbol{\tau}$ = {ϕ, {c} , {d} , {c, d} , X} . Now if cl(int(A)) ⊆ U , whenever A ⊆ U and U is regular open in X .Then U = {ϕ, {c} , {d} , X} . Then regular weakly generalized closed set will be {ϕ , {b}, {b,d}, {b,c}, {c,d}, X}. Here A = {c} is a set, $\hat{\delta}\omega$ closed set but not regular weakly generalized.

Theorem 3.9

Every regular semi closed set in X is $\hat{\delta}\omega$ closed set.

Proof: Let A be an arbitrary regular semi closed set in the space in X . Suppose U U ⊆ A ⊆ cl(U) whenever U is regular open set in X is open. i.e., U is open. Then by the definition of $\hat{\delta}\omega$ -closed set, if σcl(A) ⊆ U , whenever A ⊆ U and U is $\hat{\delta}\omega$ open in X. Hence, the arbitrary element A of regular semi closed set belongs to U and the arbitrary element A of $\hat{\delta}\omega$ -closed set belongs to U .Thus we can say that This implies that A is a $\hat{\delta}\omega$ -closed set.

The converse of the above theorem need not to be true, which is verified from the following example.

Example 3.9: Let X = {b, c, d} be with the topology τ = {ϕ, {c , {d} , {c, d} , X} and τ^c = {ϕ, {b, d} , {b, c} , {b} , X} . Then, from the definition of regular semi closed set is {ϕ, {c} , {d} , {b, d} , {b, c} , {c, d} , X} . Here let A = {b} is $\hat{\delta}\omega$ -closed set but not regular semi closed.

Theorem 3.10

Every regular weakly closed set in X is $\hat{\delta}\omega$ - closed.

Proof: Let A be an arbitrary regular weakly closed set in the space X , every semi open set is open and from the theorem 3.2, every closed set in X is $\hat{\delta}\omega$ -closed set This is implies that every regular weakly closed set in X is $\hat{\delta}\omega$ -closed set

The converse of the above theorem is not true, which is verified using following example

Example 3.10: Let X = $\{b,c,d\}$ be with the topology $\boldsymbol{\tau}$= {ϕ, {c} , {d} , {c, d} , X} .Then by the definition of regular weakly closed set {ϕ, {c} , {d} , {b} , {b, c} , {b, d} , X} . Here A = {c, d} is $\hat{\delta}\omega$ - closed set but not regular weakly closed.

Theorem 3.11

Every ∗g -closed set in X is $\hat{\delta}\omega$ - closed.

Proof: Let A be an arbitrary *g -closed set in the space X. Suppose cl(A) ⊆ U , whenever A ⊆ U and U is semi open X . i.e., whenever A ⊆ U and U is semi open, every weakly open set is open in X. Then by the definition of $\hat{\delta}\omega$ –closed set, if σcl(A) ⊆

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U , whenever A ⊆ U and U is ω open in X . Hence, the arbitrary element A of ∗g -closed set belongs to U and the arbitrary element A of $\hat{\delta}\omega$ closed set belongs to U . This implies that A of $\hat{\delta}\omega$ - closed set in X .
the converse of the above theorem need not to be true, which is verified using following example.
Example 3.11: Let X = {b, c, d} be with the topology $\boldsymbol{\tau}$= {∅, {c} , {d} , {c, d} , X} . Now if cl(A) ⊆ U , whenever A ⊆ U and U is weakly open in X . Then U={ ∅ , {c, d}, {c}, {b}, {d}, X}. Then *g closed set will be {∅,{b}, {b, d}, {b, c}, X}. Here A={c} is a $\hat{\delta}\omega$ closed set, but not ∗g -closed set in X.
Theorem 3.12
Every θ -closed set in X is $\hat{\delta}\omega$ – closed set.
Proof: Let A be an arbitrary θ -closed set in space X. Suppose cl_θ (A) ⊆ U, whenever A ⊆ U and U is open. i.e., A ⊆ U and U is open. Then by the definition of $\hat{\delta}\omega$ -closed set, if σcl(A) ⊆ U , whenever A ⊆ U and U is $\hat{\delta}\omega$ open in X . Hence, the arbitrary element A of θ -closed set belongs to U and also the arbitrary element *A* of $\hat{\delta}\omega$ - closed set belongs to U. This implies that, A is $\hat{\delta}\omega$ closed.
The converse of the above theorem is not true, which is verified from the following example.
Example 3.12: Let X = {b, c, d} be with the topology τ = { ∅ , {c}, {d}, {c, d}, X}. Now if clθ (A) ⊆ U , whenever A ⊆ U and U is open in X . Then θ –closed set will be {ϕ, {b, c}, {b, d}, {b}}. Here A= {c} is a $\hat{\delta}\omega$ - closed set, but not θ -closed set.
Theorem 3.13
Every $\hat{\delta}$ - closed set in X *is* $\hat{\delta}\omega$ - closed set in X.
Proof: Let A be an arbitrary δ -closed set in space X. Suppose clδ (A) ⊆ U, whenever A ⊆ U and U is open. i.e., A⊆ U and U is open. Then by the definition $\hat{\delta}\omega$ -closed set, if σcl(A) ⊆ U , whenever A ⊆ U and U is ω open in *X*. Hence, the arbitrary element Aof δ -closed set belongs to U and also the arbitrary element A of $\hat{\delta}$ - closed set belongs to U. This implies that, A is a $\hat{\delta}\omega$ closed.
The converse of the above theorem is not true, which is verified from the following example
Example 3.13: Let *X* = *{b,c,d}* be with the topology $\boldsymbol{\tau}$ = {ϕ, {c} ,{d} , {c, d} , X} . Now if clδ(A) ⊆U , whenever A ⊆U and U is open in X. Then δ-closed set will be {ϕ, {b, c} , {b, d} , {b}} . Here A= {c} is a $\hat{\delta}\omega$ closed set, but not δ –closed.

IV. SOME OPERATIONS ON $\hat{\delta}\omega$ - CLOSED SETS

Theorem 4.1
The union of two $\hat{\delta}\omega$ closed sets of X is also an $\hat{\delta}\omega$ -closed sets of X.
Proof: Assume that A and B are $\hat{\delta}\omega$ - closed set in X. Let U be open in X, such that A ∪ B ⊆ U. Thus A⊆ U and B ⊆ U. Since A and B are $\hat{\delta}\omega$ – closed set so σcl(A) ⊆ U and σcl(B) ⊆ U . Hence σcl(A ∪ B) = σcl(A) ∪ σcl(B) ⊆ U . i.e., σcl(A ∪ B) ⊆ UHence A ∪ B is an $\hat{\delta}\omega$ - closed set in *X*.
Theorem 4.2
If a subset A of X is $\hat{\delta}\omega$ - closed in *X* , then $\sigma cl(A)\backslash A$, *A* does not contain any non-empty open set in X .
Proof: Suppose that A is $\hat{\delta}\omega$ -closed set in X. Let U be open set such that σcl(A)\A U and U ≠∅. Now U ⊆ σcl(A)\A , i.e., U ⊆ X\A which implies that A⊆ X\U . As U is open, X\U is also open in X. Since A is an $\hat{\delta}\omega$
$\hat{\delta}\omega$ -Closed sets in ideal topological 9closed set in X , by definition of $\hat{\delta}\omega$- closed set, we have σcl(A) ⊆ X\U. So U ⊆ X\σcl(A) . Therefore U ⊆σcl (A) ∩(X\σcl(A)) = ∅ This show that U = ∅, which is contradiction. Hence σcl(A)\A doesnot contain any nonempty open set in X.
Theorem 4.3
For an element x ∈ X, the set X\ {x} is $\hat{\delta}\omega$ - closed or ω open.
Proof: Let x ∈ X. Suppose X\ {x} is not ω open. Then X is the only ω open set containing X\ {x} ,which means that the only choice of ω open set containing X\ {x} is X. i.e., X\ {x} ⊂ X. Also, we know X\ {x} is not $\hat{\delta}\omega$-closed. To prove X\ {x} is open. Suppose X\ {x} is not open. As X\ {x} is a subset of x and X\ {x} only but X\ {x} is not open. Thus the only open set in X. Also σcl(X\ {x}) ⊂ X . Therefore by the definition of $\hat{\delta}\omega$ - closed sets X\ {x}is $\hat{\delta}\omega$ - closed, which is a contradiction. Hence X\ {x} is ω open.
Theorem 4.4

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If A is an $\hat{\delta}\omega$ -closed subset of X such that $A \subset B \subset \sigma cl(A)$, then B is an $\hat{\delta}\omega$ - closed set in X.

Proof: Let A bean $\hat{\delta}\omega$ -closed in X, such that $A \subset B \subset \sigma cl(A)$. Let U be open set such that $B \subset U$, then $A \subset U$. Since A is $\hat{\delta}\omega$ - closed, we have $\sigma cl(A) \subset U$. Now as $B \subset \sigma cl(A)$. So $\sigma cl(B) \subset \sigma cl(\sigma cl(A)) \subset \sigma cl(A) \subset U$. Thus $\sigma cl(B) \subset U$, whenever $B \subset c$ and U is ω open. Therefore B is a $\hat{\delta}\omega$ - closed in X.

Converse of the theorem is not true, which is verified from the following example.

Example4.1:LetX={b,c,d}be with the topology τ = {ϕ,{c},{d},{c,d},X} $\hat{\delta}\omega$ – closed set is{ϕ,{c},{d},{b},{b,c},{c,d},{b,d},X}.Now σcl(A)={d} which is contained in each ω open set. σcl(B) = {c} , which is also contained in each open set. Thus by the definition, A and B both are $\hat{\delta}\omega$ - closed.

Theorem 4.5

If a subset Aof a topological space X is both ω open and $\hat{\delta}\omega$ - closed then it is ω closed.

Proof: Suppose a subset A of a topological space in X is both ω open and $\hat{\delta}\omega$ - closed. Now $A \subset A$ then by definition of $\hat{\delta}\omega$ - closed we have $\sigma cl(A) \subset A$. So $A \subset \sigma cl(A)$. Thus we have $\sigma cl(A) = \sigma cl(A)$. Finally A is open.

Theorem 4.6

If a subset A of a topological space X is both open and $\hat{\delta}\omega$ - closed then it is closed.

Proof: Suppose a subset A of a topological space in X is both open and $\hat{\delta}\omega$ - closed. Now $A \subset A$ then by definition of $\hat{\delta}\omega$ - closed we have $\sigma cl(A) \subset A$. So $A \subset \sigma cl(A)$. Thus we have $\sigma cl(A) = \sigma cl(A)$. Finally A is open.

Theorem 4.7

In a topological space X if open of X are {X, ϕ}, then every subset of X is an $\hat{\delta}\omega$ - closed set.

Proof: Let X be topological space and open. i.e., {X, ϕ}. Suppose A be any arbitrary subset of X, if A = ϕ then X is an $\hat{\delta}\omega$ - closed set in X. If A ⊭ ϕ then X is the only open set containig A and so $\sigma cl(A) \subset X$. Hence by the definition A is $\hat{\delta}\omega$ - closed in X.

The converse is not true, which is verified by following example.

Example 4.2: Let X = {b, c, d} be with the topology τ = ϕ, {c} , {d} , {c, d} , X} , every subset of X is an $\hat{\delta}\omega$ -closed set in X . Thus for every subset of X is an $\hat{\delta}\omega$ - closed set, we need not be open set only if {X, ϕ} .

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