

# $\delta$ mk-Closed Set and $\delta$ mk-Open Set in Topological Spaces

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**ABSTRACT:** In this paper, we introduce and investigate the notation of  $\delta$ mk-closed set and  $\delta$ mk-open set. We obtain fundamental properties of  $\delta$ mk-closed set,  $\delta$ mk-open set and discuss the relation between  $\delta$ mk-closed set,  $\delta$ mk-open set and other related sets.

**KEYWORDS:**  $\delta$ mk-closed set,  $\delta$ mk-open set.

## I. INTRODUCTION

The concept of generalized closed sets introduced by Levine [1] plays a significant role in general topology. After the introduction of generalized closed sets many research papers were published which deal with different types of generalized closed sets. Y. Gnanambal [2] introduced the concept of gpr-closed set and investigated its basic properties. H. Maki et al. [3] defined the concept of gp-closed set in topological spaces and established results related to it. These concepts motivated us to define a new class of sets called the delta generalized pre-closed sets. Throughout this paper,  $(X, \tau)$  (or simply  $X$ ) represents topological space on which no separation axioms are assumed unless explicitly stated. For a subset  $A$  of a space  $(X, \tau)$ , we denote the closure of  $A$ , the interior of  $A$  and complement of  $A$  as  $Cl(A)$ ,  $int(A)$  and  $A^c$  respectively. The modified forms of generalized closed sets and  $\hat{g}$ -closed sets were studied by K. Balachandran, P. Sundaram and H. Maki [4]. In 2008, S. Jafari, T. Noiri, N. Rajesh and M.L. Thivagar [5] introduced the concept of  $\hat{g}$ -closed sets and their properties. In this paper, we introduce new classes of sets called  $\hat{g}$ -closed sets for topological spaces.

## II. PRELIMINARIES

**2.1.** A subset  $A$  of a topological space  $X$  is called, pre-open [6] if  $A \subseteq int(Cl(A))$  and Pre-closed if  $Cl(int(A)) \subseteq A$   $Cl(int(A))$ .

**2.2.** A subset  $A$  of a topological space  $X$  is called,  $\alpha$ -open [7] if  $A \subseteq int(Cl(int(A)))$  and  $\alpha$ -closed if  $Cl(int(Cl(A))) \subseteq A$ .

**2.3.** A subset  $A$  of a topological space  $X$  is called,  $b$ -open [8] if  $A \subseteq Cl(int(A)) \cup int(Cl(A))$  and  $b$ -closed if  $Cl(int(A)) \cap int(Cl(A)) \subseteq A$ .

**2.4.** A subset  $A$  of a topological space  $X$  is called, regular-open [9] if  $A = Cl(int(A))$  and regular-closed if  $A = Cl(int(A))$ .

**2.5.** A subset  $A$  of a topological space  $X$  is called, semi-open [10] if  $A \subseteq Cl(int(A))$  and semi-closed if  $int(Cl(A)) \subseteq A$ .

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**2.6.** A subset  $A$  of a topological space  $X$  is called, Semi preopen [11] if  $A \subseteq cl(int(cl(A)))$  and semi preclosed if  $int(cl(int(A))) \subseteq A$ .

**2.7.** A subset  $A$  of a topological space  $X$  is called,  $\delta$ -closed [12] if  $A = cl_\delta(A)$  where  $cl_\delta(A) = \{x \in X : int(cl(U)) \cap A \neq \Phi, U \in \tau \text{ and } x \in U\}$ . The Complement of  $\delta$ -closed is  $\delta$ -open.

**2.8.** Let  $(X, \tau)$  be a topological space and  $A \subseteq X$ .

The pre-interior of  $A$ , denoted by  $pint(A)$ , is the union of all preopen subsets of  $A$ .

The pre-closure of  $A$ , denoted by  $Pcl(A)$ , is the intersection of all preclosed sets containing  $A$ .

**2.9.** A subset  $A$  of a topological space  $X$  is called, Generalized closed (briefly,  $g$ -closed) [1] if  $cl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is open in  $X$ . The complement of  $g$ -closed is  $g$ -open.

**2.10.** A subset  $A$  of a topological space  $X$  is called, Generalized  $\alpha$ -closed (briefly,  $g\alpha$ -closed) [113] if  $\alpha cl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is  $\alpha$ -open in  $X$ . The complement of  $g\alpha$ -closed is  $g\alpha$ -open.

**2.11.** A subset  $A$  of a topological space  $X$  is called,  $\alpha$ -generalized closed (briefly,  $\alpha g$ -closed) [14] if  $\alpha cl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is Open in  $X$ . The complement of  $\alpha g$ -closed is  $\alpha g$ -open.

**2.12.** A subset  $A$  of a topological space  $X$  is called, Generalized pre-closed (briefly,  $gp$ -closed) [15] if  $pcl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is Open in  $X$ . The complement of  $gp$ -closed is  $gp$ -open.

**2.13.** A subset  $A$  of a topological space  $X$  is called, Generalized preregular closed (briefly  $gpr$ -closed) [2] if  $pcl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is regular Open in  $X$ . The complement of  $gpr$ -closed is  $gpr$ -open.

**2.14.** A subset  $A$  of a topological space  $X$  is called,  $\delta$ -generalized closed (briefly,  $\delta g$ -closed) [16] if  $\delta cl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is Open in  $X$ . The complement of  $\delta g$ -closed is  $\delta g$ -open.

**2.15.** A subset  $A$  of a topological space  $X$  is called, Pregeneralized closed (briefly,  $pg$ -closed) [3] if  $pcl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is preopen in  $X$ . The complement of  $pg$ -closed is  $pg$ -open.

**2.16.** A subset  $A$  of a topological space  $X$  is called, Generalized semi-preclosed (briefly,  $gsp$ -closed) [17] if  $spcl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is Open in  $X$ . The complement of  $gsp$ -closed is  $gsp$ -open.

**2.17.** A subset  $A$  of a topological space  $X$  is called, Pre semi closed [18] if  $spcl(A) \subseteq U$  whenever  $A \subseteq G$  and  $G$  is  $g$ -open in  $X$ . The complement of Pre semi closed is Pre semi open.

**2.18.** A subset  $A$  of a topological space  $X$  is called a delta generalized pre-closed (briefly,  $\delta gp$ -closed) [19] set if  $pcl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is  $\delta$ -open in  $X$ . The complement of  $\delta gp$ -closed is  $\delta gb$ -open.

The family of all  $\delta gp$ -closed sets in a topological space  $X$  is denoted by  $\delta GPC(X)$ .

**Example:2.1**

Let  $X = \{a, b, c\}, \tau = \{\phi, x, \{a\}, \{b\}, \{a, b\}\}$   $\tau^c = \{\phi, x, \{b\}, \{ac\}, \{bc\}\}$  then  $\delta GPC(X) = \{\phi, x, \{c\}, \{a, c\}, \{b, c\}\}$ .

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**2.19.** Let  $(X, \tau)$  be a topological space. A subset  $A \subseteq X$  is said to be  $\hat{g}$ -closed set [20] if  $cl(A) \subseteq G$  whenever  $A \subseteq G$  and  $G$  is semi o-open in  $X$ . The complement of  $\hat{g}$ -closed is  $\hat{g}$ -open.

**Example:2.2**

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{a\}, \{a, c\}\}$  and  $\tau^c = \{\emptyset, x, \{b\}, \{b, c\}\}$  then  $\hat{g} = \{\emptyset, x, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$ .

### III. $\delta mk$ -CLOSED SET

**Definition:3.1**

.Let  $(X, \tau)$  be a topological space. A subset  $A \subseteq X$  is said to be  $\delta mk - closed$  set if

- (i)  $\delta gp$ -closed,
- (ii)  $\hat{g}$ -closed.

The complement of  $\delta mk - closed$  is  $\delta mk$ -open.

**Example:3.1**

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{b\}, \{c\}, \{bc\}\}$  and  $\tau^c = \{\emptyset, x, \{a\}, \{ac\}, \{ab\}\}$  then  $\delta mk - closed$   
 $= \{\emptyset, x, \{a\}, \{ab\}, \{ac\}\}$ .

**Theorem:3.1**

Let  $(x, \tau)$  be a Topological Space. Prove that Every closed set is  $\delta mk - closed$  set in  $X$ .

But not conversely. ( $U=X$ )

**Proof:**

Let  $A$  be a Closed set.

then  $Cl(A) = A$ ,

Take  $A \subseteq U$  and  $U$  is semiopen in  $X$ .

Then  $Cl(A) \subseteq U$

$\therefore A$  is  $\hat{g}$ -closed. Every Semi open is  $\delta$ -open in  $X$ . Therefore  $U$  is  $\delta$ -open in  $X$ .

$Cl(A) \subseteq Pcl(A)$  and  $A$  is  $\hat{g}$ -closed.

Therefore  $A$  is Preclosed in  $X$ .

Therefore  $A$  is  $\delta mk - closed$  set.

**Example:3.2**

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{b\}, \{bc\}\}$ ,  $\tau^c = \{\emptyset, x, \{a\}, \{ac\}\}$ .

$\delta mk$ -closed set  $= \{\emptyset, x, \{a\}, \{c\}, \{a, c\}\}$ , Preclosed  $= \{\emptyset, x, \{a\}, \{c\}, \{\{a, c\}\}$ ,

$\hat{g}$ -closed  $= \{\emptyset, x, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$ . The elements  $\{a\}, \{a, c\}$  are in closed, Preclosed,

$\hat{g}$ -closed and  $\delta mk$ -closed.

Therefore closed set is  $\delta mk$ -closed set.

The converse of the above theorem is not true.

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### Example:3.3

Let  $X = \{a, b, c\}$ ,  $\tau = \{\{c\}, \{a, b\}, \phi, X\}$  and  $\tau^c = \{\{c\}, \{a, b\}, \phi, X\}$ .

$\delta mk$ -closed set =  $\{\phi, x, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$

closed set =  $\{\phi, x, \{c\}, \{a, c\}\}$ . The element  $\{a\}$  is in  $\delta mk$ -closed but not in closed set

### Theorem 3.2.

Let  $(X, \tau)$  be a Topological Space. Prove that Every open set is  $\delta mk$ -open set in  $X$ . ( $U = X$ ). But not conversely.

### Example:3.4

Let  $X = \{a, b, c\}$ ,  $\tau = \{\phi, x, \{b\}, \{bc\}\}$ ,  $\tau^c = \{\phi, x, \{a\}, \{ac\}\}$ .

$\delta mk$ -open set =  $\{\phi, x, \{b, c\}, \{a, b\}, \{b\}\}$

The element  $\{a, b\} \in \delta mk$ -open set but not in open set.

### Theorem:3.3

Let  $(X, \tau)$  be a Topological Space. Prove that Regular Closed Set is  $\delta mk$ -closed set in  $X$ . But not conversely. ( $U = X$ )

### Proof:

Let  $A$  be a Regular Closed set in  $X$ .

Then  $A = Cl(Int(A))$ .

And also  $A$  is Regular open in  $X$ .

Therefore  $Int(A) = A$

$$\Rightarrow A = Cl(Int(A)) = Cl(A)$$

$$\Rightarrow A = Cl(A)$$

Take  $A \subseteq U$  and  $U$  is semiopen in  $X$ .

Then  $Cl(A) \subseteq U$

$\therefore A$  is  $\hat{g}$ -closed.

Every Semi open is  $\delta$ -open in  $X$ . Therefore  $U$  is  $\delta$ -open in  $X$ .

$$Cl(A) \subseteq Pcl(A) \subseteq A \subseteq U$$

$A$  is  $\hat{g}$ -closed.

Therefore  $A$  is  $\delta$ -generalized preclosed in  $X$ .

Therefore  $A$  is  $\delta mk$ -closed set in  $X$ .

### Example:3.5

Let  $X = \{a, b, c\}$ ,  $\tau = \{\phi, x, \{c\}, \{b\}, \{b, c\}, \{a, c\}\}$  and  $\tau^c = \{\phi, x, \{a, c\}, \{a, b\}, \{a\}\{b\}\}$ ,

Regular closed =  $\{\phi, x, \{a, c\}, \{b\}\}$ , Regular open =  $\{\phi, x, \{a, c\}, \{b\}\}$  and  $\delta mk$ -closed set =  $\{\phi, x, \{a, c\}, \{a, b\}, \{a\}\{b\}\}$ .

Here Regular closed set = Regular open set

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The converse of the above theorem need not to be true.

In the above example, element  $\{a\}$  is  $\delta$ mk-closed set but not in Regular Closed Set.

### Theorem 3.4

Let  $(X, \tau)$  be a Topological Space. Prove that Regular Open Set is  $\delta$ mk-open set in  $X$ . ( $U=X$ ). But not conversely.

### Example:3.6

Let  $X=\{a,b,c\}$ ,  $\tau = \{\emptyset, X, \{c\}, \{b\}, \{b,c\}, \{a,b\}\}$  and  $\tau^c = \{\emptyset, X, \{a,c\}, \{a,b\}, \{a\}, \{c\}\}$ ,

Regular open =  $\{\emptyset, X, \{a,b\}, \{c\}\}$  and  $\delta$ mk-Open set =  $\{\emptyset, X, \{b,c\}, \{a,b\}, \{c\}, \{b\}\}$ .

The element  $\{b\}$  is in  $\delta$ mk-Open set but not in Regular open.

### Theorem:3.5

Let  $(X, \tau)$  be a Topological Space. Prove that  $\delta$ mk-closed Set is Semi closed set in  $X$ .

But not conversely. ( $U=X$ )

### Proof:

Let  $A$  be a  $\delta$ mk- Closed set in  $X$ .

Then  $A$  is  $\hat{g}$  closed and  $\delta$ -generalized preclosed.

$\Rightarrow Cl(A) \subseteq U$  and  $Pcl(A) \subseteq U$  whenever  $A \subseteq U$  and  $U$  is Semiopen and  $\delta$ -open in  $X$ .

$\Rightarrow Cl(A) \subseteq Pcl(A) \subseteq U$

$\Rightarrow Cl(A) \subseteq U$

Every  $\delta$ -open set is open set in  $X$ .

$Int(Cl(A)) \subseteq int U = U$

$\Rightarrow Int(Cl(A)) \subseteq U$

$\Rightarrow Int(Cl(A)) \subseteq A$  . since  $A \subseteq U$

Therefore  $A$  is Semi closed in  $X$ .

The converse of the above theorem need not to be true.

### Example:3.7

Let  $X=\{a,b,c\}$ ,  $\tau = \{\emptyset, X, \{b\}, \{c\}, \{b,c\}\}$  and  $\tau^c = \{\emptyset, X, \{a\}, \{a,c\}, \{a,b\}\}$ , Semi closed =  $\{\emptyset, X, \{a\}, \{b\}, \{c\}, \{a,b\}, \{a,c\}\}$  and  $\delta$ mk-closed set =  $\{\emptyset, X, \{a\}, \{a,b\}, \{a,c\}\}$ .

The elements  $\{b\}, \{c\}$  in Semi closed set but not in  $\delta$ mk- closed set.

### Theorem:3.6

Let  $(X, \tau)$  be a Topological Space. Prove that  $\delta$ mk-open Set is Semi open set in  $X$ .

But not conversely. ( $U=X$ )

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### Example:3.8

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{b\}, \{c\}, \{b, c\}\}$  and  $\tau^c = \{\emptyset, x, \{a\}, \{a, c\}, \{a, b\}\}$ , Semi Open =  $\{\emptyset, x, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}\}$  and  $\delta$ mk-Open set =  $\{\emptyset, x, \{b\}, \{c\}, \{b, c\}\}$ .  
The elements  $\{a, c\}$  in Semi open set but not in  $\delta$ mk- open set.

### Theorem:3.7

Let  $(X, \tau)$  be a Topological Space. Prove that Every  $\delta$ mk-closed set is generalized closed set. But not conversely. ( $U = X$ )

#### Proof:

Let  $A$  be a  $\delta$ mk-closed set in  $X$ .

Then  $A$  is  $\hat{g}$  closed and  $\delta$ -generalized preclosed.

$\Rightarrow Cl(A) \subseteq U$  and  $Pcl(A) \subseteq U$  Whenever  $A \subseteq U$  and  $U$  is semiopen and  $\delta$ -open in  $X$ .

$\Rightarrow Cl(A) \subseteq Pcl(A) \subseteq U$

$\Rightarrow Cl(A) \subseteq U$

Every  $\delta$ -open set is open set in  $X$ .

Then  $A \subseteq U$  and  $U$  is open in  $X$ .

Therefore  $Cl(A) \subseteq U$  Whenever  $A \subseteq U$  and  $U$  is open in  $X$ .

Hence  $A$  is generalized closed.

The converse of the above theorem need not to be true.

### Example:3.9

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{b\}, \{bc\}\}$  and  $\tau^c = \{\emptyset, x, \{a\}, \{ac\}\}$ , generalized closed =  $\{\emptyset, x, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{bc\}\}$  and  $\delta$ mk-closed set =  $\{\emptyset, x, \{a\}, \{c\}, \{a, c\}\}$

The element  $\{b, c\}$  is in generalized closed set but not in  $\delta$ mk-closed set.

### Theorem:3.8

Let  $(X, \tau)$  be a Topological Space. Prove that Every  $\delta$ mk-open set is generalized open set. But not conversely. ( $U = X$ ).

### Example:3.10

Let  $X = \{a, b, c\}$ ,  $\tau = \{\emptyset, x, \{a\}, \{b\}, \{a, b\}, \{bc\}\}$  and  $\tau^c = \{\emptyset, x, \{a\}, \{c\}, \{ac\}, \{b, c\}\}$ , generalized Open =  $\{\emptyset, x, \{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{bc\}\}$  and  $\delta$ mk-Open set =  $\{\emptyset, x, \{a\}, \{b\}, \{b, c\}, \{a, b\}\}$

The element  $\{c\}$  is in generalized open set but not in  $\delta$ mk-open set.

#### Properties:

If  $A$  and  $B$  are  $\delta$ mk-closed sets, then

1.  $A \cap B \subseteq A \cup B$

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2.  $(A \cup B)^c = A^c \cap B^c$

3.  $A^c \cap B^c = (A \cup B)^c$

The above properties are true for  $\delta$ mk-Open set.

### IV.CONCLUSION

1.The following sets are subset of  $\delta$ mk-closed set

(i) $\alpha$ -closed, (ii)Regular closed, (iii) $g\alpha$ -closed, (iv) $\alpha g$ -closed

2. .The following sets are subset of  $\delta$ mk-open set

(i) $\alpha$ - open, (ii)Regular open, (iii) $g\alpha$ - open, (iv) $\alpha g$ - open.

3.  $\delta$ mk-closed set is subset of the following sets

(i)Semi closed, (ii)Semi preclosed, (iii) $g$ -closed, (iv) $gsp$ -closed, (v)pre semiclosed.

4.  $\delta$ mk-open set is subset of the following sets

(i)Semi open, (ii)Semi preopen, (iii) $g$ -open, (iv) $gsp$ -open, (v)pre semiopen.

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