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WEAK FORMS OF OPEN AND CLOSED FUNCTIONS BY USING b-δ OPEN SET

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ABSTRACT

The notion of b-open set and δ-open set were introduced by many topologists and several research paper with interesting results in different respects came to existence. Also the notion of b-δopen set was introduced by Almalty(2011) . The aim of this work is focused on generalization of functions in topological space and new classes of functions called weakly b-δ-open function and weakly b-δ-closed functions via b-δ-open set .The connections between these functions and other related functions are investigated. More ever we introduce some theorems and propositions that related with these functions. The result of this study show that how we can define new notations of functions by using a weak form of b-open set.

Keywords: Functions, Investigation, Topology, generation, definitions, applications, theorems

INTRODUCTION

Topology is an important and interesting area of mathematics. the study will not only introduce you to new concepts and theorems but old ones, like some definitions in to new perspective. Many topologists are focusing their research on generalized open sets which became will –known and important notations in topology and its applications. The notion of θ-open and δ-open sets were introduced by Velicko(1968).Also the notion of b-open sets was introduced by Anrijevič(1996)This type of sets was discussed by Ekici and Calads (2004)under the name of γ-open stes .Recently ,Park (2006) Introduced a new class of functions called θ-b continuous functions.Quite recently (Calas and Jafari 2007) obtained some generalized sets by utilizing b open set and studied the properties of these set. More ever Almalty(2011)Investigated new notion as a weak form of b-δopen sets, therefore this study is focused on this set and investigate new functions which are open and close b-δ-open stes.

KEY WARDS: b-open set, δ-open set. Generalized sets, regular space.

1. BASIC CONCEPT OF b- AND δ-OPEN SETS

In this study we shall state some concepts of b-open and δ-open sets and related topics that we shall need in this research. These results have been given in the form definitions, lemma or theorems. The space X and Y or (X,τ) (Y,τ) stand for topological spaces also let $A \subseteq X$,the closure of A and the interior of A will be denoted by $cl(A)$ and $int(A)$ respectively. point x is a limit point of a set A if every open set containing x contains at least one point of A distinct from x .Veličko(1986) introduced δ-interior of a subset A of X as the union of all regular open sets of X contained in A and is denoted by int_{δ}(A).The subset A is called δ-open set if A=int_{δ}(A).The complement of a δ-open set is called δ-closed.

1.1 Definition: A subset A of space X is said to be:

(1) semi-open (Levine 1963) if A$\subseteq cl\big(int(A)\big)$;

(2) α-open (Njastad 1965) if $A \subseteq int(cl(int(A))$;

(3) preopen (Mashhour 1982) if $A \subseteq int(cl(A))$;

(4) β-open (Monsef 1983)if $A \subseteq cl(int(A))$;

(5) b-open (Andrijevic 1996) if $A \subseteq cl(int(A)) \cup int(cl(A))$

The complement of b-open set is called b-closed .the family of all b-open set is denoted by $BO(X)$.The intersection of all b-open set containing A is called b-closure of A and is denoted by $bcl(A)$,and the union of all b-open sets of X contained in A is called $bint(A)$. A subset A of X is said to be b-regular if it is b-open and b-closed .The collection of all b-regular sets of X is denoted by $BR(X)$.

1.2 Definition: A subset) is said to be :$\tau$of a space (x, A

(1) a generalized closed set (briefly g-closed)(Levine 1970) if $cl(A) \subseteq U$ whenever $A \subseteq U$ and U is open;

(2) a δ –generalized closed (briefly δ-g-closed)(Dontchev2007) if $cl_{\delta}(A) \subseteq A$ whenever $A \subseteq U$ and U is open;

(3) a generalized b-closed set (briefly $gb - closed$)(Ganster 2007)if b-$cl(A) \subseteq U$ whenever A$\subseteq U$ and U is open.

The following diagrams are enlargement of some previous well-known diagrams. Note that of none of the implications is reversible.

θ-open δ-open → semi-open → b-open → β-open

↓ ↓ ↓

Open set→ α -open preopen

Diagram 1 (weak and strong forms of open set)

δ-closed set→ δ-g-closed set

↓

Closed set→ g-closed set

↓

Semi-closed set→ sg-closed set→ gb-closed s

↓ ↗

b-closed set →

Diagram1(weak forms of generalized closed sets)

Example 1.3 Let X={a,b,c} and let $\tau = \{\emptyset, X, \{\{a\}\}$,then the family of all b-closed set of X is $BC(X)$={$\emptyset, X, \{b\}, \{c\}, \{b,c\}$} but the family of all gb-closed set of X is n $GBC(X) = \{\emptyset, X, \{b\}, \{c\}, \{a,b\}, \{b,c\}, \{a,c\}\}$ then it is clear that {a,c} is gb-closed but not b-closed in X.

2. WEAK FORMA OF OPEN AND CLOSED FUNCTIONS

We introduce ,and study two new classes of functions called weakly b-δ-open functions and weakly b-δ-closed functions by using the notions of b-δ -open set and b-δ-closure operator. The connections between these functions and other related functions are investigated.

2.1.1 Definition: A point $x\epsilon X$ is called a b-δ-cluster(Almalty 2011) (resp.δ-cluster(Veličko 1968) point of A if $int(bcl(A)) \cap A \neq \emptyset$ (resp. $int(cl(U)) \cap A \neq \emptyset$)) (for every b-open containing x (resp. open) set U of x containing x.

The set of all b-δ-cluster(resp.δ-cluster) points of A is called the b-δ-closure (resp.δ-closure) of A and is denoted by $bcl_\delta(A)$ (resp.$cl_\delta(A)$). A subset A is said to be b-δ-closed (resp. δ-closed) if $bcl_\delta(A)$=A (resp. $cl_\delta(A) = A$). The complement of a b-δ-closed (resp.δ-closed) set is said to be b-δ-open (resp.δ-open).The b-δ-interior (resp.δ-interior) of A is defined by the union of all b -δ-open (resp.δ-open) sets contained in A and is denoted by $bint_\delta$(A) (resp.int_δ(A)). The family of all b-δ-open(resp.b-δ-closed) sets of a space X is denoted by $B\delta O(X)$(resp.$B\delta C(X)$).

2.1.2 Definition: A function $f: X \to Y$ is said to be b-δ open if for each open set U of X ,$f(U)$ is b-δ-open.

From the following definition we will introduce the concept of weakly b-δ function

2.1.3 Definition: A function $f: X \to Y$ is said to be weakly b-δ-open if $f(U) \subseteq bint_\delta(f(cl(U)))$ for each open U of X.

2.1.4 Example: Let $X = \{a, b, c\}$ and τ=$\{X, \emptyset, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}$. Let $f: X \to X$,be a function defined by $f(a)$ =c , $f(b)$ =b and $f(c) = a$ .then it is clear that $BO(X) = \{\emptyset, X, \{a\}, \{b\}, \{a, b\}, \{a, c\}\}$ and $B\delta OX = \{\emptyset, X, \{b\}, \{a, c\}\}$. Moreover, the set $\{a, c\}$is δ-open set .Then f is a weakly b-δ-open function which is not b –δopen set, since $f(U)$ is not b-δ-open in X.

2.1.5 Remark: Every b-δ open function is also weakly b-δ-open ,but the converse is not generally true.

2.1 Characterizations of Weakly *b*-*δ* open functions

Next, several characterizations of weakly b-δ-open functions are obtained.

2.1.6 Theorem: For a function $f: X \to Y$,the following conditions are equivalent:

(1) f *is* weakly b-δ-open

(2) $f(int_\delta(A))$⊆$bint_\delta(f(A))$ for every subset A of X;

(3) $int_\delta(f^{-1}(B) \subseteq f^{-1}(bint_\delta(B))$ for every subset B if Y;

(4)$f^{-1}(bcl_\delta(B)) \subseteq cl_\delta(f^{-1}(B))$for every subset B of Y.

Proof.(1)→(2): Let A be any subset of X and x∈ int_δ(A).Then ,there exists an open set U such that $x \in U \subseteq cl(U) \subseteq A$.Then ,$f(x) \in f(U) \subseteq f(c(U)) \subseteq f(A)$.Since f is weakly b- δopen ,$f(U) \subseteq bint_\delta\left(f(cl(U))\right) \subseteq bint_\delta(f(A))$.This implies that $f(x)$∈ $bint_\delta(f(A))$.This shows that $x \in f^{-1}\left(bint_\delta(f(A))\right)$.Then, $int_\delta(A) \subseteq f^{-1}(bint_\delta(f(A)))$,and so ,$f(int_\delta(A))$⊆$bint_\delta(f(A))$.

(2)→(3):Let B be any subset of Y .Then by (2),$f(int_\delta(f^{-1}(B))) \subseteq bint_\delta(f(f^{-1}(B)))$⊆$bint_\delta(B)$.Therefore,$int_\delta(f^{-1}(B))$⊆$f^{-1}(bint_\delta(B))$.

(3)→ (4):Let B be any subset of Y .Using (3),we have

$X - cl_\delta(f^{-1}(B)) = int_\delta(X - f^{-1}(B))$

$= int_\delta(f^{-1}(Y - B))$

$\subseteq f^{-1}(bint_\delta(Y - B))$

$f^{-1}(Y - bcl_\delta(B))$

$= X - f^{-1}(bcl_\delta$(B)).

Therefore ,we obtain $f^{-1}(bcl_\delta(B)) \subseteq cl_\delta(f^{-1}(B))$.

Therefore, we obtainf^{-1} $(bcl_\delta(B))$⊆$cl_\delta(f^{-1}(B))$.

(4)→(1):Let V be any open set of X and B=$Y - f(cl(V))$ By(4),

$f^{-1}(bcl_\delta(Y - f(cl(V))) \subseteq cl_\delta(f^{-1}(Y - f(cl(V)))$. Therefore, we obtain

$f^{-1}(Y - bint_\delta(f(cl(V))) \subseteq cl_\delta(X - f^{-1}\left(f(cl(V))\right) \subseteq cl_\delta(X - cl(V))$.

Hence V⊆ $int_\delta(cl(V)) \subseteq f^{-1}(bint_\delta(f(cl(V)))$ and $f(V) \subseteq bint_\delta\left(f(cl(V))\right)$.Then it is clear that f is weakly b-δ-open .

2.1.7 Proposition: For a function $f: X \to Y$,the following conditions are equivalent:

(1)f is weakly b-δ-open;

(2)For each $x \in X$ and each open subset U of X containing x, there exist a b-δ-open set V containing $f(x)$ such that $V \subseteq f(cl(U))$.

Proof 1→ 2:Let $x \in X$ and U be an open set in X with $x \in U$.Since f

is weakly b-δ-open ,$f(x) \in f(U) \subseteq bint_\delta\left(f(cl(U))\right)$. Let V=$bint_\delta\left(f(cl(U))\right)$.Then V is b –δ-open and $f(x) \in V \subseteq f(cl(U))$.

2→ 1:Let U be an open set in X and Let $y \in f(U)$. It follows from (2) that $V \subseteq f(cl(U))$ for some b-δ-open set V in Y containing y.Hence ,we have $y \in V \subseteq bint_\delta(f(cl(U)))$.This shows that $f(U) \subseteq bint_\delta\left(f(cl(U))\right)$.Thus f is weakly b-δ-open .

2.2 Some properties of weakly *b*-*δ*-open Functions

2.1.8 Proposition: Let X be a regular space .A function f:$(,\tau) \to (Y,\rho)$is weakly b-δ-open if and only if f is b-δ-open .

Proof. The sufficiency is clear. For the necessity, let V be a nonempty open subset of X. For x in V ,Let U_x be an open set such tha x ∈ $U_x \subseteq$ cl(U_x)⊆ V. Hence we obtain that V =∪ $\{U_x : x \in V\}$ =∪ $\{cl(U_x): x \in V\}$and f(V)= ∪{ $f(U_x): x \in V$ } ⊆ ∪$\{bint_\delta\left(f(cl(U_x))\right) : x \in V\}$⊆ $bint_\delta$(f(∪{cl(U_x): $x \in V$}))=$bint_\delta$(f(V)).Then f is b-δ-open.

Recall that a function $f:(X,\tau) \to (Y,\sigma)$ is said to be strongly continuous (Levine 1960) if for every subset of A of X , $f(cl(A)) \subseteq f(A)$.

2.1.9 Proposition: If $f(X,\tau) \to (Y,\sigma)$ is weakly b-δ-open and strongly continuous then f is b-δ-open.

Proof. Let U be an open subset of X .Since f is weakly b-δ-open f(U)⊆$bint_\delta(f(cl(U)))$. However, because f is strongly continuous ,$f(U) \subseteq bint_\delta(f(U))$.Therefore $f(U)$ is b-δ-open.

2.1.10 Definition: A space X is said to be hyperconnected(Steen 1978) if every non-empty open subset of X is dense in X.

2.1.11 Proposition: If X is a hyperconnected space ,then a function $f: X \to Y$ is weakly b-δ-open if and only if $f(X)$ is b-δ-open in Y.

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Proof. The sufficiency is clear .For the necessity observe that for open subset of X ,$f(U) \subseteq f(X) = bint_\delta(f(X)) = bint_\delta\left(f(cl(U))\right)$.Hence f is weakly b-open.

2.1.12 Definition: (Monsef et al. 1983) A function $f: X \to Y$ is said to be β- open if the image of each open set U of X is a β-open.

2.1.13 Theorem: If a function $f: X \to Y$ is weakly b-δ-open and precontinuous ,then f is β-open.

Proof. Let U be an open subset of X .Then by weak b-δ-opennes of f ,$f(U) \subseteq bint_\delta\left(f(cl(U))\right)$.Since f is precontinuous,$f(cl(U)) \subseteq cl(f(U))$.Hence we obtain that

$f(U) \subseteq bint_\delta(f(cl(U))$

$\subseteq bint_\delta(cl(f(U))$

$= bint\left(cl(f(U))\right)$

$sint(cl(f(U))) \cup pint(cl(f(U))))$

$\subseteq cl\left(int\left(cl(f(U))\right)\right) \cup int\left(cl(f(U))\right)$

$\subseteq cl(int\left(cl(f(U))\right))$

Which shows that $f(U)$ is a β-open set in Y. thus f is a β-open function.

A topological space X is said to be b-δ-connected if it cannot be written as the union of two nonempty disjoint b-δ-open sets.

2.1.14 Theorem: If : $f: X \to Y$ is a weakly b- δopen bijective function of a space X onto a b-δ-connected space Y ,Then X is connected.

Proof. Suppose that X is not connected. Then there exist non-empty open sets U and V such that $U \cap V = \emptyset$ and $U \cup V = X$.Hence we have $f(U) \cap f(V) = \emptyset$ and $f(U) \cup f(V) = Y$. Since f is weakly b-δ-open ,we have $f(U) \subseteq bint_\delta\left(f(cl(U))\right)$ and $f(V) \subseteq bint_\delta\left(f(cl(V))\right)$. Moreover U, V are open and also closed .We have $f(U) = bint_\delta(f(U))$ and $f(V) = bint_\delta(f(V))$. Hence, $f(U)$ and $f(V)$ are b-δ-open in Y. Thus$Y$ has been decomposed into two non-empty disjoint b-δ-open sets . This is contrary to the hypothesis that is a b-δ-connected space .Thus ,X is connected.

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2.1.15 Proposition: Let X be a regular space. Then for a function $f: X \to Y$,the following conditions are equivalent:

(1)f is weakly b-δ-open ;

(2)For each δ-open set A in X ,f(A) is b-δ-open in Y;

(3)For any set B of Y and any δ-closed set A in X containing $f^{-1}(B)$,there exist a b-δ-closed set F in Y containing B such that $f^{-1}(F) \subseteq A$.

Proof. 1→ 2 :Let A be a δ-open set in X .Since X is regular ,by proposition2.1.8, f is b-δ-open and A is open .Therefore $f(A)$ is b-δ-open in Y.

2→ 3:Let B be any set in Y and A is a δ-closed set in X such that f^{-1}(B)⊆A. Since $X - A$ is δ-open in X, by (2), $f(X - A)$ is b-δ-open in Y.Let $F = Y - f(X - A)$.Then F is b-δ-closed and $B \subseteq F$ .Now $f^{-1}(F) = f^{-1}\big(Y - f(X - A)\big) = X - f^{-1}\big(f(X - A)\big) \subseteq A$.

3→ 1: Let B be any set in Y. Let A=$cl_\delta(f^{-1}(B))$. Since X is regular A is a δ-closed set in X and $f^{-1}(B) \subseteq A$.Then there exist b-δ-closed set F in Y containing B such that $f^{-1}(F) \subseteq A$.Since F is b-δ-closed, $f^{-1}\big(bcl_\delta(B)\big) \subseteq f^{-1}(F) \subseteq A = cl_\delta\big(f^{-1}(B)\big)$.Therefore by theorem 2.1.6, $f$is weakly b-δ-open .

2.3 Weakly b-δ-closed Functions

2.1.16 Definition: A function $f: X \to Y$ is said to be b-δ-closed if for each closed set F of X, f(F) is b-δ-closed.

Now ,we define the generalized form of b-δ-closed functions.

2.1.17 Definition: A function $f: X \to Y$ is said to be weakly b-δ-closed if $bcl_\delta(f(\text{int}(F))) \subseteq f(F)$ for each closed set F of X.

Clearly ,every b-δ-closed function is a weakly b-δ-closed function ,but the converse is not generally true.

2.1.18 Example: Let $f: X \to Y$ be the function from example 2.1.4.Then it is clear that f is a weakly b-δ closed function which is not b-δ-closed,since $f(\{c, b\}) = \{a, b\}$ is not b-δ-closed in X.

Now we introduce several characterization of weakly b-δ-closed functions are obtained.

2.1.19 Proposition: For a function $f: X \to Y$,the following conditions are equivalent:

(1)f is weakly b-δ-closed

(2)$bcl_{\delta}\left(f(U)\right) \subseteq f\left(cl(U)\right)$for each open set U in X.

Proof.1→2: Let U be an open set in X. Since $cl(U)$ is a closed set and $U \subseteq int\left(cl(U)\right)$, we have $bcl_{\delta}(f(U)) \subseteq bcl_{\delta}(f(int\left(cl(U)\right)))\subseteq f(cl(U))$.

2→ 1: Let F be closed set of X. Then ,we have
$bcl_{\delta}\left(f\left(int(F)\right)\right) \subseteq f\left(cl\left(int(F)\right)\right) \subseteq f\left(cl(F)\right) = f(F)$ and hence f is weakly b-δ-closed.

2.1.20 Corollary: A bijective function $f: X \to Y$ is weakly b-δ-open if and only if is weakly b-δ-closed.

Proof. This is an immediate consequence of Propositions 2.1.19.

2.1.21 Proposition: For a function $f: X \to Y$,The following conditions are equivalent :

(1)f is weakly b-δ-closed;

(2) $bcl_{\delta}(f$(int(F)))$\subseteq f(F)$ for each preclosed set F in X;

(3) $bcl_{\delta}(f\left(int(F)\right)) \subseteq f(F)$ for each α-closed set F in X;

(4) $bcl_{\delta}(f(int\left(cl(U)\right))) \subseteq f(cl(U))$ for each subset U in X,

(5) $bcl_{\delta}(f(U)) \subseteq f(cl(U))$ for each propen set U in X.

The proof of the last proposition is straightforward and thus is omitted**.**

2.1.22 Theorem: For a function $f: X \to Y$,the following conditions are equivalent :

(1) f is weakly b-δ-closed;

(2) $bcl_{\delta}(f(U)) \subseteq f(cl(U))$ for each regular open set in X;

(3) For each subset F in Y and each open set U in X with $f^{-1}(F) \subseteq U$, there exists a b-δ-open set A in Y with $F \subseteq$ A and $f^{-1}(A) \subseteq cl(U)$;

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(4) For each point y in Y and each open set U in X with $f^{-1}(y) \subseteq U$, there exists a b-δ-open set A in Y containing y and $f^{-1}(A) \subseteq cl(U)$.

Proof.1→ 2:This is clear by Proposition 2.1.19

2→ 3:Let F be a subset of Y and U an open set in X with $f^{-1}(F) \subseteq U$. Then $f^{-1}(F) \cap cl\left(X - cl(U)\right) = \emptyset$ and consequently, $F \cap f(cl(X\text{-}cl(U)))=\emptyset$ .Since $X - cl(U)$ is regular open , F∩ $bcl_{\delta}\left(f\left(X - cl(U)\right)\right) = \emptyset$. Let A=$Y$-$bcl_{\delta}\left(f\left(X - cl(U)\right)\right)$.Then A is a -δ-open set with$F \subseteq A$ and we have

$f^{-1}(A) \subseteq X - f^{-1}(bcl_{\delta}\left(f\left(X - cl(U)\right)\right) \subseteq X - f^{-1}f\left(X - cl(U)\right) \subseteq cl(U)$.

3→ 4:It is clear.

4→ 1:Let F be closed in X and let y∈ $Y - f(F)$.Since $f^{-1}(y) \subseteq X - F$,by(4)there exists a b-δ-open set A in Y with $y \in A$ and $f^{-1}(A) \subseteq cl(X - F) = X - int(F)$.Therefore A∩ $f\left(int(F)\right) = \emptyset$, so that $bcl_{\delta}(f(int(F))) \subseteq f(F)$.Hence f is weakly b-δ-closed.

2.1.23 Proposition: If $f: X \to Y$ is a bijective weakly b-δ-closed function,then for every subset F in Y and every open set U in X with $f^{-1}(F) \subseteq U$,There exist a b-δ-closed set B in Y such that $F \subseteq B$ and $f^{-1}(B) \subseteq cl(U)$.

Proof .Let F be a subset of Y and U bean open subset of X with $f^{-1}(F) \subseteq U$.Put B=$bcl_{\delta}(f\left(int\left(cl(U)\right)\right)$.Then B is a b-δ-closed set in Y such that $F \subseteq B$, Since $F \subseteq f(U) \subseteq f(int\left(cl(U)\right)) \subseteq bcl_{\delta}(f\left(int\left(cl(U)\right)\right) = B$.Since f is weakly b-δ-closed ,by propositions 2.1.21 we have $f^{-1}(B) \subseteq cl(U)$.

2.4 The main results

In this research we have introduced and studied two new classes of functions called weakly b-δ-open functions and weakly b-δ-closed functions by using the notions of b-δ-open sets .The connections between these functions and other related functions are investigated .Also we have introduced some properties and theorems that related with these functions.

2.5 Future work

An important result of such a research is a new question that can be used as an idea of further research; as such a research always unearths further questions. Based on the previous results, we may suggest problems in relation to our research that we anticipated venture elsewhere in the case of b-δ-open set .The new classes of functions are investigated ,we have introduced some theorems and propositions .The questions that might be investigated is follows:

1-Since the concept of compactness plays a very important subject in the study of general topology and several branches of mathematics, our question that might be investigated :can we define the concept of compactness by utilizing b-δ-openset?

2-Can we study the characterization of T and weak form of open maps via b-δ-open set?

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