International Journal of Mathematical Archive-2(9), 2011, Page: 1691-1697
IJMA Available online through www.ijma.info ISSN 2229 – 5046

$\approx g_{\alpha}$-CLOSED SETS IN TOPOLOGICAL SPACES

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(Received on: 30-08-11; Accepted on: 16-09-11)

ABSTRACT

In this paper, we introduce a new class of sets called $\approx g_{\alpha}$-closed sets in topological spaces. We prove that this class lies between α-closed sets and α g-closed sets and discuss some basic properties of $\approx g_{\alpha}$-closed sets.

2000 Mathematics Subject Classification: *54C10, 54C08, 54C05*

Key words and Phrases: *Topological space, sg-closed set, A-closed set, B-closed set, $\approx g$-closed set, $\approx g_{\alpha}$-closed set, gp-closed set, gsp-closed set.*

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1. INTRODUCTION

The concept of generalized closed sets plays a significant role in topology. There are many research papers which deals with different types of generalized closed sets. Bhattacharya and Lahiri [4] introduced sg-closed sets in topological spaces. Arya and Nour [3] introduced gs-closed sets in topological spaces. Sheik John [17] introduced ω-closed sets in topological spaces. Ravi and Ganesan [15] introduced $\ddot{g}$-closed sets in topological spaces. Quite Recently, Ravi et. al. [16] have introduced $\approx g$-closed sets in topological spaces. In this paper we introduce a new class of sets namely $\approx g_{\alpha}$-closed sets in topological spaces and study their basic properties.

2. PRELIMINARIES

Throughout this paper (X,τ) (or X) represents topological space on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a space (X,τ), cl(A), int(A) and A^c or X − A denote the closure of A, the interior of A and the complement of A respectively.

We recall the following definitions which are useful in the sequel.

Definition: 2.1 A subset A of a space (X,τ) is called

(i) Semi-open set [9] if A $\subseteq$ cl(int(A));
(ii) preopen set [12] if A $\subseteq$ int(cl(A));
(iii) α-open set [13] if A $\subseteq$ int(cl(int(A)));
(iv) semi-preopen set [1] if A $\subseteq$ cl(int(cl(A))).

The complements of the above mentioned open sets are called their respective closed sets.

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The preclosure [14] (resp. semi-closure [6], α-closure [13], semi-pre-closure [1]) of a subset A of X, denoted by pcl(A) (resp. scl(A), αcl(A), spcl(A)), is defined to be the intersection of all preclosed (resp. semi-closed, α-closed, semi-preclosed) sets of (X, τ) containing A. It is known that pcl(A) (resp. scl(A), αcl(A), spcl(A)) is a preclosed (resp. semi-closed, α-closed, semi-preclosed) set.

Definition: 2.2 A subset A of a space (X, τ) is called
(i) a generalized closed (briefly g-closed) set [8] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of g-closed set is called g-open set;

(ii) a semi-generalized closed (briefly sg-closed) set [4] if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is semi-open in (X, τ). The complement of sg-closed set is called sg-open set;

(iii) a generalized semi-closed (briefly gs-closed) set [3] if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of gs-closed set is called gs-open set;

(iv) an α-generalized closed (briefly αg-closed) set [11] if αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of αg-closed set is called αg-open set;

(v) a generalized semi-preclosed (briefly gsp-closed) set [7] if spcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of gsp-closed set is called gsp-open set;

(vi) a generalized preclosed (briefly gp-closed) set [14] if pcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is open in (X, τ). The complement of gp-closed set is called gp-open set;

(vii) a $\ddot{g}$-closed set [15] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is sg-open in (X, τ). The complement of $\ddot{g}$-closed set is called $\ddot{g}$-open set;

(viii) a A-closed set [16] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is $\ddot{g}$-open in (X, τ). The complement of A-closed set is called A-open set;

(ix) a B-closed set [16] if scl(A) $\subseteq$ U whenever A $\subseteq$ U and U is A-open in (X, τ). The complement of B-closed set is called B-open set;

(x) a $\approx$**g**-closed set [16] if cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is B-open in (X, τ). The complement of $\approx$**g**-closed set is called $\approx$**g**-open set.

The collection of all $\approx$**g**-closed (resp. g-closed, gs-closed, gsp-closed, αg-closed, sg-closed, gp-closed, α-closed, semi-closed) sets in (X,τ) is denoted by $\approx$GC(X) (resp. GC(X), GSC(X), GSPC(X), αGC(X), SGC(X), GPC(X), αC(X), SC(X)).

We denote the power set of X by P(X).

Remark: 2.3 [16] For a topological space (X, τ), the following hold.

(1) Every semi-open set is B-open but not conversely.
(2) Every open set is B-open but not conversely.
(3) Every open set is A-open but not conversely.
(4) Every closed set is $\approx$**g**-closed but not conversely.

3. $\approx \mathbf{g}_\alpha$ - CLOSED SETS

We introduce the following definition.

Definition: 3.1 A subset A of a space (X, τ) is called an $\approx \mathbf{g}_\alpha$-closed set if αcl(A) $\subseteq$ U whenever A $\subseteq$ U and U is B-open in (X, τ).

The complement of $\approx \mathbf{g}_\alpha$-closed set is called $\approx \mathbf{g}_\alpha$-open set.

The collection of all $\approx \mathbf{g}_\alpha$-closed (resp. $\approx \mathbf{g}_\alpha$-open) sets in (X,τ) is denoted by $\approx G_\alpha$C(X) (resp. $\approx G_\alpha$O(X)).

Proposition: 3.2 Every α-closed set is $\approx \mathbf{g}_\alpha$-closed.

Proof: Let A be an α-closed set and G be any B-open set containing A. Since A is α-closed, we have α cl(A) = A $\subseteq$ G. Hence A is $\approx \mathbf{g}_\alpha$-closed.

The converse of Proposition 3.2 need not be true as seen from the following example.

Example: 3.3 Let X = {a, b, c} with τ = {ϕ, {a, b}, X}. Then $\approx G_\alpha$ C(X) = {ϕ, {c}, {a, c}, {b, c}, X} and α C(X) = {ϕ, {c}, X}. We have A = {a, c} is $\approx \mathbf{g}_\alpha$-closed set but not α-closed.

Proposition: 3.4 Every $\approx$**g**-closed set is $\approx \mathbf{g}_\alpha$-closed.

Proof: Let A be a $\approx$**g**-closed set and G be any B-open set containing A. Since A is $\approx$**g**-closed, we have G $\supseteq$ cl(A) $\supseteq$ α cl(A). Hence A is $\approx \mathbf{g}_\alpha$-closed.

The converse of Proposition 3.4 need not be true as seen from the following example.

Example: 3.5 Let X = {a, b, c} with τ = {ϕ, {b}, X}. Then $\approx$GC(X) = {ϕ, {a, c}, X} and $\approx G_\alpha$ C(X) = {ϕ, {a}, {c}, {a, c}, X}. We have A = {a} is $\approx \mathbf{g}_\alpha$-closed set but not $\approx$**g**-closed.

Proposition: 3.6 Every $\approx \mathbf{g}_\alpha$-closed set is α g-closed.

Proof: Let A be an $\approx \mathbf{g}_\alpha$-closed set and G be any open set containing A. Since any open set is B-open, we have α cl(A) $\subseteq$ G. Hence A is α g-closed.

The converse of Proposition 3.6 need not be true as seen from the following example.

Example: 3.7 Let X = {a, b, c} with τ = {ϕ, {c}, X}. Then $\approx G_\alpha$ C(X) = {ϕ, {a}, {b}, {a, b}, X}
and αG C(X) = {ϕ, {a}, {b}, {a, b}, {a, c}, {b, c}, X}. We have A = {a, c} is α g-closed set but not $\approx \mathbf{g}_\alpha$-closed.

Proposition: 3.8 Every $\approx \mathbf{g}_\alpha$-closed set is gs-closed (sg-closed).

Proof: Let A be an $\approx \mathbf{g}_\alpha$-closed set and G be any open set (semi-open set) containing A. Since any open (semi-open) set is B-open, we have scl(A) $\subseteq$ α cl(A) $\subseteq$ G. Hence A is gs-closed (sg-closed).

The converse of Proposition 3.8 need not be true as seen from the following example.

Example: 3.9 Let X = {a, b, c} with τ = {ϕ, {a}, {b}, {a, b}, X}. Then $\approx G_\alpha$ C(X) = {ϕ, {c}, {a, c}, {b, c}, X} and SG C(X) = GS C(X) = {ϕ, {a}, {b}, {c}, {a, c}, {b, c}, X}. We have A = {a} is both sg-closed set and gs-closed set but not $\approx \mathbf{g}_\alpha$-closed.

Proposition: 3.10 Every $\approx \mathbf{g}_\alpha$-closed set is gsp-closed.

Proof: Let A be an $\approx \mathbf{g}_\alpha$-closed set and G be any open set containing A. Since any open set is B-open, we have spcl (A) $\subseteq$ α cl(A) $\subseteq$ G. Hence A is gsp-closed.

The converse of Proposition 3.10 need not be true as seen from the following example.

Example: 3.11 Let X and τ be as in Example 3.5. Then GSP C(X) = {ϕ, {a}, {c}, {a, b}, {a, c}, {b, c}, X}. We have A = {a, b} is gsp-closed set but not $\approx \mathbf{g}_\alpha$-closed.

Proposition: 3.12 Every $\approx \mathbf{g}_\alpha$-closed set is gp-closed.

Proof: Let A be an $\approx \mathbf{g}_\alpha$-closed set and G be any open set containing A. Since any open set is B-open, we have pcl (A) $\subseteq$ α cl(A) $\subseteq$ G. Hence A is gp-closed.

The converse of Proposition 3.12 need not be true as seen from the following example.

Example: 3.13 Let X = {a, b, c} with τ = {ϕ, {a}, X}. Then $\approx G_\alpha C(X)$ = {ϕ, {b}, {c}, {b, c}, X} and GP C(X) = {ϕ, {b}, {c}, {a, b}, {a, c}, {b, c}, X}. We have A = {a, b} is gp-closed set but not $\approx \mathbf{g}_\alpha$-closed.

Proposition: 3.14 Every $\approx$**g**-closed set is g-closed.

Proof: Let A be a $\approx$**g**-closed set and G be any open set containing A. Since any open set is B-open, we have G $\supseteq$ cl(A). Hence A is g-closed.

The converse of Proposition 3.14 need not be true as seen from the following example.

Example: 3.15 Let X and τ be as in Example 3.13. Then G C(X) = {ϕ, {b}, {c}, {a, b}, {a, c}, {b, c}, X} and $\approx$GC(X) = {ϕ, {b, c}, X}. We have A = {a, b} is g-closed set but not $\approx$**g**-closed.

Remark: 3.16 The following examples show that $\approx \mathbf{g}_\alpha$-closedness is independent of semi-closedness and g-closedness.

Example: 3.17 Let X and τ be as in Example 3.9. Then S C(X) = {ϕ, {a}, {b}, {c}, {a, c}, {b, c}, X}. We have A = {b} is semi-closed set but not $\approx \mathbf{g}_\alpha$-closed.

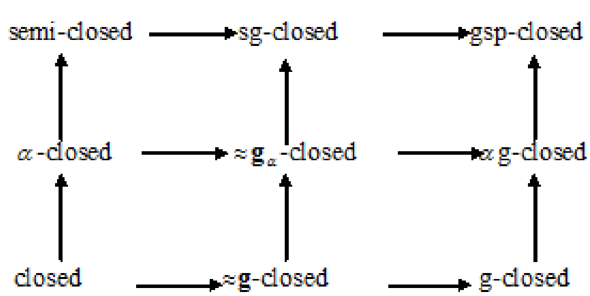
Example: 3.18 Let X and τ be as in Example 3.3. Then S C(X) = {ϕ, {c}, X}. We have A = {b, c} is $\approx \mathbf{g}_\alpha$-closed set but not semi-closed.

Example: 3.19 Let X = {a, b, c} with τ = {ϕ, {a}, {a, b}, X}. Then $\approx G_\alpha C(X)$ = {ϕ, {b}, {c}, {b, c}, X} and G C(X) = {ϕ, {c}, {a, c}, {b, c}, X}. We have

(i) A = {b} is $\approx \mathbf{g}_\alpha$-closed set but not g-closed.

(ii) B = {a, c} is g-closed set but not $\approx \mathbf{g}_\alpha$-closed.

Remark: 3.20 From the above discussions and the known results in [7, 14, 16, 18], we obtain the following diagram, where A $\rightarrow$ B represents A implies B but not conversely.



None of the above implications is reversible as shown in the above examples and in the related papers [7, 14, 16, 18].

4. PROPERTIES OF $\approx \mathbf{g}_\alpha$-CLOSED SETS

In this section, we discuss some basic properties of $\approx \mathbf{g}_\alpha$-closed sets.

Definition: 4.1 [16] The intersection of all B-open subsets in (X,τ) containing A is called the B-kernel of A and denoted by B-ker(A).

Lemma: 4.2 A subset A of (X,τ) is $\approx \mathbf{g}_\alpha$-closed if and only if α cl(A) $\subseteq$ B-ker(A).

Proof: Suppose that A is $\approx \mathbf{g}_\alpha$-closed. Then α cl(A) $\subseteq$ U whenever A $\subseteq$ U and U is B-open. Let x $\in$ α cl(A). If x $\notin$ B-ker(A), then there is an B-open set U containing A such that x $\notin$ U. Since U is an B-open set containing A, we have x $\notin$ α cl(A) and this is a contradiction.

Conversely, let α cl(A) $\subseteq$ B-ker(A). If U is any B-open set containing A, then α cl(A) $\subseteq$ B-ker(A) $\subseteq$ U. Therefore, A is $\approx \mathbf{g}_\alpha$-closed.

Proposition: 4.3 If A and B are $\approx \mathbf{g}_\alpha$-closed sets in (X,τ), then A $\cup$ B is $\approx \mathbf{g}_\alpha$-closed in (X, τ).

Proof If A $\cup$ B $\subseteq$ G and G is B-open, then A $\subseteq$ G and B $\subseteq$ G. Since A and B are $\approx \mathbf{g}_\alpha$-closed, G $\supseteq$ α cl(A) and G $\supseteq$ α cl(B) and hence G $\supseteq$ α cl(A) $\cup$ α cl(B) = α cl(A $\cup$ B). Thus A $\cup$ B is $\approx \mathbf{g}_\alpha$-closed in (X,τ).

Proposition: 4.4 If a set A is $\approx \mathbf{g}_\alpha$-closed in (X, τ) and A $\subseteq$ B $\subseteq$ α cl(A), then B is $\approx \mathbf{g}_\alpha$-closed in (X, τ).

Proof: Let G be an B-open set in (X, τ) such that B $\subseteq$ G. Then A $\subseteq$ G. Since A is an $\approx \mathbf{g}_\alpha$-closed set, α cl(A) $\subseteq$ G. Also α cl(B) = α cl(A) $\subseteq$ G. Hence B is also an $\approx \mathbf{g}_\alpha$-closed in (X,τ).

Proposition: 4.5 If A is B-open and $\approx \mathbf{g}_\alpha$-closed in (X, τ), then A is α-closed in (X, τ).

Proof: Since A is B-open and $\approx \mathbf{g}_\alpha$-closed, α cl(A) $\subseteq$ A and hence A is α-closed in (X, τ).

Proposition: 4.6 For each x $\in$ X, either {x} is B-closed or $\{x\}^c$ is $\approx \mathbf{g}_\alpha$-closed in (X, τ).

Proof Suppose that {x} is not B-closed in (X, τ). Then $\{x\}^c$ is not B-open and the only B-open set containing $\{x\}^c$ is the space X itself. Therefore α cl($\{x\}^c$) $\subseteq$ X and so $\{x\}^c$ is $\approx \mathbf{g}_\alpha$-closed in (X, τ).

Definition: 4.7 A subset A of a space (X, τ) is called Λ_B-set if A = B-ker(A).

Definition: 4.8 A subset A of a space (X, τ) is called λ_B-closed if A = L ∩ F where L is a Λ_B-set and F is α-closed.

The complement of λ_B-closed set is called λ_B-open set.

The collection of all λ_B-closed (resp. λ_B-open) sets in (X, τ) is denoted by $\lambda_B C(X)$ (resp. $\lambda_B O(X)$).

Lemma: 4.9 For a subset A of a topological space (X, τ), the following conditions are equivalent.

(i) A is λ_B-closed.
(ii) A = L ∩ αcl(A) where L is a Λ_B-set.
(iii) A = B-ker(A) ∩ αcl(A).

Lemma: 4.10

(i) Every α-closed set is λ_B-closed but not conversely.
(ii) Every Λ_B-set is λ_B-closed but not conversely.

The separate converses of Lemma 4.10 need not be true as seen from the following examples.

Example: 4.11 Let X and τ be as in Example 3.13. Then αC(X) = {ϕ, {b}, {c}, {b, c}, X} and $\lambda_B C(X)$ = P(X). We have A = {a} is λ_B-closed set but not α-closed.

Example: 4.12 Let X and τ be as in Example 3.13. Then Λ_B-sets areϕ, {a}, {a, b}, {a, c} and X ; and $\lambda_B C(X)$ = P(X). We have A = {b} is λ_B-closed set but not Λ_B-set.

Theorem: 4.13 For a subset A of a topological space (X, τ), the following conditions are equivalent.

(i) A is α-closed.

(ii) A is $\approx \mathbf{g}_{\alpha}$-closed and λ_B-closed.

Proof: (i) ⇒ (ii). Obvious.

(ii) ⇒ (i). Since A is $\approx g_{\alpha}$-closed, so by Lemma 4.2, $\alpha cl(A) \subseteq$ B-ker(A). Since A is λ_B-closed, so by Lemma 4.9, A = B-ker(A) ∩ αcl(A) = αcl(A). Hence A is α-closed.

Remark: 4.14 The following examples show that the concepts of $\approx \mathbf{g}_{\alpha}$-closed sets and λ_B-closed sets are independent of each other.

Example: 4.15 Let X and τ be as in Example 3.13. Then $\approx G_{\alpha}C(X) = \{\phi, \{b\}, \{c\}, \{b, c\}, X\}$ and $\lambda_B C(X) = P(X)$. We have A = {a} is λ_B-closed set but not $\approx \mathbf{g}_{\alpha}$-closed.

Example: 4.16 Let X and τ be as in Example 3.3. Then $\approx G_{\alpha}C(X) = \{\phi, \{c\}, \{a, c\}, \{b, c\}, X\}$ and $\lambda_B C(X) = \{\phi, \{a\}, \{b\}, \{c\}, \{a, b\}, X\}$. We have A = {a} is λ_B-closed set but not $\approx \mathbf{g}_{\alpha}$-closed.

5. PROPERTIES OF $\approx \mathbf{g}_{\alpha}$ lc*-SETS

Definition: 5.1 Let (X,τ) be a topological space. A subset A of X is called $\approx \mathbf{g}_{\alpha}$ lc*-set if A = M ∩ N where M is B-open and N is α-closed in (X,τ).

Example: 5.2 Let X and τ be as in Example 3.3. Then A= {a} is an $\approx \mathbf{g}_{\alpha}$ lc*-set.

Proposition: 5.3 Every B-open set is $\approx \mathbf{g}_{\alpha}$ lc*-set but not conversely.

Example: 5.4 Let X and τ be as in Example 3.3. Then $\approx \mathbf{g}_{\alpha}$ lc*-sets are ϕ, {a}, {b}, {c}, {a, b} and X; and B-open sets are ϕ, {a}, {b}, {a, b} and X. We have A = {c} is $\approx \mathbf{g}_{\alpha}$ lc*-set but not B-open.

Proposition: 5.5 Every α-closed set is $\approx \mathbf{g}_{\alpha}$ lc*-set but not conversely.

Example: 5.6 Let X and τ be as in Example 3.3. Then $\approx \mathbf{g}_{\alpha}$ lc*-sets areϕ, {a}, {b}, {c}, {a, b} and X; and αC(X) = {ϕ, {c}, X}. We have A = {a} is $\approx \mathbf{g}_{\alpha}$ lc*-set but not α -closed.

Theorem: 5.7 Let (X,τ) be a topological space and A a subset of X. Then, A is α-closed if and only if it is $\approx \mathbf{g}_{\alpha}$-closed and $\approx \mathbf{g}_{\alpha}$ lc*-set.

Proof: Let A be an α-closed. By Propositions 3.2 and 5.5, A is $\approx \mathbf{g}_{\alpha}$-closed and $\approx \mathbf{g}_{\alpha}$ lc*-set.
Conversely, let A = M ∩ N. Then M is B-open and N is α-closed. Since A is $\approx \mathbf{g}_{\alpha}$-closed, $\alpha cl(A) \subseteq M$.
Also $\alpha cl(A) \subseteq \alpha cl(N) = N$. We have $\alpha cl(A) \subseteq M \cap N = A$. Hence A is α-closed.

Remark: 5.8 The following example shows that the concepts of $\approx \mathbf{g}_{\alpha}$-closed sets and $\approx \mathbf{g}_{\alpha}$ lc*-sets are independent of each other.

Example: 5.9 Let X and τ be as in Example 3.3. Then $\approx \mathbf{g}_{\alpha}$ lc*- sets are ϕ, {a}, {b}, {c}, {a, b} and X; and $\approx G_{\alpha}C(X) = \{\phi, \{c\}, \{a, c\}, \{b, c\}, X\}$. We have

(i) A = {a} is $\approx \mathbf{g}_{\alpha}$ lc*-set but not $\approx \mathbf{g}_{\alpha}$-closed.

(ii) A= {a, c} is $\approx \mathbf{g}_{\alpha}$-closed set but not $\approx \mathbf{g}_{\alpha}$ lc* -set.

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