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ON *sgI*-CLOSED SETS IN IDEAL TOPOLOGICAL SPACE

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ABSTRACT: In this paper, we introduce *sgI*-closed sets in ideal topological space and study some of their properties.

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1. Introduction and Preliminaries

An ideal I on a topological space (X, τ) is a Collection of subsets of X which satisfies (i) $A \in I$ and $B \subset A$ implies $B \in I$ and (ii) $A \in I$ and $B \in I$ implies $A \cup B \in I$. Given a topological space (X, τ) with an ideal I on X and if $\rho(X)$ is the set of all subsets of X, a set operator $(\cdot)^* : \rho(X) \to \rho(X)$, called a local function [13] of A with respect to τ and I is defined as follows: for $A \subset X$, $A^*(I, \tau) = \{x \in X / U \cap A \notin I$ for every $U \in \tau(x)\}$ where $\tau(x) = U \in \tau \,|\, x \in U$. We will make use of the basic facts about the local functions without mentioning it explicitly. A Kuratowski closure operator $cl^*(\cdot)$ for a topology $\tau^*(I, \tau)$, called the *-topology, finer than τ and is defined by $cl^*(A) = A \cup A^*(I, \tau)$. When there is no chance for confusion we simply write A^* instead $A^*(I, \tau)$ and τ^* or $\tau^*(I)$ for $A^*(I, \tau)$. X^* is often a proper subset of X. The hypothesis $X = X^*$ is equivalent to the hypothesis $\tau \cap I = \phi$. For every ideal topological space (X, τ, I), there exists a topology $\tau^*(I)$, finer than τ, generated by $\beta(I, \tau) = \{U \backslash I : U \in \tau$ and $I \in I\}$, but in general $\beta(I, \tau)$ is not always a topology [10]. If is I an ideal on X, Then (X, τ, I) is called ideal space.

By a space we always mean a topological space (X, τ) with no separation properties assumed. If $A \subset X$, $cl(A)$ and $\text{int}(A)$ will respectively denote the closure and interior of A in (X, τ) and $cl^*(A)$ and $\text{int}^*(A)$ will respectively denote the closure and interior of A in (X, τ, I).

We recall some known definitions.

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

1. Closed if $cl(A) \subseteq A$ and Open if $A \subseteq \text{int}(A)$.
2. Semi open if $A \subseteq cl(\text{int}(A))$ and semi closed if $\text{int}(cl(A)) \subseteq A$.
3. Pre-open if $A \subseteq \text{int}(cl(A))$ and pre-closed if $cl(\text{int}(A)) \subseteq A$.
4. Semi generalized closed (*sg*-closed) if $scl(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-open in X, Semi generalized open (*sg*-open) if $X - A$ is *sg*-closed.

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

5. Semi-I-open if $A \subseteq cl^*(\text{Int}(A))$ semi-I-closed if $\text{int}(cl^*(A)) \subseteq A$.

Now we introduce the following concept:

2. *sgI*-CLOSED SETS

Definition 2.1: A subset A of an ideal topological space (X, τ, I) is called Semi generalized ideal closed (sgI-closed) if $scl^*(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-I-open in (X, τ, I). The complement of sgI-closed set is called Semi generalized ideal open (sgI-open) if $X - A$ is sgI-closed. We denote the family of all sgI-closed sets by $SGIC(X, \tau, I)$.

Theorem 2.2: Every semi-closed set in (X, τ, I) is sgI-closed.

Proof: Let A be any closed set and G be any semi-I-open set such that $A \subseteq U$. Since A is semi closed, $scl(A) = A$. But $scl^*(A) \subseteq scl(A)$. Thus we have, $scl^*(A) \subseteq G$ whenever $A \subseteq G$ and G is semi-I-open. Therefore, A is sgI-closed.

Theorem 2.3: Every semi-I-closed set in (X, τ, I) is sgI-closed.

Proof: Let A be any semi-I-closed set. Let $A \subseteq G$ where G is semi-I-open. Since A is semi-I-closed, $scl^*(A) = A \subseteq G$. Thus we have, $scl^*(A) \subseteq G$ whenever $A \subseteq G$ and G is semi-I-open Therefore, A is sgI-closed.

Theorem 2.4: let $\{A_i : i \in 1, 2, 3, ..., n\}$ be a locally finite family of sgI-closed sets. Then $A = \cup A_i$ is sgI-closed for every i.

Proof: Since $\{A_i : i \in 1, 2, 3, ...\}$ is locally finite, $scl^*(\cup A_i) = \cup scl^*(A_i)$. Assume that for some semi-I-open set U we have $A = \cup A_i \subset U$ then $scl^*(\cup A_i) = \cup scl^*(A_i) \subset U$ since each A_i is sgI-closed. Thus A is sgI-closed.

Theorem 2.5: For any two sets A and B $scl^*(A \cup B) = scl^*(A) \cup scl^*(B)$.

Proof: Since $A \subseteq A \cup B$ we have, $scl^*(A) \subseteq scl^*(A \cup B)$ and since $B \subseteq A \cup B$ we have, $scl^*(B) \subseteq scl^*(A \cup B)$ therefore $scl^*(A) \cup scl^*(B) \subseteq scl^*(A \cup B)$. Also $scl^*(A)$ and $scl^*(B)$ are the semi-I-closed sets. Therefore $scl^*(A) \cup scl^*(B)$ is also a semi-I-closed set. Again, $A \subseteq scl^*(A)$ and $B \subseteq scl^*(B)$ implies $A \cup B \subseteq scl^*(A) \cup scl^*(B)$. Thus $scl^*(A) \cup scl^*(B)$ is a semi-I-closed set containing $A \cup B$. Since, $scl^*(A \cup B)$ is the smallest semi-I-closed set containing $A \cup B$. We have, $scl^*(A \cup B) \subseteq scl^*(A) \cup scl^*(B)$. Thus, we have $scl^*(A \cup B) = scl^*(A) \cup scl^*(B)$.

Theorem 2.6: Union of two sgI-closed set in an ideal topological space (X, τ, I) is sgI-closed set in (X, τ, I).

Proof: Let A and B be two sgI-closed sets. Let $A \cup B \subseteq G$, G is semi-I-open. Since A and B be two sgI-closed sets, we have, $scl^*(A) \cup scl^*(B) \subseteq G$. But $scl^*(A \cup B) \subseteq scl^*(A) \cup scl^*(B)$ by **theorem (2.5).** Therefore, $scl^*(A \cup B) \subseteq G$ and G is semi-I-open. Hence, $A \cup B$ is sgI-closed set.

Theorem 2.7: The intersection of a *sgI*-closed set and a semi-*I*-closed set is always *sgI*-closed.

Proof: Let A be a *sgI*-closed set and let F be a semi-*I*-closed set. Suppose G is a semi-*I*-open set with $A \cap F \subset G$ then $A \subset G \cup F^C$ where $G \cup F^C$ is semi-*I*-open, therefore $scl^*(A) \subset G \cup F^C$. Now $cl^*(A \cap F) \subset cl^*(A) \cap cl^*(F) = cl^*(A) \cap F \subset G$ hence $A \cap F$ is *sgI*-closed.

Theorem 2.8: Let A be a *sgI*-closed subset of a space (X, τ, I) and $B \subseteq X$.

Then the following hold:

(a) $scl^*(A) - A$ contains no non empty semi-*I*-closed set.

(b) If $A \subseteq B \subseteq scl^*(A)$ then $B \in$ *sgI*-closed set.

Proof: (a) suppose by contrary that $scl^*(A) - A$ contains a non empty semi-*I*-closed set C. Then, $A \subseteq X - C$ and $X - C$ is semi-*I*-open in (X, τ, I). Thus, $scl^*(A) \subseteq X - C$ or Equivalently $C \subseteq X - scl^*(A)$. Therefore, $C \subseteq (X - scl^*(A)) \cap (scl^*(A) - A) = \phi$.

(b) Let $U \in (I, \tau)$ and $B \subseteq U$. Then $A \subseteq B \subseteq U$ since $A \in SGIC\,(X, \tau, I)$, $scl^*(B) \subseteq scl^*(scl^*(A)) = scl^*(A) \subseteq U$ and the result follows.

Theorem 2.9: If C is semi-*I*-closed and T is *sgI*-closed then $C \cap T$ is *sgI*-closed.

Proof: Since C is semi-*I*-closed it is *sgI*-closed and therefore $C \cap T$ is *sgI*-closed.

Theorem 2.10: A subset A of (X, τ, I) is *sgI*-closed if and only if $scl^*(A) - A$ does not contain any non empty semi-*I*-closed set.

Proof: Suppose that A is *sgI*-closed. Let U be a non empty semi-*I*-closed subset of $scl^*(A) - A$. Then $U \subseteq scl^*(A) - A$ implies $U \subseteq scl^*(A) \cap A^c$ since $scl^*(A) - A = scl^*(A) \cap A^c$ since U^c is a semi-*I*-open set and A is a *sgI*-closed. Therefore $scl^*(A) \subseteq U^c$ consequently, $U \subseteq [scl^*(A)]$. Hence $U \subseteq scl^*(A)] \cap [scl^*(A)]^c = \phi$. Therefore U is empty, a contradiction. Therefore, $scl^*(A) - A$ does not contain any non empty semi-*I*-closed set in X. Conversely, suppose that $scl^*(A) - A$ contains no non empty semi-*I*-closed set. Let $A \subseteq U$ and that U be semi-*I*-open. If $scl^*(A) \not\subset U$ then $scl^*(A) \cap U^c \neq \phi$ since $scl^*(A)$ is an semi-*I*-closed set and U^c is semi-*I*-closed set of (X, τ, I) by the theorem 2.9, $scl^*(A) \cap U^c$ is semi-*I*-closed set of (X, τ, I). Therefore, $\phi \neq scl^*(A) \cap U^c \subseteq scl^*(A) - A$ and so $scl^*(A) - A$ contains a non empty *sgI*-closed set which is a contradiction to the hypothesis. Thus A is *sgI*-closed.

Theorem 2.11: In an ideal topological space (X, τ, I) the following are equivalent: (i) A is *sgI*-closed (ii) For each $x \in scl^*(A)$, $scl^*(X) \cap A \neq \phi$ (iii) $scl^*(A) - A$ contains no non empty semi-*I*-closed set.

Proof: (i) $\Rightarrow$ (ii) suppose $x \in scl^*(A)$ and $scl^*(X) \cap A = \phi$. Then $A \subseteq [scl^*(X)]^c$ is semi-*I*-open set. By assumption $scl^*(A) \subseteq [scl^*(X)]^c$ which is a contradiction to $x \in scl^*(A)$.

(ii) ⇒ (iii) let $F \subseteq scl^*(A) - A$ where F is semi-I-closed. If there is a $x \in F$ then $x \in scl^*(A)$ and so by assumption, $\phi \in scl^*(X) \cap A = F \cap A \subseteq (scl^*(A) - A) \cap A = \phi$ a contradiction. Therefore, $F = \phi$.

(iii) ⇒ (ii) follows from theorem 2.10.

Corollary 2.12: A is sgI-closed if and only if $A = F - N$ where F is semi-I-closed and N contains no non empty semi-I-closed set.

Proof: Suppose that A is sgI-closed. Let $F = scl^*(A)$ and $N = scl^*(A) - A$ then $A = F - N$ by the theorem1.11 conversely, assume $A = F - N$. Let $A \subseteq U$ where U is any semi-I-open set. Then $F \cap U^c$ is semi-I-closed by theorem 2.9 and it is a subset of N. By assumption, $F \cap U^c = \phi$ that is $F \subseteq U$. Thus $scl^*(A) \subseteq F \subseteq U$ and so A is sgI-closed.

Theorem 2.13: Suppose that $B \subseteq A \subseteq X$:

(i) If B is sgI-closed set relative to A and A is sg-clopen subset of X, then B is sgI-Closed in (X, τ, I).

(ii) If B is sgI-closed in (X, τ, I) and A is semi-I-open in (X, τ, I). Then B is sgI-closed relative to A.

Proof: (i) Let B be a sgI-closed relative to A and let $B \subseteq G$ where G is semi-I-open in X. Then $scl^*_A(B) \subseteq A \cap G$. That is $A \cap scl^*(B) \subseteq A \cap G$ consequently, $A \cap scl^*(B) \subseteq G$. Hence $A \cap scl^*(B) \cup (X \backslash scl^*(B)) \subseteq G \cup (X \backslash scl^*(B)) \Rightarrow A \cap X \subseteq G \cup (X \backslash scl^*(B)) \Rightarrow A \cap X \subseteq G \cup (X \backslash scl^*(B)) \Rightarrow A \subseteq G \cup (X \backslash scl^*(B)) = V$ (Say) and V is a semi-I-open set. Since A is sg-closed $scl(B) \subseteq scl(A) \subseteq G \cup (X \backslash scl(B))$. That is $scl(B) \subseteq G$. But $scl^*(B) \subseteq scl(B) \subseteq G$. This shows that B is sgI-closed in X.

(ii) Let $B \subseteq A \cap G$ where G is semi-I-open. Since B is sgI-closed in X, $scl^*(B) \subseteq G$. This implies that $A \cap scl^*(B) \subseteq A \cap G$ where $A \cap G$ is semi-I-open. Hence, $A \cap scl^*(B) \subseteq G$.

So B is sgI-closed relative to A.

Theorem 2.14: If A is semi-I-open and sgI-closed then A is semi-I-closed.

Proof: Since $A \subseteq A$ and A is semi-I-open and sgI-closed we have $scl^*(A) \subseteq A$ therefore we have $scl^*(A) = A$ and A is semi-I-closed.

Theorem 2.15: For each $x \in X$ either $\{x\}$ is semi-I-closed or $\{x\}^c$ is sgI-closed in (X, τ, I).

Proof: Suppose that $\{x\}$ is not semi-I-closed in (X, τ, I). Then $\{x\}^c$ is not semi-I-open and only semi-I-open containing $\{x\}^c$ is the space X itself. Therefore $scl^*(\{x\}^c) \subseteq X$ and so $\{x\}^c$ is sgI-closed.

Definition: 2.16: A collection $\{A_\alpha\}_{\alpha \in A}$ of semi-I-open sets in an ideal topological space (X, τ, I) is called a semi-I-open cover of a subset A in (X, τ, I) if $\bigcup_{\alpha \in A} A_\alpha$.

Definition: 2.17: An ideal topological space (X, τ, I) is called semi-I-compact if every semi-I-open cover of (X, τ, I) has a finite subcover.

Definition: 2.18: A subset of ideal topological space (X, τ, I) is called semi-I-compact if A is semi-I-compact as a subspace of (X, τ, I).

Theorem2.19: Let $\{A_\alpha\}_{\alpha \in A}$ be a collection of semi-I-open sets in an ideal topological space (X, τ, I). Then $\bigcup_{\alpha \in A} A_\alpha$ is semi-I-open.

Theorem 2.20: Let (X, τ, I) be a compact ideal topological space and suppose that A is a sgI-closed subset of (X, τ, I). Then A is semi-I-compact.

Proof: Suppose that C be a semi-I-open cover of A. Since $\bigcup_{G \in C} G$ is semi-I-open by theorem 2.19 and A is sgI-closed, we have $scl^*(A) \subseteq \bigcup_{G \in C} G$. Also, $scl^*(A)$ is semi-I-compact in (X, τ, I). Therefore $A \subseteq scl^*(A) \subseteq \bigcup_{i = 1, 2, ..., n} G_i \in C$. Hence A is semi-I-compact.

Definition: 2.21: An ideal topological space (X, τ, I) is called semi-I-normal if for every pair of disjoint semi-I-closed sets A and B of (X, τ, I), there exist disjoint semi-I-open sets $U, V \subseteq X$ such that $A \subseteq U$ and $B \subseteq V$.

Theorem 2.22: Let (X, τ, I) be a semi-I-normal space and suppose that Y is a sgI-closed subset of (X, τ, I). Then the subspace Y is semi-I-normal.

Proof: Suppose that F_1 and F_2 are semi-I-closed sets in (X, τ, I) such that $(Y \cap F_1) \cap (Y \cap F_2) = \phi$. Then $Y \subseteq (F_1 \cap F_2)^c$ and $(F_1 \cap F_2)^c$ is semi-I-open. But Y is sgI-closed in (X, τ, I). Therefore, $scl^*(Y) \subseteq (F_1 \cap F_2)^c$ and hence $(scl^*(Y) \cap F_1) \cap (scl^*(Y) \cap F_2) = \phi$. Since (X, τ, I) is semi-I-normal, there exist disjoint semi-I-open sets G_1 and G_2 such that $(scl^*(Y) \cap F_1) \subseteq G_1$ and $(scl^*(Y) \cap F_2) \subseteq G_2$. Thus $(Y \cap G_1)$ and $(Y \cap G_2)$ are two disjoint semi-I-open sets of Y such that $(Y \cap F_1) \subseteq (Y \cap G_1)$ and $(Y \cap F_2) \subseteq (Y \cap G_2)$. Therefore, Y is semi-I-normal.

Theorem 2.23: Let (X, τ, I) be a semi-I-normal space and $F \cap A = \phi$, where F is semi-I-closed and A is sgI-closed then there exist disjoint semi-I-open sets U_1 and U_2 such that $F \subseteq U_1$ and $A \subseteq U_2$.

Proof: Since F is semi-I-closed and $F \cap A = \phi$ we have $A \subseteq F^c$ and so $scl^*(A) \subseteq F^c$. Thus $scl^* \cap F = \phi$. Since $scl^*(A)$ and F are semi-I-closed and (X, τ, I) is semi-I-normal there exists semi-I-open sets U_1 and U_2 such that $scl^*(A) \subseteq U_1$ and $F \subseteq U_2$ that is $A \subseteq U_1$ and $F \subseteq U_2$.

Theorem 2.24: Let (X, τ, I) be a semi-I-normal space and $F \cap A = \phi$, where F is I-closed and A is sgI-closed then there exist disjoint semi-I-open sets U_1 and U_2 such that $F \subseteq U_1$ and $A \subseteq U_2$.

Proof: Similar to Proposition 2.23.

Theorem 2.25: For a subset A of an ideal topological space (X, τ, I) the following conditions are equivalent (i) A is semi-I-clopen (ii) A is semi-I-open and sgI-closed.

Proof: (i) $\Rightarrow$ (ii) Obvious from the definition 2.1 (ii) $\Rightarrow$ (i) Since A is semi-I-open and sgI-closed $scl^*(A) \subseteq A$. But $A \subseteq scl^*(A)$. So $A = scl^*(A)$ implies that A is semi-I-closed. Hence A is semi-I-open and semi-I-closed. Thus A is semi-I-clopen.

Definition2.26: The intersection of all semi-I-open subsets of (X, τ, I) containing A are called semi-I-kernel of A and is denoted by sI-ker (A).

Lemma 2.27: Let (X, τ, I) be an ideal topological space and A be a subset of (X, τ, I). If A is semi-I-open in (X, τ, I), then sI-ker$(A) = A$, but not conversely.

Proof: Follows from Definition 2.26.

Lemma 2.28: For any subset A of (X, τ, I), semi-ker$(A) \subseteq sI$-ker(A).

Proof: Follows from the implication $SIO(X, \tau, I) \subseteq SO(X, \tau, I)$.

Lemma 2.29: [13] Let x be a point of (X, τ, I). Then $\{x\}$ is either nowhere I-dense or pre-I-open.

Remark 2.30: In the notion of lemma we may consider the following decomposition of a given ideal topological space (X, τ, I), namely $X = X_1 \cup X_2$, where $X_1 = \{x \in X : (x)$ is nowhere I-dense$\}$ and $X_2 = \{x \in X : \{X\}$ is pre-I-open$\}$.

Lemma 2.31: A subset A of (X, τ, I) is sgI-closed if and only if $scl^*(A) \subseteq sI$-ker(A).

Proof: Suppose that A is sgI-closed. Then $scl^*(A) \subseteq U$ whenever $A \subseteq U$ and U is semi-I-open. Let $x \in scl^*(A)$. If $x \notin sI$-ker(A) then there is a semi-I-open set U containing A such that $x \notin U$. Since U is a sgI-open set containing A, we have $x \notin scl^*(A)$, a contradiction. Hence $x \in sI$-ker(A) and so $scl^*(A) \subseteq sI$-ker(A). Conversely, let $scl^*(A) \subseteq sI$-ker(A). If U is any semi-I-open set containing A, then sI-ker$(A) \subseteq U$ that is $scl^*(A) \subseteq sgI$-ker$(A) \subseteq U$.

Therefore A is sgI-closed.

Theorem 2.32: For any subset A of (X, τ, I), $x_2 \cap scl^*(A) \subseteq sI$-ker$(A)$.

Proof: Let $x \in x_2 \cap scl^*(A)$ and suppose that $x \notin sI$-ker(A). Then there is a semi-I-open set U containing A such that $x \notin U$. If $F = X - U$. Then F is semi-I-closed set and so $scl^*(\{x\}) = \{x\} \cup \text{int}(cl^*(\{x\})) \subseteq F$. Since $cl^*(\{x\}) \subseteq cl^*(A)$ we have $\text{int}(cl^*(\{x\})) \subseteq A \cup \text{int}(cl^*(A))$. Again since $x \in X_2$ we have $x \notin X_1$ and so $scl^*(\{x\}) \neq \phi$. Therefore there has to be some point $y \in A \cap scl^*(\{x\})$ and hence $y \in F \cap A$, a contradiction.

Theorem 2.33: A subset of (X, τ, I) is sgI-closed if and only if $X_1 \cap scl^*(A) \subseteq A$.

Proof: Suppose that A is sgI-closed. Let $x \notin X_1 \cap scl^*(A)$. If $x \notin A$ then $X \backslash \{x\}$ is a semi-I-open set containing A and so $scl^*(A) \subseteq X \backslash \{x\}$, which is impossible.

Conversely, suppose that $X_1 \cap scl^*(A) \subseteq A$. Then, $X_1 \cap scl^*(A) \subseteq sI\text{-ker}(A)$ since $A \subseteq sI\text{-ker}(A)$. Now, $scl^*(A) = X \cap scl^*(A) = (X_1 \cup X_2) \cap scl^*(A) = (X_1 \cap scl^*(A)) \cup (X_2 \cap scl^*(A)) \subseteq sI\text{-ker}(A)$ since $X_1 \cap scl^*(A) \subseteq sI\text{-ker}(A)$ and by theorem 2.32. Thus A is sgI-closed by lemma 2.31.

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