iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** VIII **Month of publication:** August 2017

DOI: http://doi.org/10.22214/ijraset.2017.8096

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

On Semi-$T_{1/2}$ Spaces

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Abstract: In this paper we introduce new types of Semi-$T_{1/2}$ spaces using sg-closed type sets. We define new topological ordered spaces namely $semi-_{sgi}T_{1/2}$ space, $semi-_{sgd}T_{1/2}$ space, $semi-_{sgb}T_{1/2}$ space, $semi-_{sgi}T_{is,1/2}$ space, $semi-_{sgd}T_{ds,1/2}$ space and $semi-_{sgb}T_{bs,1/2}$ space.We lso establish relationships between these spaces. Mathematics subject classification: 54A05

Keywords: Topological ordered space, i-closed set, d-closed set, b-closed set, sg-closed set, Semi-$T_{1/2}$ space.

I. INTRODUCTION

L.Nachbin **[1]** initiated the study of Topological ordered spaces (TOS). A topological ordered space is a topological space in which a partial order is available. Using order relation one can think of increasing, decreasing and balanced sets. N. Levine **[5]** defined generalized closed (briefly g-closed) set in 1970 by slightly weakening the notion of closedness. They are not only the natural generalizations of closed sets but they can suggest more properties of topological spaces. In recent years, some authors have introduced notions which uses both topological and order structure, for example generalized increasing sets.

Let X be a non-empty set. A TOS is a triple $(X,\tau,\leq)$ where "τ" is a topology and "$\leq$" is a partial order on X. For any $x\in X$, the sets $[x,\rightarrow]$ and $[\leftarrow,x]$ are defined as $[x,\rightarrow]=\{y\in X/x\leq y\}$ and $[\leftarrow,x]=\{y\in X/y\leq x\}$. A subset A of a TOS $(X,\tau,\leq)$ is said to be increasing if $A=i[A]$ and decreasing if $A=d[A]$ where $i[A]=\bigcup_{a\in A}[a,\rightarrow]$ and $d[A]=\bigcup_{a\in A}[\leftarrow,a]$. The complement of an increasing set is a decreasing set and vice versa. A subset of a TOS $(X,\tau,\leq)$ is said to be balanced if it is both increasing and decreasing. M.K.R.S.Veera Kumar **[2]** introduced the study of increasing closed set (briefly i-closed), decreasing closed set (briefly d-closed) and balanced closed set (briefly b-closed) in 2001. N. Levine **[4]** introduced semi-open sets. The complement of a semi-open set is a semi-closed set. Bhattacharya & Lahiri **[6]** introduced and studied semi-generalized sets (briefly sg-closed).

II. PRELIMINARIES

Throughout this paper (X,τ) represent a non-empty topological space on which no separation axioms are assumed unless otherwise mentioned. For a subset A of a topological space (X,τ), the intersection of all closed sets containing A is called closure of A denoted by cl(A) and the intersection of semi-closed sets containing A is called the semi-closure of A denoted by scl(A). We recall the following definitions.

A. *Definition 2.1.*

A subset A of a topological space (X,τ) is called a semi-open set **[4]** if $A\subseteq cl(int(A))$ and a semi-closed set if $int(cl(A))\subseteq A$.

B. *Definition 2.2.*

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

1) a generalized closed set (briefly g-closed)**[5]** if $cl(A)\subseteq U$ whenever $A\subseteq U$ and U is open in (X,τ).The complement of a g-closed set is a g-open set.
2) a semi-generalized closed set (briefly *sg-closed*)**[6]** if $scl(A)\subseteq U$ whenever

$A \subseteq U$ and U is semi-open in (X, τ).The complement of a sg-closed set is

a sg-open set.

C. Definition 2.3 [7]

A subset A of a topological ordered space $(X, \tau, \leq)$ is called

1) a semi generalized increasing closed (briefly sgi-closed) set if A is a sg-closed set and an increasing set.
2) a semi generalized decreasing closed (briefly sgd-closed) set if A is a sg-closed set and a decreasing set.
3) a semi generalized balanced closed (briefly sgb-closed) set if A is a sg-closed set and a balanced set.

In view of the above definitions, we have every sgb-closed set is sgi-closed and sgd-closed also. **[9]**

D. Definition 2.4 [7]

A topological ordered space $(X, \tau, \leq)$ is called a $semi-T_{1/2}$ space if every sg-closed set is semi-closed.

III. SEMI-$T_{1/2}$ SPACES DEFINED USING SG-CLOSED TYPE SETS

In this section, we introduce new types of Semi-$T_{1/2}$ spaces using sgi-closed, sgd-closed and sgb-closed sets.

A. Definition 3.1: [8]

A topological ordered space $(X, \tau, \leq)$ is called

1) a $semi-_{sgi}T_{1/2}$ space if every sgi-closed set is semi-closed.
2) a $semi-_{sgd}T_{1/2}$ space if every sgd-closed set is semi-closed.
3) a $semi-_{sgb}T_{1/2}$ space if every sgb-closed set is semi-closed.

B. Example 3.2.

Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_4$ = {(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)}.Then, (X, τ_8, $\leq_4$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Increasing sets in this space are ϕ, X, {b}, {a, b}. Also, sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgi-closed sets are ϕ, X. Clearly, every sgi-closed set is a semi-closed set. So, the space (X, τ_8, $\leq_4$) is a $semi-_{sgi}T_{1/2}$ space.

C. Example 3.3

Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Sg-closed sets are ϕ, X, {c}, {b, c}, {a, c} and decreasing sets are ϕ, X, {a}, {a, b}.Then, sgd-closed sets are ϕ, X. Clearly, every sgd-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_1$) is a $semi-_{sgd}T_{1/2}$ space.

D. Example 3.4

Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Balanced sets in this space are ϕ, X and sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgb-closed sets are ϕ, X. Clearly, every sgb-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_1$) is a $semi-_{sgb}T_{1/2}$ space.

IV. RELATIONSHIPS BETWEEN SEMI-$T_{1/2}$ SPACES

In this section we establish relationships between $semi-T_{1/2}$ and $semi-_{sgi}T_{1/2}$, $semi-_{sgd}T_{1/2}$ and $semi-_{sgb}T_{1/2}$ spaces. We also establish independency of some of the spaces.

A. Theorem 4.1

Every $semi-T_{1/2}$ space is a $semi-_{sgi}T_{1/2}$ space but not conversely.

1) *Proof:* Let (X, τ, ≤) be a $semi-T_{1/2}$ space and A be a sgi-closed set in X. Then, A is a sg-closed set. Since X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgi-closed set in X is a semi-closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgi}T_{1/2}$ space.
2) The following example shows that the converse is not true.: Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_4$ = {(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)}.Then, (X, τ_8, $\leq_4$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Increasing sets in this space are ϕ, X, {b}, {a, b}. Also, sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgi-closed sets are ϕ, X. Clearly, every sgi-closed set is a semi-closed set. So, the space (X, τ_8, $\leq_4$) is a $semi-_{sgi}T_{1/2}$ space. The subset {b, c} is a sg-closed set but not a semi-closed set. Hence, the space (X, τ_8, $\leq_4$) is not a $semi-T_{1/2}$ space.

B. Theorem 4.2

Every $semi-T_{1/2}$ space is a $semi-_{sgd}T_{1/2}$ space but not conversely.

1) *Proof:* Let (X, τ, ≤) be a $semi-T_{1/2}$ space and A be a sgd-closed set. Then, A is a sg-closed set. Since X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgd-closed set in X is a semi- closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgd}T_{1/2}$ space.
2) *The following example shows that the converse is not true.:* Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Sg-closed sets are ϕ, X, {c}, {b, c}, {a, c} and decreasing sets are ϕ, X, {a}, {a, b}.Then, sgd-closed sets are ϕ, X. Clearly, every sgd-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_1$) is a $semi-_{sgd}T_{1/2}$ space. The subset {b, c} is a sg-closed set but not a semi-closed set. Hence, the space (X, τ_8, $\leq_1$) is not a $semi-T_{1/2}$ space.

C. Theorem 4.3

Every $semi-T_{1/2}$ space is a $semi-_{sgb}T_{1/2}$ space but not conversely.

1) *Proof:* Let (X, τ, ≤) be a $semi-T_{1/2}$ space and A be a sgb-closed set in X. Then, A is a sg-closed set. Since, X is a $semi-T_{1/2}$ space, A is a semi-closed set. Therefore, every sgb-closed set in X is a semi-closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgb}T_{1/2}$ space.
2) *The converse is not true as shown in the following example.:* Consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Balanced sets are ϕ, X and sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgb-closed sets are ϕ, X. Clearly, every sgb-closed set in X is a semi-closed set.So, the space (X, τ_8, $\leq_1$) is a $semi-_{sgb}T_{1/2}$ space. On the other hand, the subset {b, c} is a sg-closed set but not a semi-closed set. Hence, the space (X, τ_8, $\leq_1$) is not a $semi-T_{1/2}$

space.The following Figure 1 indicates the relationships between the spaces discussed above. Here, A $\longrightarrow$ B indicates A implies B but not conversely.

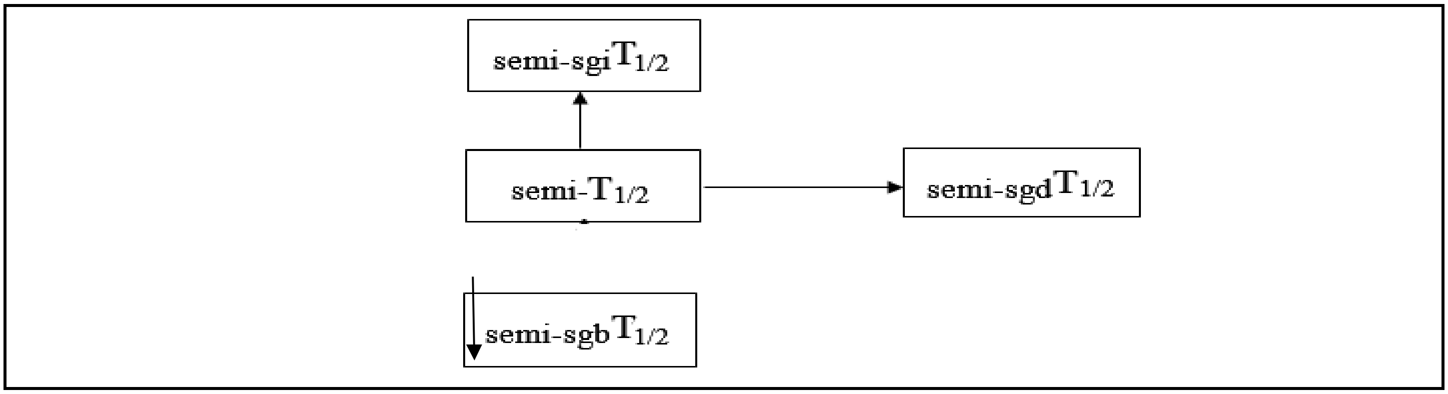

Fig. 1

V. RELATIONSHIPS BETWEEN SEMI-$T_{1/2}$ TYPE SPACES

In this section we establish relationships between $semi-T_{1/2}$ spaces defined by sgi-closed, sgd-closed and sgb-closed sets. We also establish independency of some of these spaces.

A. *Theorem 5.1*

Every $semi-_{sgi}T_{1/2}$ space is a $semi-_{sgb}T_{1/2}$ space but not conversely.

1) *Proof:* Let $(X,\tau,\leq)$ be a $semi-_{sgi}T_{1/2}$ space and A be a sgb-closed set in X. So, A is a sgi-closed set. Since X is a $semi-_{sgi}T_{1/2}$ space, A is a semi-closed set. Hence, the space $(X,\tau,\leq)$ is a $semi-_{sgb}T_{1/2}$ space.
2) *The following example shows that the converse is not true.:* Consider the set X = {a, b, c} together with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}. Increasing sets in this space are ϕ, X, {c}, {b, c} and sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgi-closed sets are ϕ, X, {c}, {b, c}.Balanced sets in this space are ϕ, X. So, sgb-closed sets are ϕ, X. Thus, every sgb-closed set in X is a semi-closed set. Hence, the space (X, τ_8, $\leq_1$) is a $semi-_{sgb}T_{1/2}$ space. Clearly, the subset {b, c} is a sgi-closed set but not a semi-closed set. So, the space (X, τ_8, $\leq_1$) is not a $semi-_{sgi}T_{1/2}$ space.

B. *Theorem 5.2*

Every $semi-_{sgd}T_{1/2}$ space is a $semi-_{sgb}T_{1/2}$ space but not conversely.

1) *Proof:* Let $(X,\tau,\leq)$ be a $semi-_{sgd}T_{1/2}$ space and A be a sgb-closed set. So, A is a sgd-closed set. Since X is a $semi-_{sgd}T_{1/2}$ space, A is a semi-closed set. Hence, the space $(X,\tau,\leq)$ is a $semi-_{sgb}T_{1/2}$ space.
2) *The following example shows that the converse is not true.:* Consider the set X = {a, b, c} together with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_2$ = {(a, a), (b, b), (c, c), (a, b), (c, b)}.Then, (X, τ_8, $\leq_2$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Decreasing sets in this space are ϕ, X, {a}, {c}, {a, c} and balanced sets are ϕ, X. Also, sg-closed sets with respect to the topology τ_8 are ϕ, X, {c}, {b, c}, {a, c}.Then, sgd-closed sets are ϕ, X, {c}, {a, c}.The sgb-closed sets are ϕ, X. Clearly, every sgb-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_2$) is a $semi-_{sgb}T_{1/2}$

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue VIII, August 2017- Available at www.ijraset.com

space. The subset {a, c} is a sgd-closed set but not a semi-closed set. So, the space (X, τ_8, $\leq_2$) is not a $semi-_{sgd}T_{1/2}$ space.

C. Theorem 5.3

The notions $semi-_{sgi}T_{1/2}$ and $semi-_{sgd}T_{1/2}$ are independent.

1) *Proof:* To prove the independency it is enough to exhibit an example of a $semi-_{sgi}T_{1/2}$ space which is not a $semi-_{sgd}T_{1/2}$ space and a space which is a $semi-_{sgd}T_{1/2}$ space but not a $semi-_{sgi}T_{1/2}$ space.

For the first part, consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_4$ = {(a, a), (b, b), (c, c), (a, b), (c, a), (c, b)}.Then, (X, τ_8, $\leq_4$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Increasing sets are ϕ, X, {b}, {a, b} and decreasing sets are ϕ, X, {c}, {a, c}.The sg-closed sets are ϕ, X, {c}, {b, c}, {a, c}.Then, sgd-closed sets are ϕ, X, {c}, {a, c} and sgi-closed sets are ϕ, X. Clearly, every sgi-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_4$) is a $semi-_{sgi}T_{1/2}$ space. The subset {a, c} is a sgd-closed set but not a semi-closed set. So, the space (X, τ_8, $\leq_4$) is not a $semi-_{sgd}T_{1/2}$ space.

For the other part, consider the set X = {a, b, c} with the topology τ_8 = {ϕ, X, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}. Then, (X, τ_8, $\leq_1$) is a topological ordered space. Semi-closed sets in this space are ϕ, X, {c}.Increasing sets are ϕ, X, {c}, {b, c} and sg-closed sets are ϕ, X, {c},{b, c}, {a, c}.Decreasing sets in this space are ϕ, X, {a}, {a, b}.Then, sgi-closed sets are ϕ, X, {c}, {b, c}.The sgd-closed sets are ϕ, X. Clearly, every sgd-closed set in X is a semi-closed set. So, the space (X, τ_8, $\leq_1$) is a $semi-_{sgd}T_{1/2}$ space. On the other hand, the subset {b, c} is a sgi-closed set but not a semi-closed set. So, the space (X, τ_8, $\leq_1$) is not a $semi-_{sgi}T_{1/2}$ space.

he following figure 2 indicates the relationships between the spaces discussed above. Here, A $\longrightarrow$ B (A $\nleftrightarrow$ B) indicates A implies B but not conversely (A and B are independent notions).

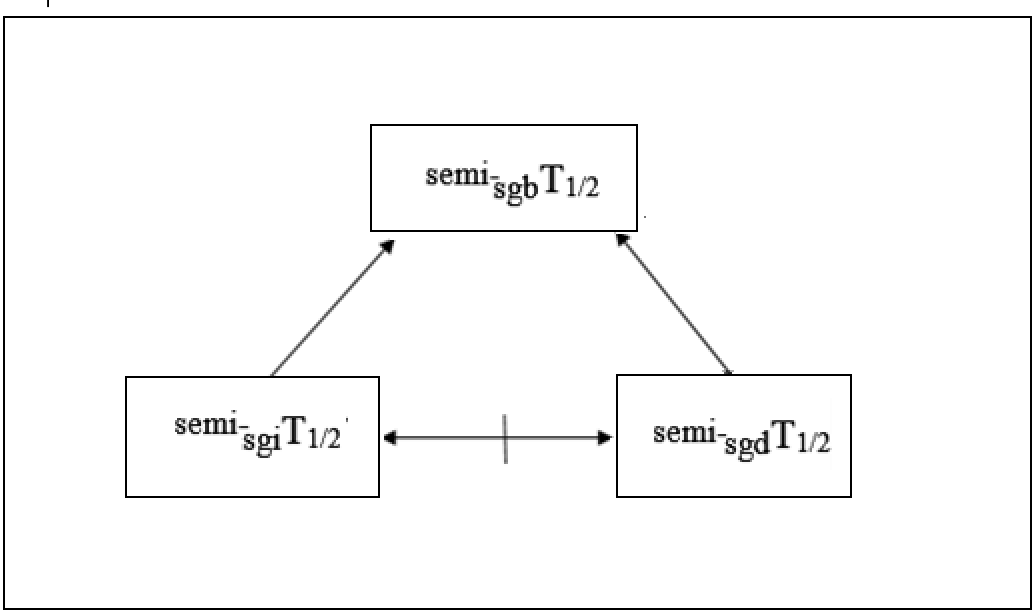

Fig. 2

VI. SOME MORE NEW SPACES

In this section we introduce some more new topological ordered spaces using semi-closed sets, increasing, decreasing and balanced closed sets.

We introduce the following definitions.

A. *Definition 6.1: [8*

A topological ordered space $(X, \tau, \leq)$ is called

1) a $semi-_{sgi}T_{is,1/2}$ space if every sgi-closed set is i-semi-closed.
2) a $semi-_{sgd}T_{ds,1/2}$ space if every sgd-closed set is d-semi-closed.
3) a $semi-_{sgb}T_{bs,1/2}$ space if every sgb-closed set is b-semi-closed.

B. *Example 6.2*

Let X = {a, b, c} with the topology τ_1 = {ϕ, X, {a}, {b}, {a, b}} and partial order $\leq_1$ = {(a, a), (b, b), (c, c), (a, b), (a, c), (b, c)}.Then, (X, τ_1, $\leq_1$) is a topological ordered space. Increasing sets in this space are ϕ, X, {b, c}, {c} and semi-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Then, i-semi-closed sets are ϕ, X, {b, c}, {c}.Also, sg-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Then, sgi-closed sets are ϕ, X, {b, c}, {c}.Clearly, every sgi-closed set is an i-semi-closed set. So, the space (X, τ_1, $\leq_1$) is a $semi-_{sgi}T_{is,1/2}$ space.

C. *Example 6.3*

Consider the set X = {a, b, c} with the topology τ_1 = {ϕ, X, {a}, {b}, {a, b}} and partial order $\leq_2$ = {(a, a), (b, b), (c, c), (a, b), (c, b)}.Then, (X, τ_1, $\leq_2$) is a topological ordered space. Decreasing sets in this space are ϕ, X ,{a, c}, {c}, {a} and semi-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Also, d-semi-closed sets in this space are ϕ, X, {a, c}, {c}, {a} and sg-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Then, sgd-closed sets are ϕ, X, {a, c}, {c}, {a}.Clearly, every sgd-closed set in this space is a d-semi-closed set.So, the space (X, τ_1, $\leq_2$) is a $semi-_{sgd}T_{ds,1/2}$ space.

D. *Example 6.4*

Let X = {a, b, c} with the topology τ_1 = {ϕ, X, {a}, {b}, {a, b}} and partial order $\leq_3$ = {(a, a), (b, b), (c, c), (a, b), (a, c)}.Then, (X, τ_1, $\leq_3$) is a topological ordered space. Balanced sets in this space are ϕ, X and semi-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Also, b-semi-closed sets in this space are ϕ, X. Sg-closed sets are ϕ, X, {a}, {b}, {c}, {b, c}, {a, c}.Then, sgb-closed sets are ϕ, X. Clearly, every sgb-closed set in X is a b-semi-closed set.So, the space (X, τ_1, $\leq_3$) is a $semi-_{sgb}T_{bs,1/2}$ space.

E. *Theorem 6.5*

Every $semi-_{sgi}T_{is,1/2}$ space is a $semi-_{sgi}T_{1/2}$ space.

1) *Proof:* Let (X, τ, ≤) be a $semi-_{sgi}T_{is,1/2}$ space and A be a sgi-closed set. Since X is a $semi-_{sgi}T_{is,1/2}$ space, the set A is an i-semi-closed set. So, A is a semi-closed set. Therefore, every sgi-closed set in X is a semi-closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgi}T_{1/2}$ space.

F. *Theorem 6.6*

Every $semi-_{sgd}T_{ds,1/2}$ space is a $semi-_{sgd}T_{1/2}$ space**.**

1) *Proof:* Let (X, τ, ≤) be a $semi-_{sgd}T_{ds,1/2}$ space and A be a sgd-closed set in X. Since X is a $semi-_{sgd}T_{ds,1/2}$ space, A is a d-semi-closed set. So, A is a semi-closed set. Therefore, every sgd-closed set in X is a semi-closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgd}T_{1/2}$ space.

G. Theorem 6.7

Every $semi-_{sgb}T_{bs,1/2}$ space is a $semi-_{sgb}T_{1/2}$ space**.**

1) *Proof:* Let (X, τ, ≤) be a $semi-_{sgb}T_{bs,1/2}$ space and A be a sgb-closed set in X. Since X is a $semi-_{sgb}T_{bs,1/2}$ space, A is a b-semi-closed set. So, A is a semi-closed set. Therefore, every sgb-closed set in X is a semi-closed set. Hence, the space (X, τ, ≤) is a $semi-_{sgb}T_{1/2}$ space.

VII. CONCLUSION

In this paper we introduced new types of Semi-$T_{1/2}$ spaces using sg-closed type sets. We studied relationships between these spaces. We also established the independency of some of these topological ordered spaces.

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