A NEW FORM OF b-OPEN SETS IN INFRA TOPOLOGICAL SPACE

VAIYOMATHI.K, DR.F.NIRMALA IRUDAYAM

Abstract: The purpose of this paper is to introduce a new class of infra open sets in infra topological spaces called infra b-open sets. The relationships among infra b-open sets and other open sets in infra topological settings are discussed. This paper also throws light on the various forms of continuity via infra topological space and explores its properties.

Keywords: Infra b-Open Sets, Infra b-Continuous Functions Infra b- Irresolute Functions.

1. Introduction: In 1996, D.Andrijevic'[3] introduced and studied the class of generalized open sets in a topological space called b-open sets .This class of sets is contained in the β -open sets [4], which contains all semi-open sets [5], and all pre-open sets[7]. Adel.M.AL.Odhari [1,2] introduced the concept of infra topological space and studied infra continuous and infra* continuous functions. O.Njastad[8] introduced some classes of nearly open sets. Vidyottamakumari, Thakur C.K. Raman [9] proposed the various characterizations of b-open sets in a topological space.

2. Preliminaries: Definition 2.1: Let X be any arbitrary set. An Infra –topological space on X is a collection τ_{iX} subsets of X such that the following axioms are satisfying:

Ax-1: ϕ , X $\epsilon\tau_{iX}$.

Ax-2: The intersection of the elements of any sub collection of τ_{iX} in X.

i.e) If $O_i \epsilon\tau_{iX}$,$1 \leq i \leq n \rightarrow \cap O_i \epsilon\tau_{iX}$.

Terminology, the order pair (X,τ_{iX}) is called infra-topological space. We simply say X is an infra space.

Definition 2.2: Let (X,τ_{iX}) be an infra-topological space and A$\subset X$. A is called infra open set (IOS) if A $\epsilon\tau_{iX}$

Definition 2.3: Let (X,τ_{iX}) be an infra topological space. A subset C $\subset X$ is called infra-closed set (ICS) in X if X \C is infra-open set in X.(i.e) C is infra-closed set (ICS) iff X \C $\epsilon\tau_{iX}$.

Definition 2.4: Let (X,τ_{iX}) be an infra topological space and A$\subset X$. The **Infra Closure Point (ICP)** of A is a set denoted by icp(A) and given by :

icp(A) = $\cap$ $\{C_i : A \subseteq C_i , X - C_i \, \epsilon\tau_{iX} \}$

(i.e)icp(A) is the intersection of all infra closed set containing the set A.

Definition 2.5: Let (X,τ_{iX}) be an infra topological space and A$\subset X$. The **Infra Interior Point (IIP)** of A is a set denoted by iip(A) and given by:

iip(A) = $\cup$ $\{O_i : O_i \subseteq A, O_i \, \epsilon\tau_{iX} \}$

(i.e)iip(A) is the union of all infra open set contained in the set A.

Definition 2.6: Let (X,τ_X) be a topological space and Let (X,τ_{iX}) be an infra topological space. We say that τ_{iX} is an infra-topological space associated with τ_X , if $\tau_{iX} \subset \tau_X$.

Definition 2.7: Let (X,τ_X) and (Y,τ_Y) be represent two topological spaces and τ_{iX} be associated infra topological space with τ_X. A function f: X ⟶Y is called I- continuous function at x ϵX , if ∀ open set O containing f(x) in Y, then ∃ Infra open set U containing x in τ_{iX} such that f(U) $\subset O$.

Definition 2.8: Let (X,τ_X) and (Y,τ_Y) be represent two topological spaces. Let τ_{iX} and τ_{iY}be associated infra topological space with τ_X *and* τ_Y respectively. A function f: X ⟶Y is called I*- continuous function, if the inverse image of each infra open set in τ_{iY} is an τ_{iX} infra open set in X.

3. Infra B-Open Sets In Infra Topological Space: In this section, we introduce the concept of new infra open sets such as infra semi- open set, infra pre- open set, infra α-open set, infra b-open set, infra semi-preopen set (or) infra β –open in an infra topological space and study some of its properties.

Definition 3.1: Let (X,τ_{iX}) be an infra topological space. A set 'A' is called infra semi-open if A $\subseteq icp\ (iip\ (A))$and infra semi- closed set if $icp\ (iip\ (A)) \subseteq A$.

Definition 3.2: Let (X,τ_{iX}) be an infra topological space. A set 'A' is called infra pre-open if A $\subseteq iip\ (icp\ (A))$ and infra pre- closed set if $iip\ (icp\ (A)) \subseteq$ A.

Definition 3.3: Let (X,τ_{iX}) be an infra topological space. A set 'A' is called infra α-open ifA$\subseteq$ $iip(icp(iip(A)))$and infraα - closed set if $iip(icp(iip(A))) \subseteq A$.

Definition 3.4: Let (X,τ_{iX}) be an infra topological space. A set 'A' is called infra b-open if A$\subseteq$ $iip(icp\ (A)) \cup icp\ (iip(A))$and infra b- closed set if

$$iip(icp\ (A)) \cup icp\ (iip(A)) \subseteq A.$$

Definition 3.5: Let (X,τ_{iX}) be an infra topological space. A set 'A' is called infra β -open if A $\subseteq$ $icp\ (iip\ (icp(A)))$ *and* infra β - closed set if$icp\ (iip\ (icp(A))) \subseteq A$.

The collection of all classes of infra semi- open , infra pre- open , infra α-open , infra b-open , infra semi-preopen (or) infra β –open subsets of (X,τ_{iX}) are denoted by ISOP(A), IPOP(A), IαOP(A),IBOP(A), ISPOP(A) respectively.

For a subset A of a space (X,τ_{iX}) the infra b-closure (respectively infra semi-closure, infra pre-closure, infra semi pre-closure) of A, denoted by b$icp(A)$

(respectively $sicp(A)$,picp(A), spicp(A)) is the intersection of all infra b-closed(respectively infra semi-closed ,infra pre-closed, infra semi pre-closed) subsets of (X,τ_{iX}) containing A.

Dually, the infra b-interior (respectively infra semi-interior , infra pre- interior, infra semi -pre- interior) of A, denoted by b$iip(A)$ (respectively s$iip(A)$, piip(A) , spiip(A)) is the union of all infra b-open(respectively infra semi-open,infra pre- open, infra semi -pre- open) subsets of (X,τ_{iX}) contained in A.

Proposition 3.6: Let A be a subset of a space (X,τ_{iX}).Then

(1) $sicp\ (A)) = A \ \cup (iip(icp(A)))$ and $siip\ (A)) = A \cap (icp\ (iip\ (A)))$

(2)$picp(A) = A \ \cup (icp\ (iip\ (A)))$ and $piip\ (A) = A \ \cap (iip\ (icp\ (A)))$

(3) $spicp(A) = A \cup (iip(icp\ (iip\ (A)))$ and $spiip\ (A) = A \ \cap (icp(iip\ (icp\ (A)))$

(4)$sicp(siip\ (A))= siip\ (A) \cup (iip(icp\ (iip(A)))$

(5) $picp(piip\ (A)) = piip(A) \ \cup (icp\ (iip(A)))$

(6) $spicp(spiip\ (A)) = spiip\ (spicp(A))$

Theorem 3.7: In an infra topological space (X,τ_{iX}) (i)Every $infra\ semi$-open set is infra b -openset.(ii)Every $infra\ pre$-open set is infra b-openset.

Proof: The result is Obvious.

The converse of the above theorem need not be true as shown by the following example.

Example 3.8: Let (X,τ_{iX}) be an infra topological space. Let X=$\{a,b,c\}$, $\tau_{iX} = \{\phi\ , X\ , \{b\}\ , \{c\}\}$ .Here $\{b,c\}$ is $infra\ b$- openset but it is not $infra\ semi$-open set and $\{a,b\}$ is infra b -openset but it is not infra pre-open set.

Proposition 3.9: For a subset A of a space X the following are equivalent:

a) A is infra b- openset.

b) A=$piip(A) \ \cup siip(A))$

c) A $\subseteq (picp\ (piip(A))$

Proof:Let A$\subseteq X$, Where (X,τ_{iX}) is an infra topological space.

(a)⇒(b) Let A be infra b- openset.

(i.e)A $\subseteq iip\ (icp\ (A)) \ \cup \ icp\ (iip(A))$.

Then by proposition (3.6)

$piip(A) \cup siip(A) = (A \cap iip(icp\ (A))) \cup (A \cap(icp\ (iip\ (A))) =$ A$\cap$ $(iip\ (\ icp\ (A)) \ \cup (icp\ (iip(A))) =$A

Therefore A=$piip(A) \ \cup sicp\ (A))$

(b) ⇒(c), By Proposition (3.6) We have,

A= $piip(A) \cup siip(A)= piip(A) \cup (A \cap icp\ (iip(A))) \subseteq piip(A) \cup (icp\ (iip\ (A))=(picp\ (piip(A))$

(c) $\Rightarrow (a)$, By Proposition (3.6) We have A$\subseteq piip(A) \cup (icp\ (iip\ (A)) \subseteq \ iip\ (icp\ (A)) \cup (icp\ (iip\ (A))$.

Therefore A is infra b-openset.

Theorem 3.10: Let A be a subset of a space (X,τ_{iX}).Then

(a) $bicp(A) = \ sicp\ (A) \cap$picp$(A)$

(b) $biip(A) = \ siip\ (A) \ \cup piip\ (A)$

Proof: Obvious.

Theorem 3.11: If A be a subset of a space (X,τ_{iX}), then $biip\ (bicp\ (A))$ =$bicp(biip\ (A))$.

Proof:Let A be a subset of a space (X,τ_{iX}).

Now $biip\ (bicp\ (A)) = siip(\ bicp\ (A)) \cup piip\ (bicp(A)) = bicp\ (\ siip\ (A)) \cup piip\ (bicp\ (A))$

$= sicp\ (\ siip\ (A)) \cup piip\ (picp\ (A))$ ---- (1)

&$bicp\ (\ biip\ (A)) = bicp\ (\ siip\ (A) \ \cup piip\ (A))= bicp\ (\ siip\ (A)) \ \cup \ bicp\ (\ piip\ (A))$

$= sicp\ (\ siip\ (A)) \cup piip\ (picp(A))$----- (2)

Hence, From (1) & (2), $biip\ (bicp(A))$ =$bicp\ (biip\ (A))$.Hence the theorem.

Proposition 3.12: Let A be a infra b-$open\ set$ such that $iip\ (A)$=ϕ, then A is infra pre-$open\ set$.

Proof: The result is obvious.

Theorem 3.13: In an Infra topological space X, we have the following:

(i)Every infra open set is infra α-open set.

(ii)Every infra α-open set is both infra semi-open set and infra pre-open set.

(iii)Every infra semi-open set and every pre- open set is infra β-open set.

The converse of the above theorem is not true as shown by the following example.

Example3.14: Let X=$\{a,b,c\}$, $\tau_{iX} = \{\phi\ , X\ , \{a\}\ , \{b\}, \{c\}, \{a,b\}\}$.Here $\{b,c\}$is infra α -open set but it is not infra open set.

Example3.15: Let X=$\{a,b,c\}$, $\tau_{iX} = \{\phi\ , X\ , \{a\}\ , \{c\}\}$. Here $\{b,c\}$is infra semi- open set but it is not infra α -open set. And here $\{a,c\}$is infra pre- open set but it is not infra α -open set.

Example3.16: Let X=$\{a,b,c\}$, $\tau_{iX} = \{\phi\ , X\ , \{a\}\ , \{c\}\}$. Here $\{a,c\}$is infra β - open set but it is not infra semi -open set. And here $\{a,b\}$is infra β - open set but it is not infra pre-open set.

Theorem 3.17: In an Infra topological space X, every infra b-open set (b-closed set) is an infra β- open set (β -closed set).

Proof:Let A be a infra b-$open\ set$ in X Then A $\subseteq icp\ (iip\ (A)) \cup \ iip\ (icp(A)) \subseteq icp(iip\ (icp\ (A))) \cup iip(icp(A) \subseteq \ icp(iip\ (icp\ (A)))$.

Therefore A is infra β - open set.

The converse is not true as seen in the following example:

Example3.18: Let X=$\{a,b,c\}$, $\tau_{iX} = \{\phi\ , X\ , \{b\}\ , \{c\}\}$.Here $\{a\}$is infra β - open set but it is not infra b-open set.

Proposition 3.19 :(a)The intersection of an infra-open set and a $infra\ b - open\ set$is a $infra\ b - open\ set$.

(b)The finite union of any family of $infra\, b-open\ set$ may fail to be a infra $b-open\ set$.

Proof: (a) The result is obvious. (b)In Example (3.5), both $\{a\}\ and\ \{b\}\ are$ infra $b-open\ set$s, but their union $\{a,b\}$is not $a\ b-open\ set$.

4. Infra B-Continuous Function In Infra Topological Space: In this section we introduce a new type of infra continuous functions and obtain some of their properties.

Definition 4.1: Let (X,τ_X) and (Y,τ_Y) be two topological spaces and τ_{iX}be an associated infra topology with τ_X.

A function f: (X,τ_X) → (Y,τ_Y) is called an infra b^i-continuous function if the inverse image of each infra open set in Y is an infra b-open set in(X,τ_{iX}).

Definition 4.2: Let (X,τ_X) and (Y,τ_Y) be two topological spaces and τ_{iX}be an associated infra topology with τ_X.

A function f: (X,τ_X) → (Y,τ_Y) is called an infra β -continuous function (respectively infra α -continuous, infra pre- continuous, infra semi-continuous), if the inverse image of each infra open set in Y is an infra β -open (respectively infra α -open, infra pre- open, infra semi- open), set in(X,τ_{iX})

.**Theorem 4.3:** Every infra continuous function is infra b-continuous function.

Proof:Let f: (X,τ_X) → (Y,τ_Y) be a infra continuous function and A is infra open in Y.Then $f^{-1}(A)$ is an infra open set in X. Since $\tau_{iX}$is associated with τ_X,then $\tau_{iX} \subset \tau_X$.Therefore, $f^{-1}(A)$ is infra open in X and it is infra b-open in X. Hence f is infra b-continuous.

The converse of the above theorem is not true as shown in the following example.

Example 4.4: Let X=$\{a,b,c\}$,$\tau = \{\phi, X,\{a\},\{b\},\{a,b\}\}$,$\tau_{iX} = \{\phi, X,\{a\},\{b\}\}$

A function f: (X,τ_X) → (X,τ_X) is an identity function. Here the inverse image of an infra open set $\{a,c\}$ is $\{a,c\}$which not an open set in X is but it is infra b-open set. Then f is infra b-continuous but it is not continuous.

The following Example shows that infra b-continuous function need not be infra semi-continuous function.

Example 4.5: Let X=$\{a,b,c\}$ and

$\tau_X = \{\phi, X,\{a\},\{b\},\{a,b\},\{a,c\}\}$,

$\tau_{iX} = \{\phi, X,\{a\},\{b\},\{a,c\}\}$.Suppose Y= $\{a,b\}$ with the topology $\tau_Y = \{\phi, X,\{a\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =a, f (b) =a, f(c) =b.

Here f is infra b -continuous function but not infra semi-continuous function.

The following Example shows that infra α -continuous function need not be infra-continuous function.

Example 4.6: Let X=$\{a,b,c\}$ and$\tau_X = \{\phi, X,\{a\},\{b\},\{c\},\{a,b\},\{a,c\},\{b,c\}\}$,$\tau_{iX} = \{\phi, X,\{a\},\{b\},\{c\},\{a,b\}\}$. Suppose Y= {1,2,3} with the topology $\tau_Y = \{\phi, X,\{1\},\{2\},\{1,2\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =3, f (b) =1, f(c) =2.Here f is infra α -continuous function but not infra -continuous function.

The following Example shows that infra pre-continuous function need not be infra α -continuous function.

Example 4.7: Let X=$\{a,b,c\}$, and $\tau_X = \{\phi, X,\{b\},\{c\},\{a,c\},\{b,c\}\}$,$\tau_{iX} = \{\phi, X,\{b\},\{c\},\{a,c\}\}$.Suppose Y= {1,2,3} with the topology $\tau_Y = \{\phi, X,\{1\},\{3\},\{1,3\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =2, f (b) =1, f(c) =3.Here f is infra pre-continuous function but not infra α –continuous.

The following Example shows that infra semi-continuous function need not be infra α -continuous function.

Example 4.8: Let X=$\{a,b,c\}$, and$\tau_X = \{\phi, X,\{a\},\{b\},\{c\},\{a,b\},\{a,c\},\{b,c\}\}$,$\tau_{iX} = \{\phi, X,\{a\},\{b\},\{c\},\{a,c\}\}$.Suppose Y= {1,2,3} with the topology $\tau_Y = \{\phi, X,\{1\},\{2\},\{1,2\},\{1,3\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =1, f (b) =3, f(c) =2.Here f is infra semi-continuous function but not infra α -continuous function.

The following Example shows that infra β-continuous function need not be infra b-continuous function.

Example 4.9: Let X=$\{a,b,c\}$ and$\tau_X = \{\phi, X,\{b\},\{c\},\{a,c\},\{b,c\}\}$,$\tau_{iX} = \{\phi, X,\{a\},\{b\},\{c\}\}$.Suppose Y= {1,2,3} with the topology $\tau_Y = \{\phi, X,\{1\},\{2\},\{1,2\},\{1,3\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =1, f (b) =2, f(c) =3. Here f is infra β -continuous function but not infra b -continuous function.

The following Example shows that infra b-continuous function need not be infra pre-continuous function.

Example 4.10: Let X=$\{a,b,c\}$ and$\tau_X = \{\phi, X,\{a\},\{c\},\{a,b\},\{a,c\}\}$,$\tau_{iX} = \{\phi, X,\{a\},\{c\}\}$.Suppose Y= {1,2,3} with the topology $\tau_Y = \{\phi, X,\{1\},\{2\},\{1,2\},\{1,3\}\}$.Define the function f: (X,τ_X) → (Y,τ_Y) by f (a) =1, f (b) =3, f(c) =2.Here f is infra b-continuous function but not infra pre -continuous function.

Theorem 4.11: Let f: (X,τ_X) → (Y,τ_Y) be a function from an infra space X to an infra space Y. Then the following statements are true:(i)f is infra b −continuous(ii)The inverse image of each infra -closed set in Y is infra b-closed set in X.

Proof: (i)⟹(ii) Let A be infra-closed set in Y. Then A^c is infra-open set.Then $f^{-1}(A^c) \in$ infra b-open set of X ⇒ X $-f^{-1}(A) \in$ infra b-open set of X. Hence $f^{-1}(A)$ is an infra b-closed set in X.

(ii) ⟹(i) Let B be infra-open set in Y. Then B^c is infra-closed set. And by (ii) we have $f^{-1}(B^c) \in$ infra b-closed set of X ⇒ X $-f^{-1}(B) \in$ infra b-closed set in X. Hence $f^{-1}(B)$ is an infra b-open set in X. Therefore f is an infra b-continuous function.

Theorem 4.12: Let (X,τ_X), (Y,τ_Y), (Z,τ_Z) be three topological spaces. If a map f: (X,τ_X) → (Y,τ_Y) is a infra b-continuous map & g: (Y,τ_Y) → (Z,τ_Z) is a continuous map then$g \circ f$: (X,τ_X) → (Z,τ_Z) is a infra b-continuous.

Proof: Obvious

5. Infra B-Irresolute Function In Infra Topological Space: Definition5.1: Let (X,τ_X) and (Y,τ_Y) be represent two topological spaces. Let (X,τ_{iX}) and (Y,τ_{iY}) be two associated infra topological spaces. A function f: (X,τ_X) → (Y,τ_Y) is said to be infra b-irresolute function if the inverse image of each infra b-open set in τ_{iY} is an τ_{iX} -infra b-open set in X.

Theorem 5.2: A function f: (X,τ_X) → (Y,τ_Y) is infra b-irresolute function if and only if the inverse image of each infra b-closed set in τ_{iY} is an τ_{iX} -infra b-closed set in X.

Theorem 5.3: Every infra b-irresolute function is infra b-continuous function.

Proof: Let f: (X,τ_X) → (Y,τ_Y) is infra b-irresolute function. Let A be infra closed set in Y then A is infra b-closed set in Y. Since f is infra b-irresolute function, $f^{-1}(A)$ is infra b-closed set in X. Hence f is infra b-continuous function.

Theorem 5.4: Let (X,τ_X), (Y,τ_Y), (Z,τ_Z) be three topological spaces. Let f: (X,τ_X) → (Y,τ_Y) & g: (Y,τ_Y) → (Z,τ_Z) be two functions. Then

(i)$g \circ f$: (X,τ_X) → (Z,τ_Z) is infra b-irresolute if f and g is infra b-irresolute functions.

(ii)$g \circ f$: (X,τ_X) → (Z,τ_Z) is infra b-continuous if f is infra b-irresolute function and g is infra b-continuous function.

Proof: (i)Let g: (Y,τ_Y) → (Z,τ_Z) is infra b-irresolute function and let O be infra b-closed of Z. Since g is infra b-irresolute by definition of infra b-irresolute, $g^{-1}(O)$ is infra b-closed set in Y. Also f: (X,τ_X) → (Y,τ_Y) is infra b-irresolute, so $f^{-1}(g^{-1}(O)) = (g \circ f)^{-1}(O)$ is infra b-closed. Thus $g \circ f$: (X,τ_X) → (Z,τ_Z) is infra b-irresolute.(ii)Let O be infra b-closed set of Z. Since g: (Y,τ_Y) → (Z,τ_Z) is infra b-continuous function, $g^{-1}(O)$ is infra b-closed set in Y. Also f: (X,τ_X) → (Y,τ_Y) is infra b-irresolute, so every infra b-closed set of Y is infra b-closed in X. Therefore $f^{-1}(g^{-1}(O)) = (g \circ f)^{-1}(O)$ is infra b-closed of X. Thus $g \circ f$: (X,τ_X) → (Z,τ_Z) is infra b-continuous.

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Vaiyomathi. K, Research Scholar, Dr. F. Nirmala Irudayam, Assistant Professor,
Nirmala College for women, Coimbatore, India.