Volume 5, No.3, March 2018
Journal of Global Research in Mathematical Archives
UGC Approved Journal
RESEARCH PAPER
Available online at http://www.jgrma.info
ISSN 2320 – 5822

NEW SPACES IN TOPOLOGICAL SPACES

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***Abstract* :**The aim of this paper is to introduce and study two new classes of spaces,namely Pre generalized pre regular weakly normal and pre generalized pre regular weaklyregular spaces and obtained their properties by utilizing pre generalized pre regular weakly closed sets.

Keywords: Pre generalized pre regular weakly closed set,Pre generalized pre regular weakly open sets, Pre generalized pre regular weakly regular space and pre generalized pre regular weakly normal space.

Mathematics subject classification (2010): 54A05.

1 INTRODUCTION

Maheshwari and Prasad[8] introduced the new class of spaces called s-normal spacesusing semi-open sets. It was further studied by Noiri and Popa[10],Dorsett[6] andArya[1]. Munshi[9], introduced g-regular and g-normal spaces using g-closed sets ofLevine[7]. Later, Benchalli et al [3] and Shik John[12] studied the concept of g*- pre-regular, g*-pre normal and w- normal, w-regular spaces in topological spaces.Recently, Benchalli et al [2,11] introduced and studied the properties of regular weakly closedsets and regular weakly continuous functions.

2 PRELIMINARIES

Throughout this paper space (X, τ) and (Y, σ) (or simply X and Y) always denote topological space on which no separation axioms are assumed unless explicitly stated. For a subset A of a space X, Cl(A), Int(A), A^c , and α-Cl(A), denote the Closure of A, Interior of A and Compliment of A and α-closure of A in X respectively.

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

(i)Generalized closed set(briefly g-closed) [7] if cl(A)$\subseteq$U whenever A $\subseteq$ U and U is open in X.

(ii)W-closed set[12] if cl(A) $\subseteq$ U whenever A$\subseteq$ U and U is semi-open in X.

Definition 2.2 :A topological space X is said to be a

(1) α - regular [4], if for each α - closed set F of X and each point x $\notin$ F, there existsdisjoint α - open sets U and V such that F $\subseteq$V and x ϵ U.
(2) w-regular[12], if for each closed set F of X and each point x $\notin$ F, there existsdisjoint w-open

sets U and V such that F⊆U and xϵV.

(3)g-regular[10], if for each g-closed set F of X and each point x ∉F,there exists disjoint open sets U and V such that F⊆U and x ϵ V.

Definition 2.3.A topological space X is said to be a

(1) α-normal [4], if for any pair of disjoint$\alpha -$ closed sets A and B, there exists dis-joint α-open sets U and V such that A⊆U and B⊆V .

(2) w-normal [12], if for any pair of disjoint w -closed sets A and B, there existsdisjoint open sets U and V such that A⊆ U and B⊆V.

(3) g- normal [10], if for any pair of disjoint g-closed sets A and B, there exists disjoint open sets U and V such that A⊆U and B⊆V.

Definition 2.4: [2] A topological space X is called $T_{\text{regular weakly}}$ -space if every pre generalized pre regular weakly closed setis closed set.

Definition 2.5:A map f: (X, τ) ⟶ (Y, τ) is said to be

(i)Pre generalized pre regular weakly continuous map[19]if f^{-1}(V)is a pre generalized pre regular weakly closed set of (X, τ) for every closed set V of (Y, τ).

(ii)Pre generalized pre regular weakly irresolute map[20]if f^{-1}(V)is a pre generalized pre regular weakly closed set of (X, τ) for everypre generalized pre regular weakly closed set V of (Y, τ).

3.PRE GENERALIZED PRE REGULAR WEAKLY REGULAR SPACE

In this section, we introduce a new class of space called pre generalized pre regular weakly regular space using Pre generalized pre regular weakly closed set and obtain some of their characterizations.

Definition 3.1. A topological space Xis said to be pre generalized pre regular weakly regular space if for each pre generalized pre regular weakly closedset F and a point x∉F, there exist disjoint open sets G and H such that F⊆G andxϵH.

We have the following interrelationship between pre generalized pre regular weakly regularity and regularity.

Theorem 3.2. Every pre generalized pre regular weakly regular space is regular.
Proof: Let X be a pre generalized pre regular weakly regular space. Let F be any closed set in X and a point x∉Xsuch that x∉F. By [2], F is pre generalized pre regular weakly topological space-closed and x ∉F. Since X is a pre generalized pre regular weakly regular space, thereexists a pair of disjoint open sets G and H such that F ⊆ G and x ϵH. Hence X is aregular space.

Remark 3.3: If X is a regular space and $T_{\text{pre generalized pre regular weakly topological space}}$, then X is pre generalized pre regular weakly regular space then we have the following characterization.

Theorem 3.4. The following statements are equivalent for a topological space X.

(i) X is a pre generalized pre regular weakly regular space

(ii) For each x ϵX and each pre generalized pre regular weakly topological spacesopen neighbourhood U of x,there exists an openneighbourhood N of x such that cl(N)⊆U.

Proof: (i)implies(ii): Suppose X is a pre generalized pre regular weakly regular space. Let U be any pre generalized pre regular weakly neighbourhood of x. Then there exists pre generalized pre regular weakly open set G such that x ϵ G ⊆U. Now X –Gis pre generalized pre regular weakly closed set and x ∉ X - G. Since X is pre generalized pre regular weakly regular space, then there exist open sets Mand N such that X - G⊆M, x ϵ N and M ∩ N = $\varphi$and so N ⊆X-M. Nowcl(N) ⊆ cl(X -M) = X-M and X -M ⊆M. This implies X -M⊆ U. Thereforecl(N)⊆U.

(ii)implies (i): Let F be any pre generalized pre regular weakly topological space closed set in X and x ϵX -F and X - F is aPre generalized pre regular weakly topological space open and so X - F is a pre generalized pre regular weakly topological space neighbourhood of x. By hypothesis, there existsan open neighbourhood N of x such that x ϵN and cl(N) ⊆X - F. This impliesF ⊆X - cl(N) is an open set containing F and N ∩ f(X - cl(N)= φ . Hence X ispre generalized pre regular weakly regular space.

We have another characterization of pre generalized pre regular weakly regularity in the following.

Theorem 3.5: A topological space X is pre generalized pre regular weakly regular if and only if for each pre generalized pre regular weakly topological space closedset F of X and each x ϵX - F there exist open sets G and H of X such that x ϵ G,F⊆H and cl(G) ∩ cl(H) = ∅.

Proof: Suppose X is pre generalized pre regular weakly regular space. Let F be a pre generalized pre regular weakly topological space closed set in X with x ∉F.Then there exists open sets M and H of X such that x ϵ M, F ⊆H and M∩H =∅.This implies M∩cl(H) = ∅.As X is pre generalized pre regular weakly regular, there exist open sets U and V suchthat x ϵ U, cl(H)⊆V and U∩V = ∅. so cl(U)∩V = ∅.Let G = M ∩U, then G andH are open sets of X such that xϵG, F ⊆ H and cl(H) ∩cl(H) =∅.

Conversely, if for each pre generalized pre regular weakly closed set F of X and each x ϵ X -F there exists opensets G and H such that x ϵ G, F⊆ H and cl(H)∩cl(H) =∅.This implies x ϵG,F⊆H and G ∩ H = ∅. Hence X is pre generalized pre regular weakly regular.

Now we prove that pre generalized pre regular weakly topological spaces- regularity is a heriditary property.

Theorem 3.6. Every subspace of a pre generalized pre regular weakly regular space is pre generalized pre regular weakly regular.

Proof: Let X be a pre generalized pre regular weakly regular space. Let Y be a subspace of X. Let x ϵ Y and F bea pre generalized pre regular weakly closed set in Y such that x∉F. Then there is a closed set and so pre generalized pre regular weakly closedset A of X with F = Y ∩ A and x ∉A. Therefore we have x ϵ X, A is pre generalized pre regular weakly closedin X such that x∉A. Since X is pre generalized pre regular weakly regular, then there exist open sets G and H suchthat x ϵG, A⊆H and G∩H = φ. Note that Y ∩G and Y∩H are open sets in Y.Also x ϵ G and x ϵY, which implies x ϵ Y ∩G and A ⊆ H implies Y∩ G⊆Y ∩H,F⊆Y∩H. Also (Y∩G)∩(Y∩H) = φ. Hence Y is pre generalized pre regular weakly regular space.

We have yet another characterization of pre generalized pre regular weakly topological spaces-regularity in the following.

Theorem 3.7 : The following statements about a topological space X are equivalent:

(i) X is pre generalized pre regular weakly regular
(ii) For each x ϵ X and each pre generalized pre regular weakly topological space open set U in X such that x ϵ U there exists anopen set V in X such that x ϵ V⊆cl(V)⊆U.

(iii) For each point x ϵX and for each pre generalized pre regular weakly topological space closed set A with x $\notin$ A, then there exists anopen set V containing x such that cl(V)∩A = φ.

Proof: (i)implies(ii): Follows from Theorem 3.5.

(ii) implies(iii): Suppose (ii) holds. Let x ϵ X and A be an pre generalized pre regular weakly topological spaceclosed set of X suchthat x $\notin$ A.Then X - A is a pre generalized pre regular weakly topological spaceopen set with xϵX -A. By hypothesis, thereexists an open set V such that x ϵV ⊆ cl(V) ⊆ X - A. That is xϵ V , V⊆ cl(A) andcl(A) ⊆ X - A. So x ϵV and cl(V)∩A = φ.

(iii) implies(i): Let x ϵ X and U be an pre generalized pre regular weakly topological space open set in X such that x ϵ U. ThenX - U is an pre generalized pre regular weakly topological spaceclosed set and x$\notin$ X - U. Then by hypothesis, there exists an openset V containing x such that cl(A) ∩(X -U) = Á. Therefore x ϵV , cl(V)⊆U sox ϵ V⊆ cl(V)⊆U.

The invariance of pre generalized pre regular weakly topological space regularity is given in the following.

Theorem 3.8: Let f : X Y→be a bijective, pre generalized pre regular weakly topological space irresolute and open map from a pre generalized pre regular weakly topological space regular space X into a topological space Y , then Y is pre generalized pre regular weakly topological spaces-regular.

Proof: Let y ϵ Y and F be a pre generalized pre regular weakly topological space closed set in Y with y $\notin$ F. Since F is pre generalized pre regular weakly topological spaceirresolute, f^{-1}(F) is pre generalized pre regular weakly topological space closed set in X. Let f(x) = y so that x = f^{-1} (y) andx $\notin$ f^{-1}(F). Again X is pre generalized pre regular weakly-regular space, then there exist open sets U and V such thatx ϵ U and f^{-1}(F) ⊆ G, U ∩ V = φ. Since f is open and bijective, we have y ϵ f(U),F ⊆ f(V) and f(U) ∩f(V) = f(U∩V) = f(φ) = φ . Hence Y is pre generalized pre regular weakly regular space.

Theorem 3.9. Let f : X Y→be a bijective, pre generalized pre regular weakly closed and open map from atopological space X into a pre generalized pre regular weakly regular space Y . If X is $T_{\text{pre generalized pre regular weakly topological spaces}}$, then X is pre generalized pre regular weakly regular.

Proof: Let x ϵX and F be an pre generalized pre regular weakly closed set in X with x $\notin$F. Since X is $T_{\text{pre generalized pre regular weakly topological spaces}}$,F is closed in X. Then f(F) is pre generalized pre regular weakly closed set with f(x)$\notin$ f(F) in Y , since f is pre generalized pre regular weakly closed. As Y is pre generalized pre regular weakly regular,then there exist open sets U and V such that x ϵ Uandf(x) ϵ U and f(F) ⊆V . Therefore x ϵ f^{-1}(U) and F⊆ f^{-1}(V). Hence X is pre generalized pre regular weakly regular space.

Theorem 3.10. If f : X⟶ Y is w-irresolute, continuous injection and Y is pre generalized pre regular weakly topological spaces-regular space,then X is pre generalized pre regular weakly topological spaces-regular.

Proof: Let F be any closed set in X with x$\notin$F. Since f is w-irresolute, f is pre generalized pre regular weakly topological space closed set in Yand f(x) ϵ f(F). Since Y is pre generalized pre regular weakly regular,then there exists open sets U and V such that f(x) ϵU and
f(F) ⊆ V . Thus x $\epsilon$$f^{-1}$(U),F ⊆ f^{-1}(V) and f^{-1} (U) ∩ f^{-1}(V) = φ. Hence X is pre generalized pre regular weakly regular space.

4 PRE GENERALIZED PRE REGULAR WEAKLY NORMAL SPACES

In this section, we introduce the concept of pre generalized pre regular weakly normal spaces and study some of theircharacterizations.

Definition 4.1. A topological space X is said to be pre generalized pre regular weakly normal if for each pair ofdisjoint pre generalized pre regular weakly topological spacesclosed sets A and B in X,then there exists a pair of disjoint open sets U andV in X such that A ⊆ U and B ⊆V

We have the following interrelationship.

Theorem 4.2. Every pre generalized pre regular weakly normal space is normal.

Proof: Let X be a pre generalized pre regular weakly normal space. Let A and B be a pair of disjoint closed sets inX. From [2], A and B are pre generalized pre regular weakly topological spacesclosed sets in X. Since X is pre generalized pre regular weakly normal, then there existsa pair of disjoint open sets G and H in X such that A⊆ G and B ⊆ H. Hence X is
normal.

Remark 4.3. The converse need not be true in general as seen from the following
example.

Example 4.4. Let X = Y ={a,b,c,d},τ ={X, ∅,{a},{c},{a,c},{b,c,d}}.Then
the space X is normal but not pre generalized pre regular weakly normal, since the pair of disjoint pre generalized pre regular weakly topological spacesclosed setsnamely, A = {a,d}and B = {b,c}for which there do not exists disjoint open sets Gand H such that A ⊆ G and B⊆ H.

Remark 4.5.:If X is normal and $T_{\text{pre generalized pre regular weakly topological spaces}}$, then X is pre generalized pre regular weakly -normal.

Hereditary property of pre generalized pre regular weakly normality is given in the following.

Theorem 4.6.A pre generalized pre regular weakly closed subspace of a pre generalized pre regular weakly normal space is pre generalized pre regular weakly normal.We have the following characterization.

Theorem 4.7. The following statements for a topological space X are equivalent:

(i) X is pre generalized pre regular weakly topological spaces is normal
(ii) For each pre generalized pre regular weakly closed set A and each pre generalized pre regular weakly topological space open set U such that A⊆U, there existsan open set V such that A⊆V⊆cl(V)⊆U
(iii) For any pre generalized pre regular weakly closed sets A, B, there exists an open set V such that A⊆V andcl(V)∩B = φ.
(iv) For each pair A, B of disjoint pre generalized pre regular weakly closed sets then there exist open sets U and V suchthat A ⊆ U,B ⊆V and cl(U) ∩cl(V) = φ.

Proof: (i)implies(ii): Let A be a pre generalized pre regular weakly closed set and U be a pre generalized pre regular weakly open set such that A⊆ U.Then A and X - U are disjoint pre generalized pre regular weakly closed sets in X. Since X is pre generalized pre regular weakly normal , then thereexists a pair of disjoint open sets V and W in X such that A ⊆ V and X -U⊆W.Now X -W ⊆ X -(X -U), so X -W⊆ U also V∩W = φ.implies V ⊆ X -W, so
cl(V)⊆cl(X -W) which implies cl(V) ⊆ X -W. Therefore cl(V)⊆X -W⊆U. So cl(V) ⊆ U. Hence A⊆V⊆cl(V)⊆U.

(ii)implies(iii): Let A and B be a pair of disjoint pre generalized pre regular weakly closed sets in X. Now A∩B = φ,so A⊆X -B, where A is pre generalized pre regular weakly closed and X - B is pre generalized pre regular weakly open . Then by (ii) thereexists an open set V such that A⊆V⊆cl(V)⊆X-B. Now cl(V)⊆X - B impliescl(V)∩B = φ. Thus A⊆V and cl(V)∩B = φ.

(iii) implies(iv): Let A and B be a pair of disjoint pre generalized pre regular weakly closed sets in X.Then from (iii)there exists an open set U such that A⊆U and cl(U)∩B = φ. Since cl(V) is closed, sopre generalized pre regular weakly closed set.Therefore cl(V) and B are disjoint pre generalized pre regular weakly closed sets in X. By hypothesis,then their exists an open set V , such that B⊆V and cl(U) ∩cl(V) = φ.

(iv) implies(i): Let A and B be a pair of disjoint pre generalized pre regular weakly closed sets in X.Then from (iv)then there exist an open sets U and V in X such that A⊆U, B⊆V and cl(U)∩cl(V) = φ.So A ⊆ U , B⊆V and U∩V = φ.Hence X is pre generalized pre regular weakly normal.

Theorem 4.8. Let X be a topological space. Then X is pre generalized pre regular weakly normal if and only if forany pair A, B of disjoint pre generalized pre regular weakly closed setthen there exist open sets U and V of X such thatA⊆U,B⊆V and cl(U) ∩cl(V) = φ.

Theorem 4.9. Let X be a topological space. Then the following are equivalent:
(i) X is normal
(ii) For any disjoint closed sets A and B,then there exist disjoint pre generalized pre regular weakly topological spaces- open sets U and Vsuch that A⊆U,B⊆V .
(iii) For any closed set A and any open set V such that A⊆ V, there exists an pre generalized pre regular weakly open set U of X such that A⊆U⊆αcl(U)⊆ V .

Proof: (i) implies(ii): Suppose X is normal. Since every open set is pre generalized pre regular weakly open [2], (ii)follows.

(ii) implies(iii): Suppose (ii) holds. Let A be a closed set and V be an open set containing A. Then A and X - V are disjoint closed sets. By (ii), then there exist disjoint pre generalized pre regular weakly open sets U and W such that A⊆U and X - V ⊆ W, since X -V is closed, sopre generalized pre regular weakly is closed. From [2], we have X -V⊆α-int(W) and U ∩ α-int(W) =φ.and so wehave α-cl(U) ∩ α-int(W) = φ. Hence A ⊆ U ⊆α-cl(U) ⊆ X – α-int(W)⊆V . ThusA ⊆ U ⊆α-cl(U) ⊆ V .

(iii) implies(i): Let A and B be a pair of disjoint closed sets of X.Then A ⊆X - B andX -B is open. There exists a pre generalized pre regular weakly open set G of X such that A ⊆ G ⊆α-cl(G) ⊆X-B.Since A is closed, it is w- closed, we have A ⊆α-int(G). Take U = int(cl(int(α-int(G))))and V = int(cl(int(X –α-cl(G)))). Then U and V are disjoint open sets of X such thatA ⊆U and B ⊆ V Hence X is normal.

We have the following characterization of pre generalized pre regular weakly topological spaces- normality and pre generalized pre regular weakly topological spaces- normality.

Theorem 4.10. Let X be a topological space. Then the following are equivalent:
(i) X is α-normal.
(ii) For any disjoint closed sets A and B, there exist disjoint pre generalized pre regular weakly topological space- open sets U and Vsuch that A⊆U,B⊆V and U∩ V = φ.

Proof: (i) implies(ii): Suppose X is α- normal. Let A and B be a pair of disjoint closedsets of X. Since X is α-normal,there exist disjoint $\alpha -$ open sets U and V such thatA⊆U and B⊆V and U ∩ V = φ.
(ii) implies(i):Let A and B be a pair of disjoint closed sets of X.The by hypothesis thereexist disjoint pre generalized pre regular weakly open sets U and V such that A⊆U and B ⊆ V and U ∩V = φ .Sincefrom [2], A⊆α-intU and B ⊆$\alpha -$ int(V)and α –intU∩ α-intV = φ. Hence X is α-normal.

Theorem 4.11. Let X bea α- normal, then the following hold good:

(i)For each closed set A and every pre generalized pre regular weakly open set B such that A⊆B ther exists a αopen set U such that A⊆U⊆α-cl(U)⊆ B.
(ii) For every pre generalized pre regular weakly closed set A and every open set B containing A, there exist a α-open set U such that A⊆U⊆ α-cl(U)⊆B.

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