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# Pentapartitioned Neutrosophic Topological Space

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**Abstract:**
The main focus of this study is to present the notions of pentapartitioned neutrosophic topological space. We introduce the notions of closure and interior operator of pentapartitioned neutrosophic sets in pentapartitioned neutrosophic topological space, and investigate some of their basic properties. Further, we define pentapartitioned neutrosophic pre-open (in short P-NPO) set, pentapartitioned neutrosophic semi-open (in short P-NSO) set, pentapartitioned neutrosophic *b*-open (in short P-N-*b*-O) set and pentapartitioned neutrosophic α-open (in short P-Nα-O) set via pentapartitioned neutrosophic topological spaces. By defining P-NPO set, P-NSO set, P-N-*b*-O set, P-Nα-O set, we furnish some suitable examples and formulate some basic results on pentapartitioned neutrosophic topological spaces.

**Keywords:** Neutrosophic Set; Pentapartitioned Neutrosophic Set; P-NPO; P-NSO; P-N-b-O; P-Nα-O.

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**1. Introduction:** In the year 1998, Smarandache [30] introduced the notions of Neutrosophic Set (in short N-S) by extending the notions of Fuzzy Set [33] and Intuitionistic Fuzzy Set [4]. Later on, the notions of Neutrosophic Topological Space (in short N-T-S) was grounded by Salama and Alblowi [29] in the year 2012. Thereafter, Arokiarani et al. [3] defined the notions of neutrosophic semi-open functions. In the year 2016, Iswaraya and Bageerathi [19] presented the concept of neutrosophic semi-open set and neutrosophic semi-closed set via N-T-Ss. Later on, Dhavaseelan and Jafari [17] introduced the idea of generalized neutrosophic closed sets. The notions of neutrosophic generalized closed sets via N-T-Ss was studied by Pushpalatha and Nandhini [27]. The idea of neutrosophic *b*-open sets in N-T-Ss was presented by Ebenanjar et al. [18]. Thereafter, Maheswari et al. [22] presented the concept of neutrosophic generalized *b*-closed sets via N-T-Ss. In the year 2019, the concept of generalized neutrosophic *b*-open set via N-T-Ss was studied by Das and Pramanik [10]. Das and Pramanik [11] also grounded the notion of neutrosophic Φ-open sets and neutrosophic Φ-continuous mappings via N-T-Ss. Afterwards, Das and Pramanik [12] presented the notions of neutrosophic simply soft open set via neutrosophic soft topological spaces. Das and Tripathy [16] introduced and studied the neutrosophic simply *b*-open set via N-T-S. Recently, Das et al. [7] applied the concept of topology on Quadripartitioned N-Ss [5] and introduced the notions of Quadripartitioned N-T-S.

In the year 2020, Mallick and Pramanik [23] grounded the notions of Pentapatitioned Neutrosophic Set (in short P-N-S) by extending the notions of N-S and Quadripartitioned N-S. The main focus of this article is to procure the notions of Pentapartitioned Neutrosophic Topological Space (in short Pentapartitioned N-T-S) and study several properties of them.

**Research Gap**: No investigation on pentapartitioned neutrosophic topological space has been reported in the recent literature.

**Motivation**: To reduce the research gap, we procure the notion of pentapartitioned neutrosophic topological space.

The remaining part of this article has been split into the following sections:

In section-2, we recall some relevant definitions and results on N-S, N-T-S, and P-N-S. In section-3, we present the notions of Pentapartitioned N-T-S and formulate some results on it. In section-4, we conclude the work done in this paper.

## 2. Preliminaries and Definitions:

In this section, we give some some basic definitions and results those are relevant to the main results of this article.

**Definition 2.1.** [23] Let $W$ be a universe of discourse. Then $P$, a P-N-S over $W$ is defined by:

$P = \{(q,T_P(q),C_P(q),G_P(q),U_P(q),F_P(q)): q\in W\}$, where $T_P(q)$, $C_P(q)$, $G_P(q)$, $U_P(q)$, $F_P(q)$ ($\in[0, 1]$) are the truth membership, contradiction membership, ignorance membership, unknown membership, and falsity membership values of $q\in W$. So, $0 \le T_P(q) + C_P(q) + G_P(q) + U_P(q) + F_P(q) \le 5$, for all $q\in W$.

**Definition 2.2.** [23] The absolute P-N-S ($1_{PN}$) and the null P-N-S ($0_{PN}$) over a fixed set $W$ are defined as follows:

(*i*) $1_{PN} = \{(q,1,1,0,0,0): q\in W\}$;

(*ii*) $0_{PN} = \{(q,0,0,1,1,1): q\in W\}$.

The absolute P-N-S $1_{PN}$ and the null P-N-S $0_{PN}$ have other seven types of representations. They are given below:

$1_{PN} = \{(q,1,1,0,0,1): q\in W\}$;

$1_{PN} = \{(q,1,1,0,1,0): q\in W\}$;

$1_{PN} = \{(q,1,1,1,0,0): q\in W\}$;

$1_{PN} = \{(q,1,1,0,1,1): q\in W\}$;

$1_{PN} = \{(q,1,1,1,0,1): q\in W\}$;

$1_{PN} = \{(q,1,1,1,1,0): q\in W\}$;

$1_{PN}$ = {($q$,1,1,1,1,1): $q\in W$};

$0_{PN}$ = {($q$,0,0,1,1,0): $q\in W$};

$0_{PN}$ = {($q$,0,0,1,0,1): $q\in W$};

$0_{PN}$ = {($q$,0,0,0,1,1): $q\in W$};

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$0_{PN}$ = {($q$,0,0,0,0,1): $q\in W$};

$0_{PN}$ = {($q$,0,0,0,0,0): $q\in W$}.

**Remark 2.1.** Throughout this article we shall use $1_{PN}$ = {($q$,1,1,0,0,0): $q\in W$} and $0_{PN}$ = {($q$,0,0,1,1,1): $q\in W$}, since the complement of $1_{PN}$ needs to be $0_{PN}$ and the complement of $0_{PN}$ needs to be $1_{PN}$. But for any combination of $1_{PN}$ and $0_{PN}$ from the other seven types of combination, it does not hold.

Clearly, $0_{PN}\subseteq X \subseteq 1_{PN}$, for any P-N-S $X$ over $W$.

**Definition 2.3.** [23] Let $X$ = {($q$,$T_X(q)$,$C_X(q)$,$G_X(q)$,$U_X(q)$,$F_X(q)$): $q\in W$} and $Y$ = {($q$,$T_Y(q)$,$C_Y(q)$,$G_Y(q)$,$U_Y(q)$, $F_Y(q)$): $q\in W$} be two P-N-Ss over a fixed set $W$. Then, $X \subseteq Y$ if and only if $T_X(q) \leq T_Y(q)$, $C_X(q) \leq C_Y(q)$, $G_X(q) \geq G_Y(q)$, $U_X(q) \geq U_Y(q)$, $F_X(q) \geq F_Y(q)$, for all $q\in W$.

**Example 2.1.** Let $W$ = {$m_1$, $m_2$}. Consider two P-NSs $X$ = {($m_1$,0.4,0.3,0.7,0.7,0.8), ($m_2$,0.2,0.5,0.8,0.7,0.8)} and $Y$ = {($m_1$,0.7,0.5,0.5,0.5,0.4), ($m_2$,0.8,0.7,0.5,0.5,0.5)} over $W$. Then, $X \subseteq Y$.

**Definition 2.4.** [23] Let $X$ = {($q$,$T_X(q)$,$C_X(q)$,$G_X(q)$,$U_X(q)$,$F_X(q)$): $q\in W$} and $Y$ = {($q$,$T_Y(q)$,$C_Y(q)$,$G_Y(q)$,$U_Y(q)$, $F_Y(q)$): $q\in W$} be two P-N-Ss over a fixed set $W$. Then, the intersection of $X$ and $Y$ is defined by

$X\cap Y$ = {($q$, min{$T_X(q)$,$T_Y(q)$}, min{$C_X(q)$,$C_Y(q)$}, max{$G_X(q)$,$G_X(q)$}, max{$U_X(q)$,$U_X(q)$}, max{$F_X(q)$,$F_X(q)$}): $q\in W$}.

**Example 2.2.** Let $W$ = {$m_1$, $m_2$}. Consider two P-N-Ss $X$ = {($m_1$,0.6,0.5,0.6,0.7,0.5), ($m_2$,0.8,0.5,0.6,0.7,0.8)} and $Y$ = {($m_1$,0.7,0.6,0.5,0.5,0.2), ($m_2$,0.9,0.7,0.4,0.3,0.8)} over $W$. Then, intersection of $X$ and $Y$ is $X\cap Y$ = {($m_1$,0.6,0.5,0.6,0.7,0.5), ($m_2$,0.8,0.5,0.6,0.7,0.8)}.

**Definition 2.5.** [23] Let $X$ = {($q$,$T_X(q)$,$C_X(q)$,$G_X(q)$,$U_X(q)$,$F_X(q)$): $q\in W$} and $Y$ = {($q$,$T_Y(q)$,$C_Y(q)$,$G_Y(q)$,$U_Y(q)$, $F_Y(q)$): $q\in W$} be two P-N-Ss over a fixed set $W$. Then, the union of $X$ and $Y$ is defined by

$X\cup Y$ = {($q$, max{$T_X(q)$,$T_Y(q)$}, max{$C_X(q)$,$C_Y(q)$}, min{$G_X(q)$,$G_X(q)$}, min{$U_X(q)$,$U_X(q)$}, min{$F_X(q)$,$F_X(q)$}): $q\in W$}.

**Example 2.3.** Let $W$ = {$m_1$, $m_2$}. Consider two P-N-Ss $X$ = {($m_1$,0.5,0.5,0.4,0.7,0.6), ($m_2$,0.7,0.5,0.7,0.8,0.4)} and $Y$ = {($m_1$,0.8,0.5,0.7,0.8,0.9), ($m_2$,1.0,0.8,0.7,0.6,0.5)} over $W$. Then, $X\cup Y$ = {($m_1$,0.8,0.5,0.4,0.7,0.6), ($m_2$,1.0,0.8,0.7,0.6,0.4)}.

**Definition 2.6.** [23] Suppose that $X$ = {($q$,$T_X(q)$,$C_X(q)$,$G_X(q)$,$U_X(q)$,$F_X(q)$): $q\in W$} be a P-N-S over $W$. Then, the complement of $X$ is defined by $X^c$ = {($q$,$F_X(q)$,$U_X(q)$,1-$G_X(q)$,$C_X(q)$,$T_X(q)$): $q\in W$}.

**Example 2.4.** Let $W$ = {$m_1$, $m_2$}. Consider a P-N-S $X$ = {($m_1$,0.7,0.8,0.6,0.8,1.0), ($m_2$,1.0,0.9,0.5,0.4,0.8)} be a P-NS over $W$. Then, the complement of $X$ is $X^c$ = {($m_1$,1.0,0.8,0.4,0.8,0.7), ($m_2$,0.8,0.4,0.5,0.9,1.0)}.

Now, we define the complement of a P-N-S in another way, which was given below:

**Definition 2.7.** Let $X = \{(q,T_X(q),C_X(q),G_X(q),U_X(q),F_X(q)): q\in W\}$ be a P-N-S over a fixed set $W$. Then, the complement of $X$ i.e. $X^c$ is defined by

$X^c = \{(q,1\text{-}T_X(q),1\text{-}C_X(q),1\text{-}G_X(q),1\text{-}U_X(q),1\text{-}F_X(q)): q\in W\}$.

**Example 2.5.** Let $W = \{m_1, m_2\}$. Let $X = \{(m_1,0.5,0.8,0.4,0.7,0.5), (m_2,0.5,0.4,0.5,0.8,0.7)\}$ be a P-N-S over $W$. Then, $X^c = \{(m_1,0.5,0.2,0.6,0.3,0.5), (m_2,0.5,0.6,0.5,0.2,0.3)\}$.

**3. Pentapartitioned Neutrosophic Topology:**

In this section, we procure the notions of pentapartitioned neutrosophic topology on P-N-Ss. Then, we introduce the interior and closure of a P-N-S from the point of view of pentapartitioned N-T-S, and prove some results on them.

**Definition 3.1.** Let $W$ be a fixed set. Then, a set $\Im$ of P-N-Ss over $W$ is called a Pentapartitioned Neutrosophic Topology (in short Pentapartitioned N-T) on $W$, if the following three conditions hold:

(i) $0_{PN}$, $1_{PN} \in\Im$;

(ii) $Y_1, Y_2 \in\Im \Rightarrow Y_1\cap Y_2 \in\Im$;

(iii) $\{Y_i: i\in\Delta\} \subseteq\Im \Rightarrow \cup Y_i\in\Im$.

Then, the pair $(W,\Im)$ is called a Pentapartitioned Neutrosophic Topological Space (in short Pentapartitioned N-T-S). Each element of $\Im$ is called a pentapartitioned neutrosophic open sets (in short P-NOS). If $Y\in\Im$, then $Y^c$ is called a pentapartitioned neutrosophic closed set (in short P-NCS).

**Example 3.1.** Let $X$, $Y$ and $Z$ be three P-N-Ss over a fixed set $W=\{p, q, r\}$ such that:

$X = \{(p,0.7,0.4,0.6,0.7,0.5), (q,0.5,0.6,0.4,0.5,0.1), (r,0.9,0.5,0.3,0.6,0.7): p, q, r\in W\}$;

$Y = \{(p,0.6,0.4,0.7,0.8,0.9), (q,0.5,0.4,0.6,0.8,0.3), (r,0.4,0.4,0.7,0.7,0.8): p, q, r\in W\}$;

$Z = \{(p,0.5,0.3,0.8,0.8,1.0), (q,0.4,0.3,0.8,0.9,0.4), (r,0.3,0.4,0.8,0.7,1.0): p, q, r\in W\}$.

Then, the collection $\Im=\{0_{PN}, 1_{PN}, X, Y, Z\}$ forms a Pentapartitioned N-T on $W$.

**Remark 3.1.** In a Pentapartitioned N-T-S $(W,\Im)$, the null P-N-S ($0_{PN}$) and the absolute P-N-S ($1_{PN}$) are both P-NOS and P-NCS in $(W,\Im)$.

The pentapartitioned neutrosophic interior and pentapartitioned neutrosophic closure of a P-N-S are defined as follows:

**Definition 3.2.** Let $(W,\Im)$ be a Pentapartitioned N-T-S. Let $X$ be a P-N-S over $W$. Then, the pentapartitioned neutrosophic interior (in short $P\text{-}N_{int}$) of $X$ is the union of all P-NOSs contained in $X$ and the pentapartitioned neutrosophic closure (in short $P\text{-}N_{cl}$) of $X$ is the intersection of all P-NCSs containing $X$, i.e.

$P\text{-}N_{int}(X) = \cup\{Y: Y\subseteq X$ and $Y$ is a P-NOS in $(W,\Im)\}$,

and $P\text{-}N_{cl}(X) = \cap\{Z: X\subseteq Z$ and $Z$ is a P-NCS in $(W,\Im)\}$.

**Remark 3.2.** It is clearly seen that $P\text{-}N_{int}(X)$ is the largest P-NOS in $(W,\Im)$, which is contained in $X$ and $P\text{-}N_{cl}(X)$ is the smallest P-NCS in $(W,\Im)$ that contains $X$.

**Theorem 3.1.** Let $(W,\Im)$ be a Pentapartitioned N-T-S. Let $Q$ and $R$ be any two P-N-Ss over $W$. Then, the following holds:

($i$) $P\text{-}N_{int}(Q) \subseteq Q \subseteq P\text{-}N_{cl}(Q)$;

($ii$) $Q \subseteq R \Rightarrow P\text{-}N_{cl}(Q) \subseteq P\text{-}N_{cl}(R)$;

($iii$) $Q \subseteq R \Rightarrow P\text{-}N_{int}(Q) \subseteq P\text{-}N_{int}(R)$;

($iv$) $P\text{-}N_{cl}(Q \cup R) = P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$;

($v$) $P\text{-}N_{cl}(Q \cap R) \subseteq P\text{-}N_{cl}(Q) \cap P\text{-}N_{cl}(R)$;

($vi$) $P\text{-}N_{int}(Q \cup R) \supseteq P\text{-}N_{int}(Q) \cup P\text{-}N_{int}(R)$;

($vii$) $P\text{-}N_{int}(Q \cap R) \subseteq P\text{-}N_{int}(Q) \cap P\text{-}N_{int}(R)$.

**Proof.** ($i$) From definition 3.2., we have $P\text{-}N_{int}(Q) = \cup\{R\text{: } R$ is a P-NOS in $(W,\mathfrak{I})$ and $R \subseteq Q\}$. Since, each $R \subseteq Q$, so $\cup\{R\text{: } R$ is a P-NOS in $(W,\mathfrak{I})$ and $R \subseteq Q\} \subseteq Q$, i.e. $P\text{-}N_{int}(Q) \subseteq Q$.

Again, $P\text{-}N_{cl}(Q) = \cap\{Z\text{: } Z$ is a P-NCS in $(W,\mathfrak{I})$ and $Q \subseteq Z\}$. Since, each $Z \supseteq Q$, so $\cap\{Z\text{: } Z$ is a P-NCS in $(W,\mathfrak{I})$ and $Q \subseteq Z\} \supseteq Q$, i.e. $P\text{-}N_{cl}(Q) \supseteq Q$.

Therefore, $P\text{-}N_{int}(Q) \subseteq Q \subseteq P\text{-}N_{cl}(Q)$.

($ii$) Let $(W,\mathfrak{I})$ be a Pentapartitioned N-T-S. Let $Q$ and $R$ be any two P-N-Ss over $W$ such that $Q \subseteq R$.

Now, $P\text{-}N_{cl}(Q) = \cap\{Z\text{: } Z$ is a P-NCS in $(W,\mathfrak{I})$ and $Q \subseteq Z\}$

$\subseteq \cap\{Z\text{: } Z$ is a P-NCS in $(W,\mathfrak{I})$ and $R \subseteq Z\}$ [Since $Q \subseteq R$]

$= P\text{-}N_{cl}(R)$

$\Rightarrow P\text{-}N_{cl}(Q) \subseteq P\text{-}N_{cl}(R)$.

Therefore, $Q \subseteq R \Rightarrow P\text{-}N_{cl}(Q) \subseteq P\text{-}N_{cl}(R)$.

($iii$) Let $(W,\mathfrak{I})$ be a Pentapartitioned N-T-S. Let $Q$ and $R$ be any two P-N-Ss over $W$ such that $Q \subseteq R$.

Now, $P\text{-}N_{int}(Q) = \cup\{Z\text{: } Z$ is a P-NOS in $(W,\mathfrak{I})$ and $Z \subseteq Q\}$

$\subseteq \cup\{Z\text{: } Z$ is a P-NOS in $(W,\mathfrak{I})$ and $Z \subseteq R\}$ [Since $Q \subseteq R$]

$= P\text{-}N_{int}(R)$

$\Rightarrow P\text{-}N_{int}(Q) \subseteq P\text{-}N_{int}(R)$.

Therefore, $Q \subseteq R \Rightarrow P\text{-}N_{int}(Q) \subseteq P\text{-}N_{int}(R)$.

($iv$) Let $Q$ and $R$ be two pentapartitioned neutrosophic subsets of a Pentapartitioned N-T-S $(W,\mathfrak{I})$. It is known that $Q \subseteq Q \cup R$ and $R \subseteq Q \cup R$.

Now, $Q \subseteq Q \cup R$

$\Rightarrow P\text{-}N_{cl}(Q) \subseteq P\text{-}N_{cl}(Q \cup R)$;

and $R \subseteq Q \cup R$

$\Rightarrow P\text{-}N_{cl}(R) \subseteq P\text{-}N_{cl}(Q \cup R)$.

Therefore, $P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R) \subseteq P\text{-}N_{cl}(Q \cup R)$ (1)

We have, $Q \subseteq P\text{-}N_{cl}(Q)$, $R \subseteq P\text{-}N_{cl}(R)$. Therefore, $Q \cup R \subseteq P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$. Further, it is known that $P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$ is a P-NCS in $(W,\mathfrak{I})$. It is clear that, $P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$ is a P-NCS in $(W,\mathfrak{I})$, which contains $Q \cup R$. But it is known that $P\text{-}N_{cl}(Q \cup R)$ is the smallest P-NCS in $(W,\mathfrak{I})$, which contains $Q \cup R$.

Therefore, $P\text{-}N_{cl}(Q \cup R) \subseteq P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$ (2)

From eq. (1) and eq. (2), we have $P\text{-}N_{cl}(Q \cup R) = P\text{-}N_{cl}(Q) \cup P\text{-}N_{cl}(R)$.

($v$) Let $Q$ and $R$ be two pentapartitioned neutrosophic subsets of a P-NTS ($W$,$\Im$). It is known that $Q\cap R\subseteq Q$, $Q\cap R\subseteq R$.

Now, $Q\cap R\subseteq Q$

$\Rightarrow P\text{-}N_{cl}(Q\cap R) \subseteq P\text{-}N_{cl}(Q)$;

and $Q\cap R\subseteq R$

$\Rightarrow P\text{-}N_{cl}(Q\cap R) \subseteq P\text{-}N_{cl}(R)$.

Therefore, $P\text{-}N_{cl}(Q\cap R) \subseteq P\text{-}N_{cl}(Q)\cap P\text{-}N_{cl}(R)$.

($vi$) Let $Q$ and $R$ be two pentapartitioned neutrosophic subsets of a Pentapartitioned N-T-S ($W$,$\Im$). It is known that $Q\subseteq Q\cup R$ and $R\subseteq Q\cup R$.

Thus, we get

$Q\subseteq Q\cup R$

$\Rightarrow P\text{-}N_{int}(Q) \subseteq P\text{-}N_{int}(Q\cup R)$;

and $R\subseteq Q\cup R$

$\Rightarrow P\text{-}N_{int}(R) \subseteq P\text{-}N_{int}(Q\cup R)$.

Therefore, $P\text{-}N_{int}(Q)\cup P\text{-}N_{int}(R) \subseteq P\text{-}N_{int}(Q\cup R)$.

($vii$) Let $Q$ and $R$ be two pentapartitioned neutrosophic subsets of a Pentapartitioned N-T-S ($W$,$\Im$). It is known that $Q\cap R\subseteq Q$, $Q\cap R\subseteq R$.

Now, $Q\cap R\subseteq Q$

$\Rightarrow P\text{-}N_{int}(Q\cap R) \subseteq P\text{-}N_{int}(Q)$;

and $Q\cap R\subseteq R$

$\Rightarrow P\text{-}N_{int}(Q\cap R) \subseteq P\text{-}N_{int}(R)$.

Therefore, $P\text{-}N_{int}(Q\cap R) \subseteq P\text{-}N_{int}(Q)\cap P\text{-}N_{int}(R)$.

**Theorem 3.2.** Let $Q$ be a pentapartitioned neutrosophic subset of a Pentapartitioned N-T-S ($W$,$\Im$). Then, the following holds:

($i$) $(P\text{-}N_{int}(Q))^c = P\text{-}N_{cl}(Q^c)$;

($ii$) $(P\text{-}N_{cl}(Q))^c = P\text{-}N_{int}(Q^c)$.

**Proof.** ($i$) Let ($W$,$\Im$) be a Pentapartitioned N-T-S and $Q = \{(w, T_Q(w), C_Q(w), G_Q(w), U_Q(w), F_Q(w)): w\in W\}$ be a pentapartitioned neutrosophic subset of $W$.

We have,

$P\text{-}N_{int}(Q) = \cup\{Z_i : i\in\Delta$ and $Z_i$ is a P-NOS in ($W$,$\Im$) such that $Z_i \subseteq Q\}$

$= \{(w, \vee T_{Z_i}(w), \vee C_{Z_i}(w), \wedge G_{Z_i}(w), \wedge U_{Z_i}(w), \wedge F_{Z_i}(w)) : w \in W\}$, where for all $i\in\Delta$ and $Z_i$ is a P-NOS in ($W$,$\Im$) such that $Z_i\subseteq Q$.

This implies, $(P\text{-}N_{int}(Q))^c = \{(w, \wedge T_{Z_i}(w), \wedge C_{Z_i}(w), \vee G_{Z_i}(w), \vee U_{Z_i}(w), \vee F_{Z_i}(w)): w\in W\}$.

Since, $\wedge T_{Z_i}(w) \leq T_E(w)$, $\wedge C_{Z_i}(w) \leq C_E(w)$, $\vee G_{Z_i}(w) \geq G_E(w)$, $\vee U_{Z_i}(w) \geq U_E(w)$, $\vee F_{Z_i}(w) \geq F_E(w)$, for each $i\in\Delta$ and $w\in W$, so $P\text{-}N_{cl}(Q^c) = \{(w, \wedge T_{Z_i}(w), \wedge C_{Z_i}(w), \vee G_{Z_i}(w), \vee U_{Z_i}(w), \vee F_{Z_i}(w)): w\in W\}\} = \cap\{Z_i: i\in\Delta$ and $Z_i$ is a P-NCS in ($W$,$\Im$) such that $Q^c\subseteq Z_i\}$. Therefore, $(P\text{-}N_{int}(Q))^c = P\text{-}N_{cl}(Q^c)$.

(*ii*) Let $(W,\Im)$ be a Pentapartitioned N-T-S and $Q = \{(w, T_Q(w), C_Q(w), G_Q(w), U_Q(w), F_Q(w)): w\in W\}$ be a pentapartitioned neutrosophic subset of $W$.

We have,

$P\text{-}N_{cl}(Q) = \cap\{Z_i: i\in\Delta$ and $Z_i$ is a P-NCS in $(W,\Im)$ such that $Z_i \supseteq Q\}$

$= \{(w, \wedge T_{Z_i}(w), \wedge C_{Z_i}(w), \vee G_{Z_i}(w), \vee U_{Z_i}(w), \vee F_{Z_i}(w)): w\in W\}$, where $Z_i$ is a P-NCS in $(W,\Im)$ such that $Z_i \supseteq Q$, for all $i\in\Delta$.

This implies, $(P\text{-}N_{cl}(Q))^c = \{(w, \vee T_{Z_i}(w), \vee C_{Z_i}(w), \wedge G_{Z_i}(w), \wedge U_{Z_i}(w), \wedge F_{Z_i}(w)): w\in W\}$.

Since $\vee T_{Z_i}(w) \geq T_E(w)$, $\vee C_{Z_i}(w) \geq C_E(w)$, $\wedge G_{Z_i}(w) \leq G_E(w)$, $\wedge U_{Z_i}(w) \leq U_E(w)$, $\wedge F_{Z_i}(w) \leq F_E(w)$, for each $i\in\Delta$ and $w\in W$, so $P\text{-}N_{int}(Q^c) = \{(w, \vee T_{Z_i}(w), \vee C_{Z_i}(w), \wedge G_{Z_i}(w), \wedge U_{Z_i}(w), \wedge F_{Z_i}(w)): w\in W\} = \cup\{Z_i: i\in\Delta$ and $Z_i$ is a P-NOS in $(W,\Im)$ such that $Z_i \subseteq Q^c\}$. Therefore, $(P\text{-}N_{cl}(Q))^c = P\text{-}N_{int}(Q^c)$.

**Theorem 3.3.** Let $X$ be a pentapartitioned neutrosophic subset of a Pentapartitioned N-T-S $(W,\Im)$. Then, the following holds:

(*i*) $Q$ is a P-NOS if and only if $P\text{-}N_{int}(Q) = Q$;

(*ii*)$Q$ is a P-NOS if and only if $P\text{-}N_{cl}(Q) = Q$.

**Proof.** (*i*) Let $Q$ be a P-NOS in a Pentapartitioned N-T-S $(W,\Im)$. Now, $P\text{-}N_{int}(Q) = \cup\{Z: Z$ is a P-NOS in $(W,\Im)$ and $Z \subseteq Q\}$. Since, $Q$ is a P-NOS in $(W,\Im)$, so $Q$ is the largest P-NOS, which is contained in $Q$. This implies, $\cup\{Z: Z$ is a P-NOS in $(W,\Im)$ and $Z \subseteq Q\} = Q$. Therefore, $P\text{-}N_{int}(Q) = Q$.

(*ii*) Let $Q$ be a P-NCS in a Pentapartitioned N-T-S $(W,\Im)$. Now, $P\text{-}N_{cl}(Q) = \cap\{Z : Z$ is a P-NCS in $(W,\Im)$ and $Q\subseteq Z\}$. Since, $Q$ is a P-NCS in $(W,\Im)$, so $Q$ is the smallest P-NCS, which contains $Q$. This implies, $\cap\{Z: Z$ is a P-NCS in $(W,\Im)$ and $Q\subseteq Z\} = Q$. Therefore, $P\text{-}N_{cl}(Q) = Q$.

**Definition 3.3.** Let $(W,\Im)$ be a Pentapartitioned N-T-S. Then $X$, a P-N-S over $W$ is called a

(*i*) pentapartitioned neutrosophic semi-open (P-NSO) set if and only if $X \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$;

(*ii*) pentapartitioned neutrosophic pre-open (P-NPO) set if and only if $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)$.

**Remark 3.3.** The complement of P-NSO set and P-NPO set in a Pentapartitioned N-T-S $(W,\Im)$ are called pentapartitioned neutrosophic semi-closed (in short P-NSC) set and pentapartitioned neutrosophic pre-closed (in short P-NPC) set respectively.

**Theorem 3.4.** Let $(W,\Im)$ be a Pentapartitioned N-T-S. Then,

(*i*) every P-NOS is a P-NSO set.

(*ii*) every P-NOS is a P-NPO set.

**Proof.** (*i*) Let $(W,\Im)$ be a Pentapartitioned N-T-S. Let $X$ be a P-NOS. Therefore, $X=P\text{-}N_{int}(X)$. It is known that $X\subseteq P\text{-}N_{cl}(X)$. This implies, $X\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$. Therefore, $X$ is a P-NSO set in $(W,\Im)$.

(*ii*) Let $(W,\Im)$ be a Pentapartitioned N-T-S. Let $X$ be a P-NOS. Therefore, $X=P\text{-}N_{int}(X)$. It is known that, $X\subseteq P\text{-}N_{cl}(X)$. This implies, $P\text{-}N_{int}(X)\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$ i.e. $X = P\text{-}N_{int}(X) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$. Therefore, $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$. Hence, $X$ is a P-NPO set in $(W,\Im)$.

**Remark 3.4.** The converse of the previous theorem may not be true in general. This follows from the following example.

**Example 3.2.** Let $(W,\Im)$ be a Pentapartitioned N-T-S, where $\Im=\{0_{PN}, 1_{PN}, \{(a,0.3,0.4,0.5,0.4,0.3), (b,0.4,0.3,0.7,0.3,0.4)\}, \{(a,0.4,0.6,0.4,0.4,0.1), (b,0.5,0.4,0.5,0.1,0.3)\}\}$. Then,

(*i*) $Q=\{(a,0.6,0.6,0.3,0.4,0.1), (b,0.9,0.8,0.4,0.1,0.2)\}$ is a P-NSO set but it is not a P-NOS in $(W,\Im)$.

(*ii*) $P=\{(a,0.3,0.7,0.2,0.9,0.2), (b,0.3,0.7,0.5,0.4,0.3)\}$ is a P-NPO set but it is not a P-NOS in $(W,\Im)$.

**Theorem 3.5.** In a Pentapartitioned N-T-S $(W,\Im)$, the union of two P-NSO sets is a P-NSO set.

**Proof.** Let $X$ and $Y$ be two P-NSO sets in a Pentapartitioned N-T-S $(W,\Im)$. Therefore,

$X\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$ (3)

and $Y\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(Y))$ (4)

From eq. (3) and eq. (4), we have

$X\cup Y \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))\cup P\text{-}N_{cl}(P\text{-}N_{int}(Y))$

$= P\text{-}N_{cl}(P\text{-}N_{int}(X)\cup P\text{-}N_{int}(Y))$

$\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X\cup Y))$.

Therefore, $X\cup Y \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X\cup Y))$. Hence, $X\cup Y$ is a P-NSO set in $(W,\Im)$.

**Theorem 3.6.** In a Pentapartitioned N-T-S $(W,\Im)$, the union of two P-NPO sets is also a P-NPO set.

**Proof.** Let $X$ and $Y$ be two P-NPO sets in a Pentapartitioned N-T-S $(W,\Im)$. Therefore,

$X\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$ (5)

and $Y\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(Y))$ (6)

From eq. (5) and eq. (6), we have,

$X\cup Y\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))\cup P\text{-}N_{int}(P\text{-}N_{cl}(Y))$

$\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)\cup P\text{-}N_{cl}(Y))$

$= P\text{-}N_{int}(P\text{-}N_{cl}(X\cup Y))$.

Therefore, $X\cup Y \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X\cup Y))$. Hence, $X\cup Y$ is a P-NPO set in $(W,\Im)$.

**Definition 3.4.** Let $(W,\Im)$ be a Pentapartitioned N-T-S. Then, a P-N-S $X$ over $W$ is called a pentapartitioned neutrosophic α-open (in short P-Nα-O) set if and only if $X\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(P\text{-}N_{int}(X)))$. The complement of a P-Nα-O set is called a pentapartitioned neutrosophic α-closed (in short P-Nα-C) set.

**Proposition 3.1.** In a Pentapartitioned N-T-S $(W,\Im)$, every P-NOS is a P-Nα-O set.

**Remark 3.5.** The converse of the above proposition may not be true in general, which follows from the following example.

**Example 3.3.** Let us consider a Pentapartitioned N-T-S $(W,\Im)$ as shown in Example 3.2. Clearly, the pentapartitioned neutrosophic set $Q=\{(a,0.6,0.6,0.3,0.4,0.1), (b,0.9,0.8,0.4,0.1,0.2)\}$ is a P-Nα-O set but it is not a P-NOS in $(W,\Im)$.

**Theorem 3.7.** In a Pentapartitioned N-T-S $(W,\Im)$, every P-Nα-O set is a P-NSO set.

**Proof.** Let $X$ be a P-Nα-O set in $(W,\Im)$. Therefore, $X\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(P\text{-}N_{int}(X)))$. It is known that $P\text{-}N_{int}(P\text{-}N_{cl}(P\text{-}N_{int}(X))) \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$. Thus we have, $X\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$. Hence, $X$ is a P-NSO set. Therefore, every P-Nα-O set is a P-NSO set.

**Remark 3.6.** The converse of the above example may not be true in general. This follows from the following example.

**Example 3.4.** Let $(W,\mathfrak{I})$ be a Pentapartitioned N-T-S, where $\mathfrak{I}=\{0_{PN}, 1_{PN}, \{(a,0.5,0.6,0.5,0.7,0.8), (b,0.5,0.5,0.5,0.5,0.6)\}, \{(a,0.4,0.4,0.8,0.8,0.8), (b,0.5,0.5,0.8,0.8,0.8)\}\}$. Then, it can be easily verified that $A=\{(a,0.6,0.6,0.3,0.3,0.3), (b,0.5,0.5,0.4,0.4,0.4)\}$ is a P-NSO set in $(W,\mathfrak{I})$, but it is not a P-Nα-O set in $(W,\mathfrak{I})$.

**Theorem 3.8.** In a Pentapartitioned N-T-S $(W,\mathfrak{I})$, every P-Nα-O set is a P-NPO set.

**Proof.** Let $(W,\mathfrak{I})$ be a Pentapartitioned N-T-S. Let $X$ be a P-Nα-O set in $(W,\mathfrak{I})$. Therefore, $X\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(P\text{-}N_{int}(X)))$. It is known that $P\text{-}N_{int}(X)\subseteq X$. This implies, $P\text{-}N_{cl}(P\text{-}N_{int}(X))\subseteq P\text{-}N_{cl}(X)$. Which implies $P\text{-}N_{int}(P\text{-}N_{cl}(P\text{-}N_{int}(X))) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)$. Therefore, $X\subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)$. Hence, $X$ is a P-NPO set. Therefore, every P-Nα-O set is a P-NPO set in $(W,\mathfrak{I})$.

**Remark 3.7.** The converse of the above example may not be true in general. This follows from the following example.

**Example 3.5.** Let us consider a Pentapartitioned N-T-S $(W,\mathfrak{I})$ as shown in Example 3.2. Then, the pentapartitioned neutrosophic set $P=\{(a,0.3,0.7,0.2,0.9,0.2), (b,0.3,0.7,0.5,0.4,0.3)\}$ is a P-NPO set in $(W,\mathfrak{I})$ but it is not a P-Nα-O set in $(W,\mathfrak{I})$.

**Definition 3.5.** Let $(W,\mathfrak{I})$ be a P-NTS. Then, a P-NS $X$ over $W$ is called a pentapartitioned neutrosophic $b$-open (in short P-N-$b$-O) set if and only if $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(X))$.

**Remark 3.8.** A pentapartitioned neutrosophic set $X$ is called a pentapartitioned neutrosophic $b$-closed (in short P-N-$b$-C) set iff $X^c$ is a P-N-$b$-O set i.e. if $P\text{-}N_{int}(P\text{-}N_{cl}(X))\cap P\text{-}N_{cl}(P\text{-}N_{int}(X)) \subseteq X$.

**Theorem 3.9.** In a P-NTS $(W,\mathfrak{I})$, every P-NPO (P-NSO) set is a P-N-$b$-O set.

**Proof.** Suppose that $X$ be a P-NPO set in a P-NTS $(W,\mathfrak{I})$. Therefore, $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$. This implies, $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(X))$. Hence, $X$ is a P-N-$b$-O set. Therefore, every P-NPO set is a P-N-$b$-O set.

Similarly, it can be shown that every P-NSO set is a P-N-$b$-O set.

**Theorem 3.10.** The union of two P-N-$b$-O sets in a P-NTS $(W,\mathfrak{I})$ is a P-N-$b$-O set.

**Proof.** Let $X$ and $Y$ be two P-N-$b$-O sets in a P-NTS $(W,\mathfrak{I})$.

Therefore, $X \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(X))$ (7)

and $Y \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(Y)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(Y))$ (8)

It is known that, $X \subseteq X\cup Y$ and $Y \subseteq X\cup Y$.

Now, $X \subseteq X\cup Y$

$\Rightarrow P\text{-}N_{int}(X) \subseteq P\text{-}N_{int}(A\cup B)$

$\Rightarrow P\text{-}N_{cl}(P\text{-}N_{int}(X)) \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X\cup Y))$ (9)

and $X \subseteq X\cup Y$

$\Rightarrow P\text{-}N_{cl}(X) \subseteq P\text{-}N_{cl}(A\cup B)$

$\Rightarrow P\text{-}N_{int}(P\text{-}N_{cl}(X)) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X\cup Y))$ (10)

Similarly, it can be shown that

$P\text{-}N_{cl}(P\text{-}N_{int}(Y)) \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X \cup Y))$ (11)

$P\text{-}N_{int}(P\text{-}N_{cl}(Y)) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X \cup Y))$ (12)

From eq. (7) and eq. (8) we have,

$X \cup Y \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(Y)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(Y))$

$\subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X \cup Y)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(X \cup Y)) \cup P\text{-}N_{cl}(P\text{-}N_{int}(X \cup Y)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(X \cup Y))$

[ by eqs (9), (10), (11), & (12)]

$= P\text{-}N_{cl}(P\text{-}N_{int}(X \cup Y)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(X \cup Y))$

$\Rightarrow X \cup Y \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X \cup Y)) \cup P\text{-}N_{int}(P\text{-}N_{cl}(X \cup Y))$.

Therefore, $X \cup Y$ is a P-N-*b*-O set.

Hence, the union of two P-N-*b*-O sets is a P-N-*b*-O set.

**Theorem 3.11.** In a P-NTS $(W,\Im)$, the intersection of two P-N-*b*-C sets is a P-N-*b*-C set.

**Proof.** Let $(W,\Im)$ be a P-NTS. Let $X$ and $Y$ be two P-N-*b*-C sets in $(W,\Im)$. Therefore,

$P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(X)) \subseteq X$ (13)

and $P\text{-}N_{int}(P\text{-}N_{cl}(Y)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(Y)) \subseteq Y$ (14)

Since, $X \cap Y \subseteq X$ and $X \cap Y \subseteq Y$, so we get

$P\text{-}N_{int}(X \cap Y) \subseteq P\text{-}N_{int}(X) \Rightarrow P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y)) \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(X))$; (15)

$P\text{-}N_{cl}(X \cap Y) \subseteq P\text{-}N_{cl}(X) \Rightarrow P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y)) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(X))$ (16)

$P\text{-}N_{int}(X \cap Y) \subseteq P\text{-}N_{int}(Y) \Rightarrow P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y)) \subseteq P\text{-}N_{cl}(P\text{-}N_{int}(Y))$ (17)

and $P\text{-}N_{cl}(X \cap Y) \subseteq P\text{-}N_{cl}(Y) \Rightarrow P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y)) \subseteq P\text{-}N_{int}(P\text{-}N_{cl}(Y))$ (18)

From eq. (13) and eq. (14) we get,

$X \cap Y \supseteq P\text{-}N_{int}(P\text{-}N_{cl}(X)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(X)) \cap P\text{-}N_{int}(P\text{-}N_{cl}(Y)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(Y))$

$\supseteq P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y)) \cap P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y))$

[by eqs (15), (16), (17) & (18)]

$= P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y)) \cap P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y))$

$\Rightarrow X \cap Y \supseteq P\text{-}N_{cl}(P\text{-}N_{int}(X \cap Y)) \cap P\text{-}N_{int}(P\text{-}N_{cl}(X \cap Y))$.

Hence, $X \cap Y$ is a P-N-*b*-C set in $(W,\Im)$.

Therefore, the intersection of two P-N-*b*-C sets is again a P-N-*b*-C set.

**4. Conclusion:** In this study, we present the notions of pentapartitioned neutrosophic topological space and studied different types of open sets namely P-NPO set, P-NSO set, P-N-*b*-O set, and P-Nα-O set. By defining P-NPO set, P-NSO set, P-N-*b*-O set and P-Nα-O set, we formulate some results on Pentapartitioned N-T-Ss in the form of Theorems, Propositions, etc. We provide few illustrative counter examples where the results fail. We hope that, in the future, based on these notions and various open sets on Pentapartitioned N-T-S, many new investigation / research can be done. Further, the notion of pentapartitioned neutrosophic topological space can be used in area of decision making, data mining, etc.

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