POSTULATES FOR THE SEPARATION OF
POINT-PAIRS IN THE FOUNDATIONS
OF GEOMETRY

By

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Introduction.

E. V. HUNTINGTON and K. E. ROSINGER have given 10 sets of postulates for the separation of point-pairs, and have established many interesting relations among them.(1)

It is the purpose of this paper to generalize these postulates and to replace the sets by a new one.

First in §1, we shall consider the definition for the separation of point-pairs given by K. KUNUGI.(2) When, in the definition, a chain becomes a circle or a straight line, the separation of point-pairs coincides with that of our intuition. And, as the definition is applicable to chains in general, it will be convenient to use it for establishing systematically the postulates for the separation of point-pairs. Now in §2, we shall see that none of the HUNTINGTON-ROSINGER postulates are satisfied by our definition, and, therefore, it will be natural to give, in §3, a new set of more general postulates and to discuss the relations among them. Finally, in §4, we shall discuss their independency.

Explanation of signs used in this paper.

The sign \( A = 0 \) means that the relation \( A \) does not exist. The sign \( A \neq 0 \) means that the relation \( A \) exists. When a chain \( K \) contains \( n \) distinct points \( P_1, P_2, \ldots, P_n \), then


$K_{P_{i_{1}}P_{i_{2}}, \ldots, P_{i_{k}}}[P_{j_{1}}, P_{j_{2}}, \ldots, P_{j_{l}}](P_{\lambda}, P_{\mu})$

means a chain which connects $P_{\lambda}$ and $P_{\mu}$ in $K$, and it contains $P_{i_{1}}, P_{i_{2}}, \ldots, P_{i_{k}}$ containing or not containing some of $P_{j_{1}}, P_{j_{2}}, \ldots, P_{j_{l}}$ and if $\nu$ is not any one of $i_{1}, i_{2}, \ldots, i_{k}, j_{1}, j_{2}, \ldots, j_{l}, \lambda, \mu$, then this chain does not contain $P_{\nu}$.

The sign $\&$ means "and", the sign $\lor$ means "or" (in the sense of "at least one"), and the sign $\rightarrow$ means "If......, then".

§ 1. Some theorems.

Definition.(1) Let $A, B, X, Y$ be four different points in a point set $K$. Then we say that $X$ and $Y$ are separated in $K$, by $A$ and $B$, if the two following conditions are both fulfilled:

(1). Any chain $K(X, Y)$ in $K$, which connects $X$ and $Y$, contains at least one of $A$ and $B$.

(2). There exists a chain $K(X, Y)$ in $K$, which connects $X$ and $Y$, and which contains one and only one of $A$ and $B$.

When two points $X$ and $Y$ are separated in $K$ by $A$ and $B$, we denote the separation by $AXBY$ (in $K$).

From the definition follows at once:

Theorem 1. Let $A, B, X, Y$ be four different points in a chain $K$. If $AXBY$ (in $K$), then we have also $AYBX, BXAY, BYAX$.

Before going further, we shall give the following axiom:

Axiom 1. If $K \supseteq X, Y, Z$, then, for at least one of chains $K_{z}(X, Y)$ in $K$,

$K(X, Z) \lor K(Y, Z) \neq 0$ and $K(X, Z) + K(Y, Z) \subseteq K_{Z}(X, Y)$.

From axiom 1, it is deducible that:

Theorem 2. If a chain $K$ involves $n$ distinct points $P_{1}, P_{2}, \ldots, P_{n}$, then for any one of them, say $P_{i}$,
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\[ \sum_j K(P_i, P_j) \neq 0 \quad i \neq j, \quad i, j = 1, 2, 3, \ldots, n. \]

Proof. Let a chain \( K \) involve \( n \) distinct points \( P_1, P_2, \ldots, P_n \), and let \( P_i \) be any one of them. Let a chain \( K' \) be one of the chains involving \( P_i \), containing the least number of these points. If \( K'(P_i, P_j) \) exists for some one point \( P_j (P_j \neq P_i) \), then the theorem is evident.

Let \( K' \) contain at least two points \( P_j, P_k \) which are not \( P_i \). By axiom 1, then, there exists a chain \( K'' \) in \( K' \), which fulfils the following condition:

\[ K'' \supset P_i, \quad P_j \quad \text{and} \quad K'' \cdot P_k = 0 \]

or

\[ K'' \supset P_i, \quad P_k \quad \text{and} \quad K'' \cdot P_j = 0. \]

This result is inconsistent with the definition of the chain \( K' \); thus, for some one point of \( P_1, P_2, \ldots, P_{i-1}, P_{i+1}, \ldots, P_n \), \( K(P_i, P_l) \) exists. Hence

\[ \sum_j K(P_i, P_j) \neq 0 \quad i \neq j, \quad i, j = 1, 2, 3, \ldots, n. \]

Q. E. D.

Theorem 3. \( ABCD \rightarrow ABCXV \ ABXD \rightarrow AXCD \rightarrow XBCD \).

Proof. From \( ABCD \), hence \( K_{[X]}(B, D) = 0 \). In the following proof, we shall assume that (\( a \)): \( K_{[X]}(B, D) = 0 \), (\( \beta \)): \( K_{[A\{X\]}(B, D) \neq 0 \).

Case 1. Suppose \( K(D, X) \neq 0 \). Let \( K(B, X) \neq 0 \), then \( K(D, X) + K(B, X) = K(D, X) \neq 0 \). The result is inconsistent with (\( a \)). Thus \( K(B, X) = 0 \). Similarly, let \( K_D(B, X) \neq 0 \), then \( K_{[X]}(B, D) \neq 0 \). The result is inconsistent with (\( a \)); thus \( K_D(B, X) = 0 \). Hence \( K_{[D]}(B, X) = 0 \). Next, from (\( \beta \)) and the supposition \( K(D, X) \neq 0 \), \( K_{[A\{X\]}(B, D) + K(D, X) = K_{A\{D\]}(B, X) \neq 0 \). Therefore \( ABCX \).

Case 2. Suppose \( K(B, X) \neq 0 \). Substituting \( D \) in place of \( B \) in case 1, we get \( ADCX \).

Case 3. Suppose \( K(B, X) + K(D, X) = 0 \), \( K(A, X) \neq 0 \). By (\( \beta \)), \( K_{[A\{X\]}(B, D) \neq 0 \). Hence \( K_{[D, X]}(B, A) + K(A, X) = K_{[A,D]}(B, X) \neq 0 \).

By (\( a \)), \( K_{[D]}(B, X) = 0 \). Hence \( ABCX \). \((\text{1})\)

(\(1\)) In this case, exchanging \( B \) and \( D \), we obtain \( AXCD \) also.
Case 4. Suppose $K(A, X) + K(B, X) + K(D, X) = 0$. Then by theorem 2, $K(C, X) \neq 0$. There are three possible cases:

1°) Suppose $K(B, C) \neq 0$. By (a), $K_{[D]}(B, X) = 0$, and $K(B, C) + K(C, X) = K_C(B, X) \neq 0$. Hence $ABCX$.

2°) Suppose $K(C, D) \neq 0$. By (a), $K_{[B]}(D, X) = 0$ and $K(C, D) + K(C, X) = K_C(D, X) \neq 0$. Hence $AXCD$.

3°) Suppose $K(B, C) + K(C, D) = 0$. Then by theorem 2, $K(A, B) \neq 0$, and $K(A, D) \neq 0$. Hence $K_{[C]}(B, D) = 0$. Therefore $ABXD$.

In preceding proofs, we have obtained the three cases, $ABCX$, $ABXD$, $AXCD$. And assuming that $K_{[X]}(B, D) = 0$, and axiom 1, we get $K_C(B, D) = 0$. Hence $K_{[C]}(B, D) = 0$. Therefore $ABXD$.

In preceding proofs, we have obtained the three cases, $ABCX$, $ABXD$, $AXCD$. And assuming that $K_{[X]}(B, D) = 0$, and axiom 1, we get $K_C(B, D) = 0$. Hence $K_{[C]}(B, D) = 0$. Therefore $ABXD$.

$ABCD. X \rightarrow ABCX V ABXD V AXCD V XBCD$.

**Theorem 4.** Suppose $G$: $ABCD \rightarrow BCDA$ and $R$: $ABCD \rightarrow DCBA$, then $K_1$: $ABCD \rightarrow ADCE$, $K_2$: $ABCD \rightarrow CBAD$.


**Remark.** $G$ and $R$ are those of postulates which were established by E. V. HUNTINGTON and K. E. ROSINGER.

**Theorem 5.** If $K_1$ and $K_2$ are true, and $H$: $ABCD \& ABDC = 0$ is not true in a chain $K$, then all the twenty-four permutations of four different points $A, B, C, D$ are true.

Proof. $H$ is not true; therefore $ABCD \& ABDC$ is true. Hence $ABCD \rightarrow ABDC$ .... (1), therefore $ABCD$ .... (2), and $ABDC$ ............. (3), are both true.

By (3) and $K_1$, $ACDB$ (4). By (4) and (1), $ACBD$ (5).

By (5) and $K_1$, $ADBC$ (6). By (6) and (1), $ADCB$. 
By (5) and $K_2$, $BCAD$ (7). By (7) and (1), $BCDA$ (8).
By (7) and $K_1$, $BDAC$ (9). By (9) and (1), $BDCA$ (10).
By (10) and $K_1$, $BACD$ (11). By (11) and (1), $BADC$.

Exchanging $A$ and $C$, $B$ and $D$ respectively we get the theorem.

**Theorem 6.** If $K_1$, $K_2$ and axiom 1 are true in a chain $K$, then $H$: $ABCD \& ABDC = 0$.

Proof. Suppose that $H$ is not true in $K$, then, by theorem 5, all the twenty-four permutations of $A, B, C, D$ are true.
Now, by theorem 2,

$$K(A, D) + K(B, D) + K(C, D) \neq 0.$$  

Then it is evident that at least one of $BACD, ABCD, ACBD$ is not true in $K$. It is inconsistent with the fact that $H$ is not true in $K$. Thus we get the theorem.

**Theorem 7.** When a chain $K$ contains $n$ distinct points $P_1, P_2, \ldots, P_n$, if $K$ is decomposed in pieces involving only two points, then axiom 1 is true in this chain $K$.

Proof. Let $X, Y, Z$ be three any different points in $P_1, P_2, \ldots P_n$. Hence $K \supset X, Y, Z$. As $K$ is decomposed in pieces involving only two points, for at least one of chains $K_Z(X, Y)$ in $K$,

$$K(X, Z) \cup K(Y, Z) \neq 0$$

and

$$K(X, Z) + K(Y, Z) \subseteq K_Z(X, Y).$$

Hence axiom 1 is true in $K$.  

Q. E. D.

§ 2. Examples which do not fulfil the postulates of E. V. HUNTINGTON and K. E. ROSINGER.

In translating to our definition, there exist two possible significations of the notation $ABCD$, viz.

(1) $B$ and $D$ are separated in $K$ by $A$ and $C$.
(2) $A$ and $C$ are separated in $K$ by $B$ and $D$.  

In the following examples, we shall show case (1) on the left-hand side and case (2) on the right-hand side.

1) An example which does not fulfil postulates $F$ and $F'$:

Postulate $F$: If $A, B, C, D$ are any distinct points, then at least one of the twenty-four permutations $ABCD, ABDC, \ldots, DCBA$ will form a true tetrad.

Postulate $F'$: At least one tetrad is true.

Let
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In these cases, there is a chain which contains any two points only of $A, B, C, D$. Hence postulates $F$ and $F'$ are not true.

2) An example which does not fulfil postulates $G, H, R$ and $R'$.

Postulate $G$: $ABCD \rightarrow BCDA$.
Postulate $H$: $ABCD \& ABDC = 0$.
Postulate $R$: $ABCD \rightarrow DCBA$.
Postulate $R'$: At least one true tetrad is reversible.

Let
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G) In this case, $K(A, C) \neq 0$. Hence $BCDA$ is not true; therefore $G$ is not true.

H) In this case, $K(B, C) = 0$, $K(A, B, C) \neq 0$. Hence $ABCD$ and $ABDC$ are true. Therefore $H$ is not true.

R) In this case, $K(A, C) \neq 0$. Hence $DCBA$ is not true. Therefore $R$ is not true.
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R') In this case, all the true tetrads are $ABCD$, $ABDC$, $ACBD$. However $K(C, A) \neq 0$, $K(D, A) \neq 0$ and $K(A, B) \neq 0$, therefore $DCBA$, $CDBA$, $DBC$ are not true tetrads. Hence $R'$ is not true.

3) An example which does not fulfil postulate 10.

Postulate 10: $ABCD.X \rightarrow AXCD \lor ABCX$.

Let $K = K(A, B) + K(A, C) + K(A, D) + K(C, X)$.

In this case, $K_{A}(B, X) + K_{C}(B, X) = 0$.

Hence $AXCD$ is not true. And then, $K_{A}(B, D) + K_{C}(B, D) = 0$.

Hence $ABCX$ is not true. Therefore postulate 10 is not true.

4) An example which does not fulfil postulates 11, 12, and 13.

Postulate 11. $ABXC \& ABCY \rightarrow ABXY$.

Postulate 12. $ABXC \& ABCY \rightarrow BXCY$.

Postulate 13. $ABXC \& ABCY \rightarrow AXCY$.

Let $K = K(A, B) + K(A, C) + K(A, X)$.

11) In this case, $K_{A}(C, B) + K_{C}(B, Y) = 0$.

Hence $ABXY$ is not true. Therefore postulate 11 is not true.
12, 13) In these cases, $K(X, Y) \neq 0$. Hence $BXY$ and $AXY$ are not true. Therefore postulates 12 and 13 are not true.

12) In this case, $K(B, C) = 0$. Hence $BXY$ is not true. Therefore postulate 12 is not true.

13) In this case, $K(A, C) = 0$. Hence $ACY$ is not true. Therefore postulate 13 is not true.

5) An example which does not fulfil postulates 14, 15, 16, 17, 18 and 19.

Postulate 14: \( ABCX \& ABCY \rightarrow ABXY V ABYX \).
Postulate 15: \( ABCX \& ABCY \rightarrow ACXY V ACYX \).
Postulate 16: \( ABCX \& ABCY \rightarrow BCXY V BCYX \).
Postulate 17: \( ABCX \& ABCY \rightarrow (ABXY \& ACYX) \& (ABYX \& ACXY) \).
Postulate 18: \( ABCX \& ABCY \rightarrow (ABXY \& BCYX) \& (ABYX \& BCXY) \).
Postulate 19: \( ABCX \& ABCY \rightarrow (ACXY \& BCYX) \& (ACYX \& BCXY) \).

Let \( K = K(A, B) + K(A, X) + K(A, Y) + K(C, B) + K(C, X) + K(C, Y) \).

14) In this case, \( K_C(B, Y) \neq 0 \), \( K_C(B, X) \neq 0 \). Hence $ABXY$ and $ABYX$ are not true, therefore postulate 14 is not true.

15, 16) In these cases, \( K(C, Y) \neq 0 \), \( K(C, X) \neq 0 \). Hence $ACXY$, $ACYX$, $BCXY$ and $BCYX$ are not true, therefore postulates 15 and 16 are not true.

Let \( K = K(A, Y) + K(Y, X) + K(X, A) + K(A, B) + K(B, C) \).

14, 15) In these cases, \( K(A, X) \neq 0 \), \( K(A, Y) \neq 0 \). Hence $ABXY$, $ABYX$, $ACXY$ and $ACYX$ are not true, therefore postulates 14 and 15 are not true.

16) In this case, $K_A(B, X) = 0$, \( K_A(B, Y) \neq 0 \). Hence $BCXY$ and $BCYX$ are not true, therefore postulate 16 is not true.
17, 18, 19) In these cases, postulates 14, 15 and 16 are not true, therefore, it is evident that postulates 17, 18 and 19 are not true.

§ 3. New sets of postulates for the separation of point-pairs.

As shown in §2, the postulates of E. V. HUNTINGTON and K. E. ROSINGER do not explain our definition for even a chain which is decomposed in pieces involving only two points. They are too strong for our definition for a chain which fulfills axiom 1 only. In this §, let us see how we can establish new postulates for the separation of point-pairs, by using the theorems in §1.

Postulates which we propose to study are:

Postulate D. If $ABCD$, then $A, B, C$ and $D$ are distinct.

Postulate F. If $A, B, C$ and $D$ are any distinct points, then at least one of the twenty-four permutations $ABCD$, $ABDC, \ldots, DCBA$ will form a true tetrad.

Postulate N. If $A, B, C$ and $D$ are any distinct points, then at least one of the twenty-four permutations $ABCD$, $ABDC, \ldots, DCBA$ will not form a true tetrad.

Postulate $K_1$. $ABCD \rightarrow ADCB^{(1)}$.

Postulate $K_2$. $ABCD \rightarrow CBAD^{(1)}$.

Postulate $C$. $ABCD.X \rightarrow ABCXV ABXD V AXCD V XBCD$.

Postulates $D$ and $F$ are identical with those which were considered by E. V. HUNTINGTON and K. E. ROSINGER. $K_1$ and $K_2$ are used in place of $G$ and $R$ respectively. $N$ and $C$ are used in place of $H$ and 10 respectively.

(1) Postulates $K_1$ and $K_2$ say that the points $A, C$ and $B, D$ are points of pairs, that is to say, $A$ and $C$ or $B$ and $D$, respectively, are permutable without changing the tetrad.
As shown in §1, it is evident that postulates $D, F, N, K_1, K_2$ and $C$ are deduced from postulates $D, F, G, H, R$ and 10 under axiom 1. Conversely, we shall show that postulates $D, F, G, H, R$ and 10 may be deduced by adding some conditions from the new postulates $D, F, N, K_1, K_2$ and $C$.

**Theorem 8.** Suppose $K_1$: $ABCD \rightarrow ADCB$, and $G$: $ABCD \rightarrow BCDA$ are both true, then $R$: $ABCD \rightarrow DCBA$.

Proof. By $K_1$, $ABCD \rightarrow ADCB$. By $G$, $ADCB \rightarrow DCBA$.

Hence $ABCD \rightarrow DCBA$. Therefore $R$ is true. Q. E. D.

**Theorem 9.** Suppose $K_2$: $ABCD \rightarrow CBAD$, and $G$: $ABCD \rightarrow BCDA$ are both true, then $R$: $ABCD \rightarrow DCBA$.

Proof. By $G$, $ABCD \rightarrow BCDA$. By $K_2$, $BCDA \rightarrow DCBA$.

Hence $ABCD \rightarrow DCBA$. Therefore $R$ is true. Q. E. D.

**Theorem 10.** Suppose $K_1$: $ABCD \rightarrow ADCB$, and $R$: $ABCD \rightarrow DCBA$ are both true, then $G$: $ABCD \rightarrow BCDA$.

Proof. By $K_1$, $ABCD \rightarrow ADCB$. By $R$, $ADCB \rightarrow BCDA$.

Hence $ABCD \rightarrow BCDA$. Therefore $G$ is true. Q. E. D.

**Theorem 11.** Suppose $K_2$: $ABCD \rightarrow CBAD$, and $R$: $ABCD \rightarrow DCBA$ are both true, then $G$: $ABCD \rightarrow BCDA$.


Hence $ABCD \rightarrow BCDA$. Therefore $G$ is true. Q. E. D.

Remark. It is clear that either $G$ or $R$ is deducible, by adding $R$ or $G$, respectively, in either $K_1$ or $K_2$.

**Theorem 12.** When $G$, $R$ and $N$ are true, then $H$ is true.

Proof. By theorems 4 and 5 in §1, it is evident. Q. E. D.

For the purpose of deducing postulate 10 from postulate $C$, we shall introduce the following axiom on $K$.

**Axiom 2.** A chain $K$ is decomposed in pieces involving only two points.

**Theorem 13.** When axiom 2, postulate $C$ and either $G$ or $R$ are true, and $X$ is neither $A$ nor $C$, then postulate 10 is true.
Proof. By theorem 7 in §1, axiom 1 is true in this chain. Consequently, we can make use of the results of theorem 3 in §1. That the case, \( XBCD \) and \( ABXD \) are true, was shown already in the case 4, \( 3^o \) in theorem 3 in §1.

In this case, \( K(A, X) = K(B, X) = K(D, X) = K(B, C) = K(D, C) = 0\).

Thus \( K(A, B) \neq 0 \), \( K(A, D) \neq 0 \) and \( K(C, X) \neq 0 \).

By axiom 2 and the preceding results,

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From the supposition that either \( G \) or \( R \) is true, \( K(A, C) = 0 \) \( \ldots (1) \).

Hence

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Therefore, the piece \( K(C, X) \) has no common point with the other pieces \( K(A, B) \) and \( K(A, D) \). This is inconsistent with the definition of a chain.\(^{10} \) Hence \( K(A, C) = 0 \). This is inconsistent with (1). Consequently, case 4, \( 3^o \) in theorem 3 in §1 does not occur. Thus postulate 10 can be deduced from postulate \( C \). Q. E. D.

By theorems 8, 9, 10, 11, 12 and 13, it is clear that the postulates \( D, F, G, H, R \) and 10 can be deduced from new postulates \( D, F, N, K_1, K_2 \) and \( C \), by applying axiom 2 and either \( G \) or \( R \).

The new postulates which we have established are more general than those of E. V. Huntington and K. E. Rosinger, and, at the same time, almost all of them (except \( F \)) satisfy the definition given in §1 under axiom 1.

Now let us (we propose to) give two sets of postulates for the separation of point-pairs.

(1), for the non reversible case, viz. \( D, F, N, K_1, K_2, C \).

(2), for the reversible case, viz. \( D, F, N, K_1, R, C \).

Remark. It is evident that our new set of postulates for a non reversible case (1) does not coincide with that of E. V. Huntington and K. E. Rosinger. We shall show that the new set of postulates

\(^{10} \) See K. Kunugi, loc. cit., p. 414.
for a reversible case (2) does not coincide with that of E. V. HUNT-INGTON and K. E. ROSINGER.

Let \( K = K(A, B) + K(B, C) + K(C, D) + K(D, A) \)
and let \( X \) is either \( A \) or \( C \). It is evident that \( D, F, G, R, N \) and \( C \) are true, but not 10.

Moreover, the preceding example show the consistency of our new sets of postulates for the separation of point-pairs.

\[ \S 4. \text{ Independency between } K_1, K_2, G, R, N \text{ and } C. \]

In this \( \S \), we shall consider independency between \( K_1, K_2, G, R, N \) and \( C \).

1) \( G \) and \( R \) are both independent of \( K_1, K_2, N \) and \( C \).

Let \( K = K(A, B) + K(B, C) + K(C, D) + K(D, A) + K(A, C) \).

All the true tetrads in \( K \) are \( ABCD, ADCB, CBAD, CDAB \), therefore \( K_1, K_2, N \) and \( C \) are true. Therefore \( G \) and \( R \) are independent of \( K_1, K_2, N \) and \( C \).

2) \( N \) is independent of \( K_1, K_2, G, R \) and \( C \).

Let \( K = K_A(B, D) + K_C(B, D) + K_B(A, C) + K_D(A, C) \), where the chains \( K_A(B, D), K_C(B, D), K_B(A, C), K_D(A, C) \) are chains which cannot be decomposed in other chains. Since any chain in \( K \) contains some three points of \( A, B, C, D \), it is evident that all the twenty-four permutations \( ABCD, ABDC, \ldots, DCBA \) are all true. Hence \( K_1, K_2, G, R \) and \( C \) are true. Therefore \( N \) is independent of \( K_1, K_2, G, R \) and \( C \).

3) \( C \) is independent of \( K_1, K_2, G, R \) and \( N \).

Let \( K = K(A, B) + K(B, C) + K(C, D) + K(D, A) + K_{B,C,D}(A, X) \), where the chain \( K_{B,C,D}(A, X) \) is a chain which cannot be decomposed in other chains.

It is clear that \( K_1, K_2, G, R \) and \( N \) are true in \( K \), but not \( C \). Therefore \( C \) is independent of \( K_1, K_2, G, R \) and \( N \).
In order to show that $K_1$ is independent of $K_2$, $N$ and $C$, we shall consider an oriented chain $K$.

$K(\overrightarrow{X,Y})$ means a chain in $K$ which connects $X$ and $Y$, from $X$ to $Y$.

We shall introduce the following definition for the separation of point-pairs.

**Definition.** Let $A, B, X, Y$ be four different points in an oriented chain $K$. Then we may say that $X$ and $Y$ are separated in $K$, by $A$ and $B$, if the two following conditions are both fulfilled:

1. $K(\overrightarrow{X,Y}) = 0$.
2. $K_A(\overrightarrow{X,Y}) + K_B(\overrightarrow{X,Y}) \neq 0$.

When two points $X$ and $Y$ are separated in $K$ by $A$ and $B$, we denote it by $AXBY$ (in $K$).

From the definition it follows at once that:

If $AXBY$ (in $K$), then we have also $BXAY$. But we cannot say in general that $AYBX$, $BYAX$.

4) $K_1$ is independent of $K_2$, $N$ and $C$.

Let $K = K(\overrightarrow{B,A}) + K(\overrightarrow{A,D}) + K(\overrightarrow{B,C}) + K(\overrightarrow{C,D})$.

All the true tetrads in $K$ are $ABCD$, $CBAD$; $K_2$, $N$ and $C$ are all true, but not $K_1$. Therefore $K_1$ is independent of $K_2$, $N$ and $C$.

Next, we shall introduce the following definition for the separation of point-pairs.

**Definition.** Let $A, B, X, Y$ be four different points in an oriented chain $K$. Then we may say that $X$ and $Y$ are separated in $K$, by $A$ and $B$, if the following condition is fulfilled:

One and only one of $A$ and $B$ is between $X$ and $Y$ in $K$.

When two points $X$ and $Y$ are separated in $K$, by $A$ and $B$, and if $B$ is between $X$ and $Y$ in $K$, we denote it by $AXBY$ (in $K$).

\footnote{B is between $X$ and $Y$, if each chain in $K$ which connects $X$ and $Y$, from $X$ to $Y$, according to definite direction in $K$, contains $B$.}
From the definition it follows at once that:

We cannot say in general that $AXBY$ means $AYBX$.

If $AXBY$ is true, then $BXAY$ is not true.

5) $K_2$ is independent of $K_1$, $N$ and $C$.

Let

$$K = K(\overrightarrow{A,D}) + K(\overrightarrow{D,C}) + K(\overrightarrow{C,B}) + K(\overrightarrow{B,C}) + K(\overrightarrow{C,D}) + K(\overrightarrow{D,A}) .$$

All the true tetrads in $K$ are $ABCD$, $ADCB$, $BCDA$, $BADC$. Hence $K_1$, $N$ and $C$ are true, but not $K_2$. Therefore $K_2$ is independent of $K_1$, $N$ and $C$.

6) $K_1$, $K_2$ and $G$ are all independent of $R$, $N$ and $C$.

Let

$$K = K(\overrightarrow{C,D}) + K(\overrightarrow{C,B}) + K(\overrightarrow{B,A}) + K(\overrightarrow{B,C}) .$$

All the true tetrads in $K$ are $ABCD$, $DCBA$; $R$, $N$ and $C$ are true, but not $K_1$, $K_2$, $G$. Therefore $K_1$, $K_2$ and $G$ are independent of $R$, $N$ and $C$.

7) $K_1$, $K_2$ and $R$ are all independent of $G$, $N$ and $C$.

Let

$$K = K(\overrightarrow{A,B}) + K(\overrightarrow{B,C}) + K(\overrightarrow{C,D}) + K(\overrightarrow{D,A}) .$$

All the true tetrads in $K$ are $ABCD$, $BCDA$, $CDAB$, $DABC$. Thus $G$, $N$ and $C$ are all true, but not $K_1$, $K_2$, $R$. Therefore $K_1$, $K_2$ and $R$ are all independent of $G$, $N$ and $C$. 