Neutrosophic Sets and Systems, Vol. 60, 2023
University of New Mexico

# The indefinite symbolic plithogenic integrals

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**Abstract**: In order to calculate the indefinite integrals of the symbolic plithogenic field, we used the substitution method, which was provided in this article. We also established a theorem that allowed us to locate the majority of the integrals for the symbolic plithogenic functions, in addition to the condition that must be met for the integration operation to be possible.

**Keywords:** symbolic plithogenic; division of symbolic plithogenic numbers; indefinite; integrals; substitution.

## 1. Introduction and Preliminaries

To The genesis, origination, formation, development, and evolution of new entities through dynamics of contradictory and/or neutral and/or noncontradictory multiple old entities is known as plithogenic. Plithogeny advocates for the integration of theories from several fields.

We use numerous "knowledges" from domains like soft sciences, hard sciences, arts and literature theories, etc. as "entities" in this study, this is what Smarandache introduced, as he presented a study on plithogeny, plithogenic set, logic, probability, and statistics [2], in addition to presenting introduction to the symbolic plithogenic algebraic structures (revisited), through which he discussed several ideas, including mathematical operations on plithogenic numbers [1]. Also, an overview of plithogenic set and symbolic plithogenic algebraic structures was discussed by him [3]. It is thought that the symbolic n-plithogenic sets are a good place to start when developing algebraic extensions for other classical structures including rings, vector spaces, modules, and equations [4-5-6-7].

Alhasan also presented several papers on calculus, in which he discussed neutrosophic definite and indefinite integrals. He also presented the most important applications of definite integrals in neutrosophic logic [8-9].

Integration is important in human life, and one of its most important applications is the calculation of area, size and arc length. In our reality we find things that cannot be precisely defined, and that contain an indeterminacy part. This is the reason for studying neutrosophic integration and methods of its integration in this paper.

Smarandache presented the division operation in the symbolic plithogenic field as follows [1]:

*Division of Symbolic Plithogenic Components*

$$\frac{P_i}{P_j} = \begin{cases} x_0 + x_1P_1 + x_2P_2 + \cdots + x_jP_j + P_i & x_0 + x_1 + x_2 + \cdots + x_j = 0 \quad i > j \\ x_0 + x_1P_1 + x_2P_2 + \cdots + x_iP_i & x_0 + x_1 + x_2 + \cdots + x_i = 1 \quad i = j \\ \emptyset & i < j \end{cases}$$

where all coefficients $x_0, x_1, x_2, \dots, x_i, \dots \in$ SPS.

*Division of Symbolic Plithogenic Numbers*

Let consider two symbolic plithogenic numbers as below:

$$PN_r = a_0 + a_1P_1 + a_2P_2 + \cdots + a_rP_r$$

$$PN_s = b_0 + b_1P_1 + b_2P_2 + \cdots + b_sP_s$$

$$\frac{PN_r}{PN_s} = \begin{cases} none, one \ \ many & r \geq s \\ \emptyset & r < s \end{cases}$$

This paper dealt with several topics, in the first part of which introduction and preliminaries were presented, and in the main discussion part the indefinite symbolic plithogenic integrals. In the last part, a conclusion to the paper is given.

## Main Discussion

### The indefinite symbolic plithogenic integrals

**Definition 1**

Let $f: SPS \to SPS$ to evaluate $\int f(x, PN)dx$

where $PN = d_0 + d_1P_1 + d_2P_2 + \cdots + d_nP_n$

put: $x = g(u) \quad \Rightarrow \quad dx = \acute{g}(u)du$

by substitution, we get:

$$\int f(x, PN)dx = \int f(u)\acute{g}(u)du$$

then we can directly integral it.

**Theorem 1**

If $\int f(x, PN)dx = \varphi(x, PN)$, then:

$$\int PN_r f(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s}\varphi(PN_s x + PN_n) + PC$$

provided that $\frac{PN_r}{PN_s}$ is divisible.

where $PN_r = a_0 + a_1P_1 + a_2P_2 + \cdots + a_rP_r$ , $PN_s = b_0 + b_1P_1 + b_2P_2 + \cdots + b_sP_s$ , $PN_n = c_0 + c_1P_1 + c_2P_2 + \cdots + c_nP_n$ and $PC = c_0 + c_1P_1 + c_2P_2 + \cdots + c_rP_r \in SPS$ is symbolic plithogenic constant.

Proof:

put: $PN_s x + PN_n = u \quad \Rightarrow \quad PN_s dx = du$

$$\Rightarrow \quad dx = \frac{1}{PN_s} \; du$$

$$\int PN_r f(PN_s x + PN_n)\, dx = \int PN_r f(u) \frac{1}{PN_s} \; du$$

$$= \int \frac{PN_r}{PN_s} f(u)\, du$$

$$= \frac{PN_r}{PN_s} \varphi(u) + PC$$

back to the variable $x$, we get:

$$\int PN_r f(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} \varphi(PN_s x + PN_n) + PC$$

**Using the previous theorem, we get on:**

1) $\int PN_r (PN_s x + PN_n)^n dx = \frac{PN_r}{PN_s} \frac{(PN_s x + PN_n)^{n+1}}{n+1} + PC$

2) $\int \frac{PN_r}{PN_s x + PN_n} dx = \frac{PN_r}{PN_s} ln|PN_s x + PN_n| + PC$

3) $\int PN_r e^{PN_s x + PN_n} dx = \frac{PN_r}{PN_s} e^{PN_s x + PN_n} + PC$

4) $\int \frac{PN_r}{\sqrt{PN_s x + PN_n}} dx = 2\frac{PN_r}{PN_s} \sqrt{PN_s x + PN_n} + PC$

5) $\int PN_r cos(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} sin(PN_s x + PN_n) + PC$

6) $\int PN_r sin(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} cos(PN_s x + PN_n) + PC$

7) $\int PN_r sec^2(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} tan(PN_s x + PN_n) + PC$

8) $\int PN_r csc^2(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} cot(PN_s x + PN_n) + PC$

9) $\int PN_r sec(PN_s x + PN_n) \; tan(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} sec(PN_s x + PN_n) + PC$

10) $\int PN_r csc(PN_s x + PN_n) \; cot(PN_s x + PN_n)\, dx = \frac{PN_r}{PN_s} csc(PN_s x + PN_n) + PC$

Example 1

1) $\int P_2 (P_1 x + 5 - 3P_1 + 4P_2)^5 \; dx = \frac{P_2}{P_1} \frac{(P_1 x + 5 - 3P_1 + 4P_2)^6}{6} + PC$

$$= (x_0 + x_1P_1 + P_2)\frac{(P_1x + 5 - 3P_1 + 4P_2)^6}{6} + PC$$

where:

$$\frac{P_2}{P_1} = x_0 + x_1P_1 + x_2P_2 \quad \Rightarrow \quad P_2 = x_0P_1 + x_1P_1 + x_2P_2$$

$$\Rightarrow \quad P_2 = (x_0 + x_1)P_1 + x_2P_2 \text{ , then:}$$

$$x_0 + x_1 = 0 \text{ and } x_2 = 1$$

hence: $\frac{P_2}{P_1} = x_0 + x_1P_1 + P_2$ , where: $x_0 + x_1 = 0$

let's check the answer:

$$\frac{d}{dx}\left[(x_0 + x_1P_1 + P_2)\frac{(P_1x + 5 - 3P_1 + 4P_2)^6}{6} + PC\right] = 6P_1(x_0 + x_1P_1 + P_2)\frac{(P_1x + 5 - 3P_1 + 4P_2)^5}{6}$$

$$= (x_0P_1 + x_1P_1 + P_2)(P_1x + 5 - 3P_1 + 4P_2)^5$$

$$= \big((x_0 + x_1)P_1 + P_2\big)(P_1x + 5 - 3P_1 + 4P_2)^5$$

but we have: $x_0 + x_1 = 0$, then:

$$\frac{d}{dx}\left[(x_0 + x_1P_1 + P_2)\frac{(P_1x + 5 - 3P_1 + 4P_2)^6}{6} + PC\right] = P_2(P_1x + 5 - 3P_1 + 4P_2)^5$$

$= (The \ \ same \ \ integral \ \ function)$

2) $\int \frac{2P_1 + 3}{P_1x + 1 + 2P_1 - 7P_2 + 4P_5} dx = does \ \ not \ \ exist$

because:

$$\frac{2P_1 + 3}{P_1} = x_0 + x_1P_1$$

$$2P_1 + 3 = x_0P_1 + x_1P_1$$

$$2P_1 + 3 = (x_0 + x_1)P_1$$

then: $x_0 + x_1 = 2$ , but we are not able to catch the free coefficient 1 from the left-hand side so:

$$\frac{2P_1 + 3}{P_1} = (does \ \ not \ \ exist)$$

3) $\int \boldsymbol{e}^{P_3x - 3 + P_2} dx = does \ \ not \ \ exist$

because: $\frac{1}{P_3} = (does \ \ not \ \ exist)$

4) $\int 6P_4 cos\big((P_4 - 3P_2)x + 2 - P_3 + P_4\big) dx = \frac{6P_4}{P_4 - 3P_2} sin\big((P_4 - 3P_2)x + 2 - P_3 + P_4\big) + PC$

$$= (x_0 + x_1P_1 + x_2P_2 - 3P_4) sin\big((P_4 - 3P_2)x + 2 - P_3 + P_4\big) + PC$$

where:

$$\frac{6P_4}{P_4-3P_2}=x_0+x_1P_1+x_2P_2+x_3P_3+x_4P_4$$

$$6P_4=(P_4-3P_2)(x_0+x_1P_1+x_2P_2+x_3P_3+x_4P_4)$$

$$6P_4=x_0P_4+x_1P_4+x_2P_4+x_3P_4+x_4P_4-3x_0P_2-3x_1P_2-3x_2P_2-3x_3P_3-3x_4P_4$$

$$6P_4=-3(x_0+x_1+x_2)P_2-3x_3P_3+(x_0+x_1+x_2+x_3-2x_4)P_4$$ , then:

$$x_0+x_1+x_2=0\ ,\ x_3=0 \text{ and } x_4=-3$$

hence: $\frac{6P_4}{P_4-3P_2}=x_0+x_1P_1+x_2P_2-3P_4$ , where: $x_0+x_1+x_2=0$

5) $\int(P_3+5P_2-5P_1+6)sec^2\big((P_3+5)x-8+4P_1-5P_2+3P_3\big)\,dx$

$$=\frac{P_3+5P_2-5P_1+6}{P_3+5}tan\big((P_3+5)x-8+4P_1-5P_2+3P_3\big)+PC$$

$$=\left(\frac{6}{5}+P_1+P_2-\frac{1}{30}P_3\right)tan\big((P_3+5)x-8+4P_1-5P_2+3P_3\big)+PC$$

where:

$$\frac{P_3+5P_2-5P_1+6}{P_3+5}=x_0+x_1P_1+x_2P_2+x_3P_3$$

$$P_3+5P_2-5P_1+6=(P_3+5)(x_0+x_1P_1+x_2P_2+x_3P_3)$$

$$P_3+5P_2-5P_1+6=x_0P_3+x_1P_3+x_2P_3+x_3P_3+5x_0+5x_1P_1+5x_2P_2+5x_3P_3$$

$P_3+5P_2-5P_1+6=5x_0+5x_1P_1+5x_2P_2+(x_0+x_1+x_2+6x_3)P_3$ , then:

$$x_0=\frac{6}{5}\ ,\ x_1=1\ ,\ x_2=-1 \text{ and } x_3=-\frac{1}{30}$$

hence: $\frac{P_3+5P_2-5P_1+6}{P_3+5}=\frac{6}{5}+P_1+P_2-\frac{1}{30}P_3$

6) $\int P_2csc(P_4x)\ cot(P_4x)\,dx=does\ \ not\ \ exist$

because: $\frac{P_2}{P_4}=(does\ \ not\ \ exist)$

7) $\int\frac{P_2}{\sqrt{P_2x+3-P_1}}dx$

$$=\frac{2P_2}{P_2}\sqrt{P_2x+3-P_1}+PC$$

$$=2(x_0+x_1P_1+x_2P_2)\sqrt{P_2x+3-P_1}+PC$$

where:

$$\frac{2P_2}{P_2}=x_0+x_1P_1+x_2P_2$$

$$2P_2 = x_0P_2 + x_1P_2 + x_2P_2$$

$$2P_2 = (x_0 + x_1 + x_2)P_2$$

then: $x_0 + x_1 + x_2 = 2$

hence: $\frac{2P_2}{P_2} = x_0 + x_1P_1 + x_2P_2$ , where: $x_0 + x_1 + x_2 = 2$

**Theorem 2**

Let $f: SPS \to SPS$ , then:

$$\int \frac{\acute{f}(x,PN)}{f(x,PN)} dx = ln|f(x,PN)| + PC$$

Proof:

put: $f(x,PN) = u \qquad \Rightarrow \acute{f}(x,PN)dx = du$

$$\Rightarrow dx = \frac{1}{\acute{f}(x,PN)} du$$

$$\Rightarrow dx = \frac{1}{\acute{u}} du$$

$$\int \frac{\acute{f}(x,PN)}{f(x,PN)} dx = \int \frac{\acute{u}}{u}\frac{1}{\acute{u}} du = \int \frac{1}{u} du = ln|u| + PC$$

back to the $f(x,PN)$, we get:

$$\int \frac{\acute{f}(x,PN)}{f(x,PN)} dx = ln|f(x,PN)| + PC$$

Example 2

1) $\int \frac{(3 + 2P_1 - 7P_2 + P_3 - 5P_4)x^7}{(3 + 2P_1 - 7P_2 + P_3 - 5P_4)x^8 + 8 - P_1} dx = \frac{1}{8} ln|(3 + 2P_1 - 7P_2 + P_3 - 5P_4)x^8 + 8 - P_1| + PC$

2) $\int \frac{(1 + 4P_1 - P_2)e^{(1+4P_1-P_2)x+2P_3}}{e^{(1+4P_1-P_2)x+2P_3} + 5P_4} dx = ln\left|e^{(1+4P_1-P_2)x+2P_3} + 5P_4\right| + PC$

3) $\int (P_5 + 3)\, tan(P_4 + 1)x\, dx = (P_5 + 3) \int \frac{sin(P_5 + 1)x}{cos(P_5 + 1)x} dx = \frac{P_5 + 3}{P_4 + 1} ln|(P_4 + 1)x| + PC$

$$= (3 - P_5) ln|cos(P_4 + 1)x| + PC$$

where:

$$\frac{P_5 + 3}{P_4 + 1} = x_0 + x_1P_1 + x_2P_2 + x_3P_3 + x_4P_4 + x_5P_5$$

$$P_5 + 3 = (P_4 + 1)(x_0 + x_1P_1 + x_2P_2 + x_3P_3 + x_4P_4 + x_5P_5)$$

$$P_5 + 3 = x_0P_4 + x_1P_4 + x_2P_4 + x_3P_4 + x_4P_4 + x_5P_5 + x_0 + x_1P_1 + x_2P_2 + x_3P_3 + x_4P_4 + x_5P_5$$

$P_5 + 3 = x_0 + x_1P_1 + x_2P_2 + x_3P_3 + (x_0 + x_1 + x_2 + x_3 + 2x_4)P_4 + (2x_5)P_5$ , then:

$$x_0 = 3 \ , x_1 = 0 \ , x_2 = 0 \ , x_3 = 0 \ , x_4 = \frac{-3}{2} \ , x_5 = \frac{1}{2}$$

hence: $\frac{P_5+3}{P_4+1} = 3 - \frac{3}{2}P_4 + \frac{1}{2}P_5$

4) $\int \frac{-7P_4}{1+tan(P_3x)}dx = \int \frac{-7P_4}{1+\frac{sin(P_3x)}{cos(P_3x)}}dx$

$$= \frac{1}{2}\int \frac{-14P_4\,cos(P_3x)}{cos(P_3x)+sin(P_3x)}dx$$

$$= \frac{-7P_4}{2P_3}\int \frac{cos(P_3x)+sin(P_3x)+cos(P_3x)-sin(P_3x)}{cos(P_3x)+sin(P_3x)}dx$$

$$= \frac{-7P_4}{2P_3}\int dx + \frac{-7P_4}{2P_3}\int \frac{cos(P_3x)-sin(P_3x)}{cos(P_3x)+sin(P_3x)}dx$$

$$= \left(x_0 + x_1P_1 + x_2P_2 + x_3P_3 - \frac{7}{2}P_4\right)x + \left(x_0 + x_1P_1 + x_2P_2 + x_3P_3 - \frac{7}{2}P_4\right)ln|cos(P_3x)+sin(P_3x)| + PC$$

where:

$$\frac{-7P_4}{2P_3} = x_0 + x_1P_1 + x_2P_2 + x_3P_3 + x_4P_4$$

$$-7P_4 = (2P_3)(x_0 + x_1P_1 + x_2P_2 + x_3P_3 + x_4P_4)$$

$$-7P_4 = 2x_0P_3 + 2x_1P_3 + 2x_2P_3 + 2x_3P_3 + 2x_4P_4$$

$-7P_4 = 2(x_0 + x_1 + x_2 + x_3)P_3 + 2x_4P_4$ , then:

$x_0 + x_1 + x_2 + x_3 = 0$ and $x_4 = -\frac{7}{2}$

hence: $\frac{6P_4}{P_4-3P_2} = x_0 + x_1P_1 + x_2P_2 + x_3P_3 - \frac{7}{2}P_4$ , where: $x_0 + x_1 + x_2 + x_3 = 0$

**Theorem 3**

Let $f: SPS \to SPS$, then:

$$\int \frac{\acute{f}(x,PN)}{\sqrt{f(x,PN)}}dx = 2\sqrt{f(x,PN)} + PC$$

Proof:

put: $f(x,PN) = u \quad \Rightarrow \acute{f}(x,PN)dx = du$

$$\Rightarrow dx = \frac{1}{\acute{f}(x,PN)}\ du$$

$$\Rightarrow dx = \frac{1}{\acute{u}}\ du$$

$$\int \frac{\acute{f}(x,PN)}{\sqrt{f(x,PN)}}dx = \int \frac{\acute{u}}{\sqrt{u}}\frac{1}{\acute{u}}du = \int \frac{1}{\sqrt{u}}du = 2\sqrt{u} + PC$$

back to $f(x,PN)$, we get:

$$\int \frac{\acute{f}(x,PN)}{\sqrt{f(x,PN)}}dx = 2\sqrt{f(x,PN)} + PC$$

Example 3

$$1) \int \frac{(5+P_1-4P_2+2P_3)x-7P_2}{\sqrt{(10+2P_1-8P_2+4P_3)x^2-28P_2x}}dx = \frac{-1}{2}\sqrt{(10+2P_1-8P_2+4P_3)x^2-28P_2x} + PC$$

$$2) \int \frac{(1+P_1)x^9}{\sqrt{(1+P_1)x^{10}-P_1+9P_2}}dx = \frac{2}{9}\sqrt{(1+P_1)x^{10}-P_1+9P_2} + PC$$

**Theorem 4**

$f: SPS \to SPS$ , then:

$$\int [f(x,PN)]^n \acute{f}(x,PN)\ \ dx = \frac{[f(x,PN)]^{n+1}}{n+1} + PC$$

Proof:

put: $f(x,PN) = u \qquad \Rightarrow \acute{f}(x,PN)dx = \ \ du$

$$\Rightarrow dx = \frac{1}{\acute{f}(x,PN)}\ \ du$$

$$\Rightarrow dx = \frac{1}{\acute{u}}\ \ du$$

$$\int [f(x,PN)]^n \acute{f}(x,PN)\ \ dx = \int u^n \acute{u}\frac{1}{\acute{u}}du = \int u^n du = \frac{u^{n+1}}{n+1} + PC$$

back to $f(x,PN)$, we get:

$$\int [f(x,PN)]^n \acute{f}(x,PN)\ \ dx = \frac{[f(x,PN)]^{n+1}}{n+1} + PC$$

Example 5

$$1) \int P_3x^3[(P_2+1)x^3]^4dx = \frac{1}{4}\int 4P_3x^3[(P_2+1)x^3]^4dx$$

$$= \frac{P_3}{P_2+1}\frac{[(3+2I_1+2I_2)x^3]^5}{5} + PC$$

$$= \frac{1}{2}P_3\frac{[(3+2I_1+2I_2)x^3]^5}{5} + PC$$

$$= \frac{1}{10}P_3[(3+2I_1+2I_2)x^3]^5 + PC$$

where:

$$\frac{P_3}{P_2+1} = x_0 + x_1P_1 + x_2P_2 + x_3P_3$$

$$P_3 = (P_2+1)(x_0 + x_1P_1 + x_2P_2 + x_3P_3)$$

$$P_3 = x_0P_3 + x_1P_3 + x_2P_3 + x_3P_3 + x_0 + x_1P_1 + x_2P_2 + x_3P_3$$

$$P_3 = x_0 + x_1P_1 + x_2P_2 + (x_0 + x_1 + x_2 + 2x_3)P_3 \text{ , then:}$$

$$x_0 = 0 \ , x_1 = 0 \ , x_2 = 0 \ , x_3 = \frac{1}{2}$$

hence: $\frac{P_3}{P_2+1} = \frac{1}{2}P_3$

$$2) \int \frac{P_2}{\sqrt{P_1x - 5P_1 + 8P_2}}\left(\sqrt{P_1x - 5P_1 + 8P_2}\right)^{11} dx$$

$$= \frac{P_2}{P_1}\frac{\left(\sqrt{(2 + I_1 + I_2)x - I_1 + 2I_2}\right)^{12}}{12} + PC$$

$$= (x_0 + x_1P_1 + P_2)\frac{\left(\sqrt{(2 + I_1 + I_2)x - I_1 + 2I_2}\right)^{12}}{12} + PC$$

where:

$$\frac{P_2}{P_1} = x_0 + x_1P_1 + x_2P_2 \quad \Rightarrow \quad P_2 = x_0P_1 + x_1P_1 + x_2P_2$$

$$\Rightarrow \quad P_2 = (x_0 + x_1)P_1 + x_2P_2 \text{ , then:}$$

$$x_0 + x_1 = 0 \text{ and } P_2 = 1$$

hence: $\frac{P_2}{P_1} = x_0 + x_1P_1 + P_2$ , where: $x_0 + x_1 = 0$

## 5. Conclusions

In this paper, we discussed integrations in the symbolic plithogenic field, where we presented direct methods for solving most integrations of symbolic plithogenic functions, and we arrived at the condition that must be met in order for integration to be possible.

**Acknowledgments** " This study is supported via funding from Prince sattam bin Abdulaziz University project number (PSAU/2023/R/1445)".

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Received: July 12, 2023. Accepted: Nov 21, 2023