

Finite integral involving the product of generalized Zeta-function, a class of polynomials and multivariable Aleph-functions

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ABSTRACT

In the present paper we evaluate a finite integral of four parameters involving the product of generalized Zeta-function, multivariable Aleph-functions and general class of polynomials of several variables. The importance of the result established in this paper lies in the fact they involve the Aleph-function of several variables which is sufficiently general in nature and capable to yielding a large of results merely by specializing the parameters their in.

Keywords:Multivariable Aleph-function, general class of polynomials, Ramanujan integral, generalized Zeta-function

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1.Introduction and preliminaries.

The function Aleph of several variables generalize the multivariable I-function recently study by C.K. Sharma and Ahmad [3] , itself is an a generalisation of G and H-functions of multiple variables. The multiple Mellin-Barnes integral occurring in this paper will be referred to as the multivariables Aleph-function throughout our present study and will be defined and represented as follows.

We define : $\aleph(z_1, \dots, z_r) = \aleph_{p_i, q_i, \tau_i; R: p_i^{(1)}, q_i^{(1)}, \tau_i^{(1)}; R^{(1)}; \dots; p_i^{(r)}, q_i^{(r)}, \tau_i^{(r)}; R^{(r)}}^{0, n: m_1, n_1, \dots, m_r, n_r}$ $\left(\begin{matrix} z_1 \\ \cdot \\ \cdot \\ \cdot \\ z_r \end{matrix} \right)$

$[(a_j; \alpha_j^{(1)}, \dots, \alpha_j^{(r)})_{1, n}]$, $[\tau_i(a_{ji}; \alpha_{ji}^{(1)}, \dots, \alpha_{ji}^{(r)})_{n+1, p_i}]$:
 , $[\tau_i(b_{ji}; \beta_{ji}^{(1)}, \dots, \beta_{ji}^{(r)})_{m+1, q_i}]$:

$[(c_j^{(1)}; \gamma_j^{(1)})_{1, n_1}], [\tau_i^{(1)}(c_{ji}^{(1)}; \gamma_{ji}^{(1)})_{n_1+1, p_i^{(1)}}]; \dots ; [(c_j^{(r)}; \gamma_j^{(r)})_{1, n_r}], [\tau_i^{(r)}(c_{ji}^{(r)}; \gamma_{ji}^{(r)})_{n_r+1, p_i^{(r)}}]$ $\left(\begin{matrix} \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \end{matrix} \right)$
 $[(d_j^{(1)}; \delta_j^{(1)})_{1, m_1}], [\tau_i^{(1)}(d_{ji}^{(1)}; \delta_{ji}^{(1)})_{m_1+1, q_i^{(1)}}]; \dots ; [(d_j^{(r)}; \delta_j^{(r)})_{1, m_r}], [\tau_i^{(r)}(d_{ji}^{(r)}; \delta_{ji}^{(r)})_{m_r+1, q_i^{(r)}}]$ $\left(\begin{matrix} \cdot \\ \cdot \\ \cdot \\ \cdot \\ \cdot \end{matrix} \right)$

$= \frac{1}{(2\pi\omega)^r} \int_{L_1} \dots \int_{L_r} \psi(s_1, \dots, s_r) \prod_{k=1}^r \theta_k(s_k) y_k^{s_k} ds_1 \dots ds_r$ (1.1)

with $\omega = \sqrt{-1}$

$\psi(s_1, \dots, s_r) = \frac{\prod_{j=1}^n \Gamma(1 - a_j + \sum_{k=1}^r \alpha_j^{(k)} s_k)}{\sum_{i=1}^R [\tau_i \prod_{j=n+1}^{p_i} \Gamma(a_{ji} - \sum_{k=1}^r \alpha_{ji}^{(k)} s_k) \prod_{j=1}^{q_i} \Gamma(1 - b_{ji} + \sum_{k=1}^r \beta_{ji}^{(k)} s_k)]}$ (1.2)

and $\theta_k(s_k) = \frac{\prod_{j=1}^{m_k} \Gamma(d_j^{(k)} - \delta_j^{(k)} s_k) \prod_{j=1}^{n_k} \Gamma(1 - c_j^{(k)} + \gamma_j^{(k)} s_k)}{\sum_{i^{(k)}=1}^{R^{(k)}} [\tau_{i^{(k)}} \prod_{j=m_k+1}^{q_i^{(k)}} \Gamma(1 - d_{ji}^{(k)} + \delta_{ji}^{(k)} s_k) \prod_{j=n_k+1}^{p_i^{(k)}} \Gamma(c_{ji}^{(k)} - \gamma_{ji}^{(k)} s_k)]}$ (1.3)

Suppose, as usual, that the parameters

$$a_j, j = 1, \dots, p; b_j, j = 1, \dots, q;$$

$$c_j^{(k)}, j = 1, \dots, n_k; c_{j i^{(k)}}^{(k)}, j = n_k + 1, \dots, p_{i^{(k)}};$$

$$d_j^{(k)}, j = 1, \dots, m_k; d_{j i^{(k)}}^{(k)}, j = m_k + 1, \dots, q_{i^{(k)}};$$

$$\text{with } k = 1, \dots, r, i = 1, \dots, R, i^{(k)} = 1, \dots, R^{(k)}$$

are complex numbers, and the α' s, β' s, γ' s and δ' s are assumed to be positive real numbers for standardization purpose such that

$$U_i^{(k)} = \sum_{j=1}^n \alpha_j^{(k)} + \tau_i \sum_{j=n+1}^{p_i} \alpha_{j i}^{(k)} + \sum_{j=1}^{n_k} \gamma_j^{(k)} + \tau_{i^{(k)}} \sum_{j=n_k+1}^{p_{i^{(k)}}} \gamma_{j i^{(k)}}^{(k)} - \tau_i \sum_{j=1}^{q_i} \beta_{j i}^{(k)} - \sum_{j=1}^{m_k} \delta_j^{(k)} - \tau_{i^{(k)}} \sum_{j=m_k+1}^{q_{i^{(k)}}} \delta_{j i^{(k)}}^{(k)} \leq 0 \tag{1.4}$$

The real numbers τ_i are positives for $i = 1$ to R , $\tau_{i^{(k)}}$ are positives for $i^{(k)} = 1$ to $R^{(k)}$

The contour L_k is in the s_k -p plane and run from $\sigma - i\infty$ to $\sigma + i\infty$ where σ is a real number with loop, if necessary, ensure that the poles of $\Gamma(d_j^{(k)} - \delta_j^{(k)} s_k)$ with $j = 1$ to m_k are separated from those of $\Gamma(1 - a_j + \sum_{i=1}^r \alpha_j^{(k)} s_k)$ with $j = 1$ to n and $\Gamma(1 - c_j^{(k)} + \gamma_j^{(k)} s_k)$ with $j = 1$ to n_k to the left of the contour L_k . The condition for absolute convergence of multiple Mellin-Barnes type contour (1.9) can be obtained by extension of the corresponding conditions for multivariable H-function given by as :

$$|\arg z_k| < \frac{1}{2} A_i^{(k)} \pi, \text{ where}$$

$$A_i^{(k)} = \sum_{j=1}^n \alpha_j^{(k)} - \tau_i \sum_{j=n+1}^{p_i} \alpha_{j i}^{(k)} - \tau_i \sum_{j=1}^{q_i} \beta_{j i}^{(k)} + \sum_{j=1}^{n_k} \gamma_j^{(k)} - \tau_{i^{(k)}} \sum_{j=n_k+1}^{p_{i^{(k)}}} \gamma_{j i^{(k)}}^{(k)} + \sum_{j=1}^{m_k} \delta_j^{(k)} - \tau_{i^{(k)}} \sum_{j=m_k+1}^{q_{i^{(k)}}} \delta_{j i^{(k)}}^{(k)} > 0, \text{ with } k = 1, \dots, r, i = 1, \dots, R, i^{(k)} = 1, \dots, R^{(k)} \tag{1.5}$$

The complex numbers z_i are not zero. Throughout this document, we assume the existence and absolute convergence conditions of the multivariable Aleph-function.

We may establish the asymptotic expansion in the following convenient form :

$$\aleph(z_1, \dots, z_r) = O(|z_1|^{\alpha_1}, \dots, |z_r|^{\alpha_r}), \max(|z_1|, \dots, |z_r|) \rightarrow 0$$

$$\aleph(z_1, \dots, z_r) = O(|z_1|^{\beta_1}, \dots, |z_r|^{\beta_r}), \min(|z_1|, \dots, |z_r|) \rightarrow \infty$$

where, with $k = 1, \dots, r: \alpha_k = \min[Re(d_j^{(k)} / \delta_j^{(k)})], j = 1, \dots, m_k$ and

$$\beta_k = \max[Re((c_j^{(k)} - 1) / \gamma_j^{(k)})], j = 1, \dots, n_k$$

Series representation of Aleph-function of several variables is given by

$$\aleph(y_1, \dots, y_r) = \sum_{G_1, \dots, G_r=0}^{\infty} \sum_{g_1=0}^{m_1} \dots \sum_{g_r=0}^{m_r} \frac{(-)^{G_1+\dots+G_r}}{\delta_{g_1}^{G_1!} \dots \delta_{g_r}^{G_r!}} \psi(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \times \theta_1(\eta_{G_1, g_1}) \dots \theta_r(\eta_{G_r, g_r}) y_1^{-\eta_{G_1, g_1}} \dots y_r^{-\eta_{G_r, g_r}} \tag{1.6}$$

Where $\psi(\dots), \theta_i(\dots), i = 1, \dots, r$ are given respectively in (1.2), (1.3) and

$$\eta_{G_1, g_1} = \frac{d_{g_1}^{(1)} + G_1}{\delta_{g_1}^{(1)}}, \dots, \eta_{G_r, g_r} = \frac{d_{g_r}^{(r)} + G_r}{\delta_{g_r}^{(r)}} \tag{1.7}$$

which is valid under the conditions $\delta_{g_i}^{(i)} [d_j^i + p_i] \neq \delta_j^{(i)} [d_{g_i}^i + G_i]$

$$\text{for } j \neq m_i, m_i = 1, \dots, \eta_{G_i, g_i}; p_i, n_i = 0, 1, 2, \dots, ; y_i \neq 0, i = 1, \dots, r \tag{1.8}$$

Consider the Aleph-function of s variables

$$\aleph(z_1, \dots, z_s) = \aleph_{P_i, Q_i, l_i; r': P_i(1), Q_i(1), l_i(1); r^{(1)}; \dots; P_i(s), Q_i(s), l_i(s); r^{(s)}}^{0, N: M_1, N_1, \dots, M_s, N_s} \left(\begin{matrix} z_1 \\ \cdot \\ \cdot \\ z_s \end{matrix} \right) \left(\begin{matrix} [(u_j; \mu_j^{(1)}, \dots, \mu_j^{(r')})_{1, N}] & , [l_i(u_{ji}; \mu_{ji}^{(1)}, \dots, \mu_{ji}^{(r')})_{N+1, P_i}] : \\ \dots & , [l_i(v_{ji}; \nu_{ji}^{(1)}, \dots, \nu_{ji}^{(r')})_{M+1, Q_i}] : \\ [(a_j^{(1)}; \alpha_j^{(1)})_{1, N_1}] & , [l_{i(1)}(a_{ji(1)}^{(1)}; \alpha_{ji(1)}^{(1)})_{N_1+1, P_i(1)}] ; \dots ; [(a_j^{(s)}; \alpha_j^{(s)})_{1, N_s}] & , [l_{i(s)}(a_{ji(s)}^{(s)}; \alpha_{ji(s)}^{(s)})_{N_s+1, P_i(s)}] \\ [(b_j^{(1)}; \beta_j^{(1)})_{1, M_1}] & , [l_{i(1)}(b_{ji(1)}^{(1)}; \beta_{ji(1)}^{(1)})_{M_1+1, Q_i(1)}] ; \dots ; [(b_j^{(s)}; \beta_j^{(s)})_{1, M_s}] & , [l_{i(s)}(b_{ji(s)}^{(s)}; \beta_{ji(s)}^{(s)})_{M_s+1, Q_i(s)}] \end{matrix} \right) \tag{1.9}$$

$$= \frac{1}{(2\pi\omega)^s} \int_{L_1} \dots \int_{L_s} \zeta(t_1, \dots, t_s) \prod_{k=1}^s \phi_k(t_k) z_k^{t_k} dt_1 \dots dt_s$$

with $\omega = \sqrt{-1}$

$$\zeta(t_1, \dots, t_s) = \frac{\prod_{j=1}^N \Gamma(1 - u_j + \sum_{k=1}^s \mu_j^{(k)} t_k)}{\sum_{i=1}^{r'} [l_i \prod_{j=N+1}^{P_i} \Gamma(u_{ji} - \sum_{k=1}^s \mu_{ji}^{(k)} t_k) \prod_{j=1}^{Q_i} \Gamma(1 - v_{ji} + \sum_{k=1}^s \nu_{ji}^{(k)} t_k)] } \tag{1.10}$$

$$\text{and } \phi_k(t_k) = \frac{\prod_{j=1}^{M_k} \Gamma(b_j^{(k)} - \beta_j^{(k)} t_k) \prod_{j=1}^{N_k} \Gamma(1 - a_j^{(k)} + \alpha_j^{(k)} t_k)}{\sum_{i(k)=1}^{r^{(k)}} [l_{i(k)} \prod_{j=M_k+1}^{Q_{i(k)}} \Gamma(1 - b_{ji(k)}^{(k)} + \beta_{ji(k)}^{(k)} t_k) \prod_{j=N_k+1}^{P_{i(k)}} \Gamma(a_{ji(k)}^{(k)} - \alpha_{ji(k)}^{(k)} t_k)] } \tag{1.11}$$

Suppose, as usual, that the parameters

$$u_j, j = 1, \dots, P; v_j, j = 1, \dots, Q;$$

$$a_j^{(k)}, j = 1, \dots, N_k; a_{j i^{(k)}}^{(k)}, j = n_k + 1, \dots, P_{i^{(k)}};$$

$$b_{j i^{(k)}}^{(k)}, j = m_k + 1, \dots, Q_{i^{(k)}}; b_j^{(k)}, j = 1, \dots, M_k;$$

$$\text{with } k = 1 \dots, s, i = 1, \dots, r', i^{(k)} = 1, \dots, r^{(k)}$$

are complex numbers, and the $\alpha's, \beta's, \gamma's$ and $\delta's$ are assumed to be positive real numbers for standardization purpose such that

$$U_i^{(k)} = \sum_{j=1}^N \mu_j^{(k)} + \iota_i \sum_{j=N+1}^{P_i} \mu_{ji}^{(k)} + \sum_{j=1}^{N_k} \alpha_j^{(k)} + \iota_{i^{(k)}} \sum_{j=N_k+1}^{P_{i^{(k)}}} \alpha_{ji^{(k)}}^{(k)} - \iota_i \sum_{j=1}^{Q_i} v_{ji}^{(k)} - \sum_{j=1}^{M_k} \beta_j^{(k)} - \iota_{i^{(k)}} \sum_{j=M_k+1}^{Q_{i^{(k)}}} \beta_{ji^{(k)}}^{(k)} \leq 0 \tag{1.12}$$

The reals numbers τ_i are positives for $i = 1, \dots, r$, $\iota_{i^{(k)}}$ are positives for $i^{(k)} = 1 \dots r^{(k)}$

The contour L_k is in the t_k -p lane and run from $\sigma - i\infty$ to $\sigma + i\infty$ where σ is a real number with loop, if necessary, ensure that the poles of $\Gamma(b_j^{(k)} - \beta_j^{(k)} t_k)$ with $j = 1$ to M_k are separated from those of $\Gamma(1 - u_j + \sum_{i=1}^s \mu_j^{(k)} t_k)$ with $j = 1$ to N and $\Gamma(1 - a_j^{(k)} + \alpha_j^{(k)} t_k)$ with $j = 1$ to N_k to the left of the contour L_k . The condition for absolute convergence of multiple Mellin-Barnes type contour (1.9) can be obtained by extension of the corresponding conditions for multivariable H-function given by as :

$$|arg z_k| < \frac{1}{2} B_i^{(k)} \pi, \text{ where}$$

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The complex numbers z_i are not zero. Throughout this document, we assume the existence and absolute convergence conditions of the multivariable Aleph-function.

We may establish the the asymptotic expansion in the following convenient form :

$$\aleph(z_1, \dots, z_s) = O(|z_1|^{\alpha'_1}, \dots, |z_s|^{\alpha'_s}), \max(|z_1|, \dots, |z_s|) \rightarrow 0$$

$$\aleph(z_1, \dots, z_s) = O(|z_1|^{\beta'_1}, \dots, |z_s|^{\beta'_s}), \min(|z_1|, \dots, |z_s|) \rightarrow \infty$$

where, with $k = 1, \dots, s, z : \alpha'_k = \min[Re(b_j^{(k)} / \beta_j^{(k)})], j = 1, \dots, M_k$ and

$$\beta'_k = \max[Re((a_j^{(k)} - 1) / \alpha_j^{(k)})], j = 1, \dots, N_k$$

We will use these following notations in this paper

$$U = P_i, Q_i, l_i; r'; V = M_1, N_1; \dots; M_s, N_s \tag{1.15}$$

$$W = P_{i(1)}, Q_{i(1)}, l_{i(1)}; r^{(1)}, \dots, P_{i(r)}, Q_{i(r)}, l_{i(s)}; r^{(s)} \tag{1.16}$$

$$A = \{(u_j; \mu_j^{(1)}, \dots, \mu_j^{(s)})_{1,N}\}, \{l_i(u_{ji}; \mu_{ji}^{(1)}, \dots, \mu_{ji}^{(s)})_{N+1, P_i}\} \tag{1.17}$$

$$B = \{l_i(v_{ji}; v_{ji}^{(1)}, \dots, v_{ji}^{(s)})_{M+1, Q_i}\} \tag{1.18}$$

$$C = (a_j^{(1)}; \alpha_j^{(1)})_{1, N_1}, l_{i(1)}(a_{ji(1)}^{(1)}; \alpha_{ji(1)}^{(1)})_{N_1+1, P_{i(1)}}, \dots, (a_j^{(s)}; \alpha_j^{(s)})_{1, N_s}, l_{i(s)}(a_{ji(s)}^{(s)}; \alpha_{ji(s)}^{(s)})_{N_s+1, P_{i(s)}} \tag{1.19}$$

$$D = (b_j^{(1)}; \beta_j^{(1)})_{1, M_1}, l_{i(1)}(b_{ji(1)}^{(1)}; \beta_{ji(1)}^{(1)})_{M_1+1, Q_{i(1)}}, \dots, (b_j^{(s)}; \beta_j^{(s)})_{1, M_s}, l_{i(s)}(\beta_{ji(s)}^{(s)}; \beta_{ji(s)}^{(s)})_{M_s+1, Q_{i(s)}} \tag{1.20}$$

The multivariable Aleph-function write :

$$\aleph(z_1, \dots, z_s) = \aleph_{U:W}^{0, N; V} \left(\begin{matrix} z_1 \\ \cdot \\ \cdot \\ z_s \end{matrix} \middle| \begin{matrix} A : C \\ \cdot \\ \cdot \\ B : D \end{matrix} \right) \tag{1.21}$$

The generalized polynomials defined by Srivastava [6], is given in the following manner :

$$S_{N_1, \dots, N_t}^{M_1, \dots, M_t} [y_1, \dots, y_t] = \sum_{K_1=0}^{[N_1/M_1]} \dots \sum_{K_t=0}^{[N_t/M_t]} \frac{(-N_1)_{M_1 K_1}}{K_1!} \dots \frac{(-N_t)_{M_t K_t}}{K_t!}$$

$$A[N_1, K_1; \dots; N_t, K_t] y_1^{K_1} \dots y_t^{K_t} \tag{1.22}$$

Where M_1, \dots, M_s are arbitrary positive integers and the coefficients $A[N_1, K_1; \dots; N_t, K_t]$ are arbitrary constants, real or complex. In the present paper, we use the following notation

$$a_1 = \frac{(-N_1)_{M_1 K_1}}{K_1!} \dots \frac{(-N_t)_{M_t K_t}}{K_t!} A[N_1, K_1; \dots; N_t, K_t] \tag{1.23}$$

The Riemann Zeta-function given by Goyal and Laddha [1] is defined by

$$\phi_u [z, s, a', g] = \sum_{g=0}^{\infty} (u)_g (a' + g)^{-s} \frac{z^g}{g!}, u \geq 1, |z| < 1, Re(a') > 0 \tag{1.24}$$

In the document , we note :

$$G(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) = \phi(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \theta_1(\eta_{G_1, g_1}) \dots \theta_r(\eta_{G_r, g_r}) \tag{1.25}$$

where $\phi(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}), \theta_1(\eta_{G_1, g_1}), \dots, \theta_r(\eta_{G_r, g_r})$ are given respectively in (1.2) and (1.3)

2. Required integral

We have the following result , Marichev et al ([2], 2.2.8, eq.1 page 306)

Lemme

$$\int_a^b \frac{(x-a)^{\alpha-1}(b-x)^{\beta-1}(x+z)^m}{(cx+d)^{\alpha+\beta+n}} dx = \frac{(b-a)^{\alpha+\beta-1}}{(bc+d)^\alpha(ac+d)^\beta} \sum_{k=0}^n \frac{B(\alpha+k, \beta+n-k)}{(bc+d)^k(ac+d)^{n-k}}$$

$$\sum_{l=0}^l \binom{m}{l} \binom{n-m}{k-l} (b+z)^l (a+z)^{m-l}, \text{ where } (ac+d)(bc+d) > 0, \text{Re}(\alpha) > 0, \text{Re}(\beta) > 0 \quad (2.1)$$

3. main integral

Let $G_i = \frac{(b-a)^{\eta_i+\epsilon_1}}{(bc+d)^{\eta_i}(ac+d)^{\epsilon_i}}, i = 1, \dots, s$

We have the following formula

$$\int_a^b \frac{(x-a)^{\alpha-1}(b-x)^{\beta-1}(x+z)^m}{(cx+d)^{\alpha+\beta+n}} \phi_u \left(z \frac{(x-a)^A(b-x)^B}{(cx+d)^{A+B}} \right) S_{N_1, \dots, N_t}^{M_1, \dots, M_t} \left(\begin{matrix} y_1 \frac{(x-a)^{\gamma_1}(b-x)^{\mu_1}}{(cx+d)^{\gamma_1+\mu_1}} \\ \vdots \\ y_t \frac{(x-a)^{\gamma_t}(b-x)^{\mu_t}}{(cx+d)^{\gamma_t+\mu_t}} \end{matrix} \right)$$

$$N_{u:w}^{0, n:v} \left(\begin{matrix} Z_1 \frac{(x-a)^{\alpha_1}(b-x)^{\beta_1}}{(cx+d)^{\alpha_1+\beta_1}} \\ \vdots \\ Z_r \frac{(x-a)^{\alpha_r}(b-x)^{\beta_r}}{(cx+d)^{\alpha_r+\beta_r}} \end{matrix} \right) N_{U:W}^{0, N:V} \left(\begin{matrix} Z_1 \frac{(x-a)^{\eta_1}(b-x)^{\epsilon_1}}{(cx+d)^{\eta_1+\epsilon_1}} \\ \vdots \\ Z_s \frac{(x-a)^{\eta_s}(b-x)^{\epsilon_s}}{(cx+d)^{\eta_s+\epsilon_s}} \end{matrix} \right) dx$$

$$= \frac{(b-a)^{\alpha+\beta-1}}{(bc+d)^\alpha(ac+d)^\beta} \sum_{g=0}^{\infty} \sum_{G_1, \dots, G_r=0}^{\infty} \sum_{g_1=0}^{m_1} \dots \sum_{g_r=0}^{m_r} \sum_{K_1=0}^{[N_1/M_1]} \dots \sum_{K_t=0}^{[N_t/M_t]} \sum_{k=0}^n \sum_{l=0}^k \frac{(u)_g (a'+g)^{-s}}{g!}$$

$$\frac{(-)^{G_1+\dots+G_r}}{\delta_{g_1} G_1! \dots \delta_{g_r} G_r!} G(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \binom{m}{l} \binom{n-m}{k-l} (b+z)^l (a+z)^{m-l} y_1^{K_1} \dots y_t^{K_t}$$

$$z_1^{\eta_{G_1, g_1}} \dots z_r^{\eta_{G_r, g_r}} z^g (b-a)^{(A+B)g + \sum_{i=1}^t K_i(\gamma_i + \mu_i) + \sum_{i=1}^r (\alpha_i + \beta_i)\eta_{G_i, g_i}}$$

$$(bc+d)^{-Ag - \sum_{i=1}^t \gamma_i K_i - \sum_{i=1}^r \alpha_i \eta_{G_i, g_i}} (ac+d)^{k-n-Bg - \sum_{i=1}^t \mu_i K_i - \sum_{i=1}^r \beta_i \eta_{G_i, g_i}} N_{U:W}^{0, N+2:V} \left(\begin{matrix} G_1 Z_1 \\ \vdots \\ G_s Z_s \end{matrix} \right)$$

$$(1-k-\alpha - Ag - \sum_{i=1}^t K_i \gamma_i - \sum_{i=1}^r \eta_{G_i, g_i} \alpha_i; \eta_1, \dots, \eta_s),$$

$$(1-n-\alpha - \beta - (A+B)g - \sum_{i=1}^t K_i(\gamma_i + \mu_i) - \sum_{i=1}^r \eta_{G_i, g_i}(\alpha_i + \beta_i); \eta_1 + \epsilon_1, \dots, \eta_s + \epsilon_s),$$

$$(1+k-n-\beta - Bg - \sum_{i=1}^t K_i \mu_i - \sum_{i=1}^r \eta_{G_i, g_i} \beta_i; \epsilon_1, \dots, \epsilon_s), A : C \Bigg) \quad (3.1)$$

$$\begin{matrix} \vdots \\ \vdots \\ B : D \end{matrix}$$

where $U_{21} = P_i + 2; Q_i + 1; \mu_i; r'$

Provided that

a) $\min\{\alpha, \beta, \gamma_i, \mu_i, \alpha_j, \beta_j, \eta_k, \epsilon_k\} > 0, i = 1, \dots, t, j = 1, \dots, r, k = 1, \dots, s,$

b) $Re[\alpha + gA + \sum_{i=1}^r \alpha_i \min_{1 \leq j \leq m_i} \frac{d_j^{(i)}}{\delta_j^{(i)}} + \sum_{i=1}^s \eta_i \min_{1 \leq j \leq M_i} \frac{b_j^{(i)}}{\beta_j^{(i)}}] > 0$

c) $Re[\beta + gB + \sum_{i=1}^r \beta_i \min_{1 \leq j \leq m_i} \frac{d_j^{(i)}}{\delta_j^{(i)}} + \sum_{i=1}^s \epsilon_i \min_{1 \leq j \leq M_i} \frac{b_j^{(i)}}{\beta_j^{(i)}}] > 0$

c) $|arg z_k| < \frac{1}{2} A_i^{(k)} \pi,$ where $A_i^{(k)}$ is defined by (1.5); $i = 1, \dots, r$

d) $|arg Z_k| < \frac{1}{2} B_i^{(k)} \pi,$ where $B_i^{(k)}$ is defined by (1.13); $i = 1, \dots, s$

e) $(ac + d)(bc + d) > 0$

Proof

Expressing the general sequence of functions $\phi_u[z, s, a', g]$ with the help of equation (1.24), the Aleph-function of r variables in series with the help of equation (1.6), the general class of polynomial of several variables $S_{N_1, \dots, N_t}^{M_1, \dots, M_t}$ with the help of equation (1.22) and the Aleph-function of s variables in Mellin-Barnes contour integral with the help of equation (1.9), changing the order of integration and summation (which is easily seen to be justified due to the absolute convergence of the integral and the summations involved in the process) and then evaluating the resulting integral with the help of equation (2.1). Finally interpreting the result thus obtained with the Mellin-barnes contour integral, we arrive at the desired result.

4. Multivariable I-function

If $l_i, l_{i(1)}, \dots, l_{i(s)} \rightarrow 1$, the Aleph-function of several variables degenerate to the I-function of several variables. The simple integral have been derived in this section for multivariable I-functions defined by Sharma et al [6].

Corollary 1

$$\int_a^b \frac{(x-a)^{\alpha-1} (b-x)^{\beta-1} (x+z)^m}{(cx+d)^{\alpha+\beta+n}} \phi_u \left(z \frac{(x-a)^A (b-x)^B}{(cx+d)^{A+B}} \right) S_{N_1, \dots, N_t}^{M_1, \dots, M_t} \left(\begin{matrix} Y_1 \frac{(x-a)^{\gamma_1} (b-x)^{\mu_1}}{(cx+d)^{\gamma_1+\mu_1}} \\ \vdots \\ Y_t \frac{(x-a)^{\gamma_t} (b-x)^{\mu_t}}{(cx+d)^{\gamma_t+\mu_t}} \end{matrix} \right)$$

$$I_{u:w}^{0,n:v} \left(\begin{matrix} Z_1 \frac{(x-a)^{\alpha_1} (b-x)^{\beta_1}}{(cx+d)^{\alpha_1+\beta_1}} \\ \vdots \\ Z_r \frac{(x-a)^{\alpha_r} (b-x)^{\beta_r}}{(cx+d)^{\alpha_r+\beta_r}} \end{matrix} \right) I_{U:W}^{0,N:V} \left(\begin{matrix} Z_1 \frac{(x-a)^{\eta_1} (b-x)^{\epsilon_1}}{(cx+d)^{\eta_1+\epsilon_1}} \\ \vdots \\ Z_s \frac{(x-a)^{\eta_s} (b-x)^{\epsilon_s}}{(cx+d)^{\eta_s+\epsilon_s}} \end{matrix} \right) dx$$

$$= \frac{(b-a)^{\alpha+\beta-1}}{(bc+d)^\alpha (ac+d)^\beta} \sum_{g=0}^\infty \sum_{G_1, \dots, G_r=0}^\infty \sum_{g_1=0}^{m_1} \dots \sum_{g_r=0}^{m_r} \sum_{K_1=0}^{[N_1/M_1]} \dots \sum_{K_t=0}^{[N_t/M_t]} \sum_{k=0}^n \sum_{l=0}^k \frac{(u)_g (a'+g)^{-s}}{g!}$$

$$\frac{(-)^{G_1+\dots+G_r}}{\delta_{g_1} G_1! \dots \delta_{g_r} G_r!} G(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \binom{m}{l} \binom{n-m}{k-l} (b+z)^l (a+z)^{m-l} y_1^{K_1} \dots y_t^{K_t}$$

$$z_1^{\eta_{G_1, g_1}} \dots z_r^{\eta_{G_r, g_r}} z^g (b-a)^{(A+B)g + \sum_{i=1}^t K_i(\gamma_i + \mu_i) + \sum_{i=1}^r (\alpha_i + \beta_i) \eta_{G_i, g_i}}$$

$$(bc+d)^{-Ag - \sum_{i=1}^t \gamma_i K_i - \sum_{i=1}^r \alpha_i \eta_{G_i, g_i}} (ac+d)^{k-n-Bg - \sum_{i=1}^t \mu_i K_i - \sum_{i=1}^r \beta_i \eta_{G_i, g_i}} I_{U_{21}:W}^{0, N+2:V} \left(\begin{array}{c} G_1 Z_1 \\ \dots \\ G_s Z_s \end{array} \right)$$

$$(1-k-\alpha - Ag - \sum_{i=1}^t K_i \gamma_i - \sum_{i=1}^r \eta_{G_i, g_i} \alpha_i; \eta_1, \dots, \eta_s),$$

$$(1-n-\alpha - \beta - (A+B)g - \sum_{i=1}^t K_i(\gamma_i + \mu_i) - \sum_{i=1}^r \eta_{G_i, g_i}(\alpha_i + \beta_i); \eta_1 + \epsilon_1, \dots, \eta_s + \epsilon_s),$$

$$(1+k-n-\beta - Bg - \sum_{i=1}^t K_i \mu_i - \sum_{i=1}^r \eta_{G_i, g_i} \beta_i; \epsilon_1, \dots, \epsilon_s), A : C \Bigg) \quad (4.1)$$

$$\dots$$

$$B : D$$

under the same notations and conditions that (3.1) with $l_i, l_{i(1)}, \dots, l_{i(s)} \rightarrow 1$

5. Aleph-function of two variables

If $s = 2$, we obtain the Aleph-function of two variables defined by K.Sharma [8], and we have the following simple integrals.

Corollary 2

$$\int_a^b \frac{(x-a)^{\alpha-1} (b-x)^{\beta-1} (x+z)^m}{(cx+d)^{\alpha+\beta+n}} \phi_u \left(z \frac{(x-a)^A (b-x)^B}{(cx+d)^{A+B}} \right) S_{N_1, \dots, N_t}^{M_1, \dots, M_t} \left(\begin{array}{c} y_1 \frac{(x-a)^{\gamma_1} (b-x)^{\mu_1}}{(cx+d)^{\gamma_1 + \mu_1}} \\ \dots \\ y_t \frac{(x-a)^{\gamma_t} (b-x)^{\mu_t}}{(cx+d)^{\gamma_t + \mu_t}} \end{array} \right)$$

$$N_{u:w}^{0, n:v} \left(\begin{array}{c} Z_1 \frac{(x-a)^{\alpha_1} (b-x)^{\beta_1}}{(cx+d)^{\alpha_1 + \beta_1}} \\ \dots \\ Z_r \frac{(x-a)^{\alpha_r} (b-x)^{\beta_r}}{(cx+d)^{\alpha_r + \beta_r}} \end{array} \right) N_{U:W}^{0, N:V} \left(\begin{array}{c} Z_1 \frac{(x-a)^{\eta_1} (b-x)^{\epsilon_1}}{(cx+d)^{\eta_1 + \epsilon_1}} \\ \dots \\ Z_2 \frac{(x-a)^{\eta_2} (b-x)^{\epsilon_2}}{(cx+d)^{\eta_2 + \epsilon_2}} \end{array} \right) dx$$

$$\begin{aligned}
 &= \frac{(b-a)^{\alpha+\beta-1}}{(bc+d)^\alpha (ac+d)^\beta} \sum_{g=0}^{\infty} \sum_{G_1, \dots, G_r=0}^{\infty} \sum_{g_1=0}^{m_1} \dots \sum_{g_r=0}^{m_r} \sum_{K_1=0}^{[N_1/M_1]} \dots \sum_{K_t=0}^{[N_t/M_t]} \sum_{k=0}^n \sum_{l=0}^k \frac{(u)_g (a'+g)^{-s}}{g!} \\
 &\frac{(-)^{G_1+\dots+G_r}}{\delta_{g_1} G_1! \dots \delta_{g_r} G_r!} G(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \binom{m}{l} \binom{n-m}{k-l} (b+z)^l (a+z)^{m-l} y_1^{K_1} \dots y_t^{K_t} \\
 &z_1^{\eta_{G_1, g_1}} \dots z_r^{\eta_{G_r, g_r}} z^g (b-a)^{(A+B)g + \sum_{i=1}^t K_i(\gamma_i + \mu_i) + \sum_{i=1}^r (\alpha_i + \beta_i)\eta_{G_i, g_i}} \\
 &(bc+d)^{-Ag - \sum_{i=1}^t \gamma_i K_i - \sum_{i=1}^r \alpha_i \eta_{G_i, g_i}} (ac+d)^{k-n-Bg - \sum_{i=1}^t \mu_i K_i - \sum_{i=1}^r \beta_i \eta_{G_i, g_i}} \mathfrak{N}_{U:W}^{0, N+2; V} \left(\begin{matrix} G_1 Z_1 \\ \dots \\ G_2 Z_2 \end{matrix} \right) \\
 &(1-k-\alpha - Ag - \sum_{i=1}^t K_i \gamma_i - \sum_{i=1}^r \eta_{G_i, g_i} \alpha_i; \eta_1, \eta_2), \\
 &\dots \\
 &(1-n-\alpha - \beta - (A+B)g - \sum_{i=1}^t K_i(\gamma_i + \mu_i) - \sum_{i=1}^r \eta_{G_i, g_i}(\alpha_i + \beta_i); \eta_1 + \epsilon_1, \eta_2 + \epsilon_2), \\
 &(1+k-n-\beta - Bg - \sum_{i=1}^t K_i \mu_i - \sum_{i=1}^r \eta_{G_i, g_i} \beta_i; \epsilon_1, \epsilon_2), A : C \\
 &\quad \quad \quad \begin{matrix} \dots \\ B : D \end{matrix} \quad \quad \quad (5.1)
 \end{aligned}$$

under the same conditions and notation that (3.1) with $s = 2$

6. I-function of two variables

If $l_i, l'_i, l''_i \rightarrow 1$, then the Aleph-function of two variables degenerate in the I-function of two variables defined by sharma et al [7] and we obtain the same formula with the I-function of two variables.

Corollary 3

$$\begin{aligned}
 &\int_a^b \frac{(x-a)^{\alpha-1} (b-x)^{\beta-1} (x+z)^m}{(cx+d)^{\alpha+\beta+n}} \phi_u \left(z \frac{(x-a)^A (b-x)^B}{(cx+d)^{A+B}} \right) S_{N_1, \dots, N_t}^{M_1, \dots, M_t} \left(\begin{matrix} y_1 \frac{(x-a)^{\gamma_1} (b-x)^{\mu_1}}{(cx+d)^{\gamma_1 + \mu_1}} \\ \dots \\ y_t \frac{(x-a)^{\gamma_t} (b-x)^{\mu_t}}{(cx+d)^{\gamma_t + \mu_t}} \end{matrix} \right) \\
 &\mathfrak{N}_{u:w}^{0, n; v} \left(\begin{matrix} Z_1 \frac{(x-a)^{\alpha_1} (b-x)^{\beta_1}}{(cx+d)^{\alpha_1 + \beta_1}} \\ \dots \\ Z_r \frac{(x-a)^{\alpha_r} (b-x)^{\beta_r}}{(cx+d)^{\alpha_r + \beta_r}} \end{matrix} \right) I_{U:W}^{0, N; V} \left(\begin{matrix} Z_1 \frac{(x-a)^{\eta_1} (b-x)^{\epsilon_1}}{(cx+d)^{\eta_1 + \epsilon_1}} \\ \dots \\ Z_2 \frac{(x-a)^{\eta_2} (b-x)^{\epsilon_2}}{(cx+d)^{\eta_2 + \epsilon_2}} \end{matrix} \right) dx
 \end{aligned}$$

$$\begin{aligned}
 &= \frac{(b-a)^{\alpha+\beta-1}}{(bc+d)^\alpha(ac+d)^\beta} \sum_{g=0}^{\infty} \sum_{G_1, \dots, G_r=0}^{\infty} \sum_{g_1=0}^{m_1} \dots \sum_{g_r=0}^{m_r} \sum_{K_1=0}^{[N_1/M_1]} \dots \sum_{K_t=0}^{[N_t/M_t]} \sum_{k=0}^n \sum_{l=0}^k \frac{(u)_g (a'+g)^{-s}}{g!} \\
 &\frac{(-)^{G_1+\dots+G_r}}{\delta_{g_1} G_1! \dots \delta_{g_r} G_r!} G(\eta_{G_1, g_1}, \dots, \eta_{G_r, g_r}) \binom{m}{l} \binom{n-m}{k-l} (b+z)^l (a+z)^{m-l} y_1^{K_1} \dots y_t^{K_t} \\
 &z_1^{\eta_{G_1, g_1}} \dots z_r^{\eta_{G_r, g_r}} z^g (b-a)^{(A+B)g + \sum_{i=1}^t K_i(\gamma_i + \mu_i) + \sum_{i=1}^r (\alpha_i + \beta_i)\eta_{G_i, g_i}} \\
 &(bc+d)^{-Ag - \sum_{i=1}^t \gamma_i K_i - \sum_{i=1}^r \alpha_i \eta_{G_i, g_i}} (ac+d)^{k-n-Bg - \sum_{i=1}^t \mu_i K_i - \sum_{i=1}^r \beta_i \eta_{G_i, g_i}} I_{U_{21}:W}^{0, N+2; V} \left(\begin{matrix} G_1 Z_1 \\ \dots \\ G_2 Z_2 \end{matrix} \middle| \right. \\
 &\quad (1-k-\alpha - Ag - \sum_{i=1}^t K_i \gamma_i - \sum_{i=1}^r \eta_{G_i, g_i} \alpha_i; \eta_1, \eta_2), \\
 &\quad (1-n-\alpha - \beta - (A+B)g - \sum_{i=1}^t K_i(\gamma_i + \mu_i) - \sum_{i=1}^r \eta_{G_i, g_i}(\alpha_i + \beta_i); \eta_1 + \epsilon_1, \eta_2 + \epsilon_2), \\
 &\quad (1+k-n-\beta - Bg - \sum_{i=1}^t K_i \mu_i - \sum_{i=1}^r \eta_{G_i, g_i} \beta_i; \epsilon_1, \epsilon_2), A : C \\
 &\quad \left. \begin{matrix} \dots \\ B : D \end{matrix} \right) \tag{6.1}
 \end{aligned}$$

under the same conditions and notation that (3.1) with $s = 2$ and $\iota_i, \iota'_i, \iota''_i \rightarrow 1$

7. Conclusion

In this paper we have evaluated a integral involving the multivariable Aleph-functions, a class of polynomials of several variables and the generalized Zeta-function. The integral established in this paper is of very general nature as it contains Multivariable Aleph-function, which is a general function of several variables studied so far. Thus, the integral established in this research work would serve as a key formula from which, upon specializing the parameters, as many as desired results involving the special functions of one and several variables can be obtained.

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