# NAG C Library Function Document

# nag_real_polygamma (s14aec)

## 1 Purpose

nag_real_polygamma (s14aec) returns the value of the $k$th derivative of the psi function $\psi(x)$ for real $x$ and $k = 0, 1, \ldots, 6$.

## 2 Specification

```
double nag_real_polygamma (double x, Integer k, NagError *fail)
```

## 3 Description

This routine evaluates an approximation to the $k$th derivative of the psi function $\psi(x)$ given by

$$\psi^{(k)}(x) = \frac{d^k}{dx^k}\psi(x) = \frac{d^k}{dx^k}\left(\frac{d}{dx}\log_e\Gamma(x)\right),$$

where $x$ is real with $x \neq 0, -1, -2, \ldots$ and $k = 0, 1, \ldots, 6$. For negative non-integer values of $x$, the recurrence relationship

$$\psi^{(k)}(x+1) = \psi^{(k)}(x) + \frac{d^k}{dx^k}\left(\frac{1}{x}\right)$$

is used. The value of $\frac{(-1)^{k+1}\psi^{(k)}(x)}{k!}$ is obtained by a call to a routine based on PSIFN in Amos (1983).

Note that $\psi^{(k)}(x)$ is also known as the *polygamma* function. Specifically, $\psi^{(0)}(x)$ is often referred to as the *digamma* function and $\psi^{(1)}(x)$ as the *trigamma* function in the literature. Further details can be found in Abramowitz and Stegun (1972).

## 4 Parameters

1: **x** – double *Input*

*On entry:* the argument $x$ of the function.

*Constraint:* **x** must not be 'too close' (see Section 5) to a non-positive integer.

2: **k** – Integer *Input*

*On entry:* the function $\psi^{(k)}(z)$ to be evaluated.

*Constraint:* $0 \leq \mathbf{k} \leq 6$.

3: **fail** – NagError * *Input/Output*

The NAG error parameter (see the Essential Introduction).

## 5 Error Indicators and Warnings

**NE_INT**

On entry, **k** = <*value*>.
Constraint: $0 \leq \mathbf{k} \leq 6$.

**NE_REAL**

On entry, **x** = <*value*>.
Constraint: **x** must not be 'too close' to a non-positive integer. That is, $|x - \text{nint}(x)| \geq$ ***machine precision*** $\times \text{nint}(x)$

**NE_UNDERFLOW_LIKELY**

The evaluation has been abandoned due to the likelihood of underflow. The result is returned as zero.

**NE_OVERFLOW_LIKELY**

The evaluation has been abandoned due to the likelihood of overflow. The result is returned as zero.

**NE_INTERNAL_ERROR**

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please consult NAG for assistance.

# 6 Further Comments

## 6.1 Accuracy

All constants in the underlying functions are given to approximately 18 digits of precision. If $t$ denotes the number of digits of precision in the floating-point arithmetic being used, then clearly the maximum number in the results obtained is limited by $p = \min(t, 18)$. Empirical tests by Amos (1983) have shown that the maximum relative error is a loss of approximately two decimal places of precision. Further tests with the function $-\psi^{(0)}(x)$ have shown somewhat improved accuracy, except at points near the positive zero of $\psi^{(0)}(x)$ at $x = 1.46\ldots$, where only absolute accuracy can be obtained.

## 6.2 References

Amos D E (1983) Algorithm 610: A portable FORTRAN subroutine for derivatives of the psi function *ACM Trans. Math. Software* **9** 494–502

Abramowitz M and Stegun I A (1972) *Handbook of Mathematical Functions* Dover Publications (3rd Edition)

# 7 See Also

None.

# 8 Example

The example program evaluates $\psi^{(2)}(x)$ at $x = 2.5$, and prints the results.

## 8.1 Program Text

```
/* nag_real_polygamma (s14aec) Example Program.
 *
 * Copyright 2000 Numerical Algorithms Group.
 *
 * NAG C Library
 *
 * Mark 6, 2000.
 */

#include <stdio.h>
#include <nag.h>
```

```
#include <nag_stdlib.h>
#include <nags.h>

int main(void)
{
  double x, y;
  Integer exit_status=0;
  NagError fail;
  Integer k;

  INIT_FAIL(fail);

  Vprintf("s14aec Example Program Results\n\n");
  /*  Skip heading in data file */
  Vscanf("%*[^\n]");
  Vprintf("\n   X      K    (D^K/DX^K)psi(X)\n\n\n");

  while(scanf("%lf %ld%*[^\n]", &x, &k) != EOF)
    {
      y = s14aec  (x, k, &fail);
      if (fail.code == NE_NOERROR)
        Vprintf("%5.1f %5ld     %12.4e\n",  x, k, y);
      else
        {
          Vprintf("Error from s14aec.\n%s\n", fail.message);
          exit_status = 1;
          goto END;
        }
    }
 END:
  return exit_status;
}
```

## 8.2 Program Data

```
s14aec Example Program Data
 1.0   0
 0.5   1
-3.6   2
 8.0   3
 2.9   4
-4.7   5
-5.4   6  : Values of x and k
```

## 8.3 Program Results

```
s14aec Example Program Results


   X      K    (D^K/DX^K)psi(X)

  1.0     0      -5.7722e-01
  0.5     1       4.9348e+00
 -3.6     2      -2.2335e+01
  8.0     3       4.6992e-03
  2.9     4      -1.5897e-01
 -4.7     5       1.6566e+05
 -5.4     6       4.1378e+05
```