

# NAG Library Function Document

## nag\_elliptic\_integral\_F (s21bec)

### 1 Purpose

nag\_elliptic\_integral\_F (s21bec) returns a value of the classical (Legendre) form of the incomplete elliptic integral of the first kind.

### 2 Specification

```
#include <nag.h>
#include <nags.h>
double nag_elliptic_integral_F (double phi, double dm, NagError *fail)
```

### 3 Description

nag\_elliptic\_integral\_F (s21bec) calculates an approximation to the integral

$$F(\phi | m) = \int_0^\phi (1 - m \sin^2 \theta)^{-\frac{1}{2}} d\theta,$$

where  $0 \leq \phi \leq \frac{\pi}{2}$ ,  $m \sin^2 \phi \leq 1$  and  $m$  and  $\sin \phi$  may not both equal one.

The integral is computed using the symmetrised elliptic integrals of Carlson (Carlson (1979) and Carlson (1988)). The relevant identity is

$$F(\phi | m) = R_F(q, r, 1) \sin \phi,$$

where  $q = \cos^2 \phi$ ,  $r = 1 - m \sin^2 \phi$  and  $R_F$  is the Carlson symmetrised incomplete elliptic integral of the first kind (see nag\_elliptic\_integral\_rf (s21bbc)).

### 4 References

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

Carlson B C (1979) Computing elliptic integrals by duplication *Numerische Mathematik* **33** 1–16

Carlson B C (1988) A table of elliptic integrals of the third kind *Math. Comput.* **51** 267–280

### 5 Arguments

1:	<b>phi</b> – double	<i>Input</i>
2:	<b>dm</b> – double	<i>Input</i>

*On entry:* the arguments  $\phi$  and  $m$  of the function.

*Constraints:*

$0.0 \leq \mathbf{phi} \leq \frac{\pi}{2}$ ;  
 $\mathbf{dm} \times \sin^2(\mathbf{phi}) \leq 1.0$ ;  
 Only one of  $\sin(\mathbf{phi})$  and  $\mathbf{dm}$  may be 1.0.

Note that  $\mathbf{dm} \times \sin^2(\mathbf{phi}) = 1.0$  is allowable, as long as  $\mathbf{dm} \neq 1.0$ .

- 3: **fail** – NagError \* *Input/Output*  
 The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

## 6 Error Indicators and Warnings

### NE\_ALLOC\_FAIL

Dynamic memory allocation failed.  
 See Section 3.2.1.2 in How to Use the NAG Library and its Documentation for further information.

### 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 contact NAG for assistance.

An unexpected error has been triggered by this function. Please contact NAG.  
 See Section 3.6.6 in How to Use the NAG Library and its Documentation for further information.

### NE\_NO\_LICENCE

Your licence key may have expired or may not have been installed correctly.  
 See Section 3.6.5 in How to Use the NAG Library and its Documentation for further information.

### NE\_REAL

On entry, **phi** =  $\langle value \rangle$ .  
 Constraint:  $0 \leq \mathbf{phi} \leq \frac{\pi}{2}$ .  
 On failure, the function returns zero.

### NE\_REAL\_2

On entry, **phi** =  $\langle value \rangle$  and **dm** =  $\langle value \rangle$ ; the integral is undefined.  
 Constraint:  $\mathbf{dm} \times \sin^2(\mathbf{phi}) \leq 1.0$ .  
 On failure, the function returns zero.

### NW\_INTEGRAL\_INFINITE

On entry,  $\sin(\mathbf{phi}) = 1$  and **dm** = 1.0; the integral is infinite.  
 On failure, the function returns the largest machine number (see `nag_real_largest_number` (X02ALC)).

## 7 Accuracy

In principle `nag_elliptic_integral_F` (s21bec) is capable of producing full *machine precision*. However round-off errors in internal arithmetic will result in slight loss of accuracy. This loss should never be excessive as the algorithm does not involve any significant amplification of round-off error. It is reasonable to assume that the result is accurate to within a small multiple of the *machine precision*.

## 8 Parallelism and Performance

`nag_elliptic_integral_F` (s21bec) is not threaded in any implementation.

## 9 Further Comments

You should consult the s Chapter Introduction, which shows the relationship between this function and the Carlson definitions of the elliptic integrals. In particular, the relationship between the argument-constraints for both forms becomes clear.

For more information on the algorithm used to compute  $R_F$ , see the function document for `nag_elliptic_integral_rf` (s21bbc).

If you wish to input a value of **phi** outside the range allowed by this function you should refer to Section 17.4 of Abramowitz and Stegun (1972) for useful identities. For example,  $F(-\phi|m) = -F(\phi|m)$  and  $F(s\pi \pm \phi|m) = 2sK(m) \pm F(\phi|m)$  where  $s$  is an integer and  $K(m)$  is the complete elliptic integral given by `nag_elliptic_integral_complete_K` (s21bhc).

A parameter  $m > 1$  can be replaced by one less than unity using  $F(\phi|m) = \frac{1}{\sqrt{m}}F(\theta|\frac{1}{m})$ ,  $\sin \theta = \sqrt{m} \sin \phi$ .

## 10 Example

This example simply generates a small set of nonextreme arguments that are used with the function to produce the table of results.

### 10.1 Program Text

```

/* nag_elliptic_integral_F (s21bec) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */
/* Pre-processor includes */
#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nags.h>
#include <nagx01.h>

int main(void)
{
    /*Integer scalar and array declarations */
    Integer exit_status = 0;
    Integer ix;
    /*Double scalar and array declarations */
    double dm, f, phi, pi;
    NagError fail;

    INIT_FAIL(fail);

    printf("%s\n", "nag_elliptic_integral_F (s21bec) Example Program Results");
    printf("\n");
    printf("%s\n", "    phi      dm      nag_elliptic_integral_F");
    printf("\n");
    pi = nag_pi;
    for (ix = 1; ix <= 3; ix++) {
        phi = ix * pi / 6.00e0;
        dm = ix * 0.250e0;
        /*
         * nag_elliptic_integral_F (s21bec)
         * Elliptic integral of 1st kind, Legendre form, F( phi |m)
         */
        f = nag_elliptic_integral_F(phi, dm, &fail);
        if (fail.code != NE_NOERROR) {
            printf("Error from nag_elliptic_integral_F (s21bec).\n%s\n",
                fail.message);
            exit_status = 1;
            goto END;
        }
    }
    printf("%7.2f%7.2f%12.4f\n", phi, dm, f);
}

```

END:

```
    return exit_status;  
}
```

## 10.2 Program Data

None.

## 10.3 Program Results

nag\_elliptic\_integral\_F (s21bec) Example Program Results

phi	dm	nag_elliptic_integral_F
0.52	0.25	0.5294
1.05	0.50	1.1424
1.57	0.75	2.1565

**Example Program**  
Classical (Legendre) Form of the Incomplete Elliptic Integral of the First Kind

