NAG Toolbox

nag_specfun_fresnel_s (s20ac)

1 Purpose

nag_specfun_fresnel_s (s20ac) returns a value for the Fresnel integral $S(x)$, via the function name.

2 Syntax

```
[result, ifail] = nag_specfun_fresnel_s(x)
[result, ifail] = s20ac(x)
```

3 Description

nag_specfun_fresnel_s (s20ac) evaluates an approximation to the Fresnel integral

$$S(x) = \int_0^x \sin\left(\frac{\pi}{2}t^2\right) dt.$$

Note: $S(x) = -S(-x)$, so the approximation need only consider $x \geq 0.0$.

The function is based on three Chebyshev expansions:

For $0 < x \leq 3$,

$$S(x) = x^3 \sum_{r=0} a_r T_r(t), \qquad \text{with } t = 2\left(\frac{x}{3}\right)^4 - 1.$$

For $x > 3$,

$$S(x) = \frac{1}{2} - \frac{f(x)}{x}\cos\left(\frac{\pi}{2}x^2\right) - \frac{g(x)}{x^3}\sin\left(\frac{\pi}{2}x^2\right),$$

where $f(x) = \sum_{r=0} b_r T_r(t)$,

and $g(x) = \sum_{r=0} c_r T_r(t)$,

with $t = 2\left(\frac{3}{x}\right)^4 - 1$.

For small x, $S(x) \simeq \frac{\pi}{6}x^3$. This approximation is used when x is sufficiently small for the result to be correct to ***machine precision***. For very small x, this approximation would underflow; the result is then set exactly to zero.

For large x, $f(x) \simeq \frac{1}{\pi}$ and $g(x) \simeq \frac{1}{\pi^2}$. Therefore for moderately large x, when $\frac{1}{\pi^2 x^3}$ is negligible compared with $\frac{1}{2}$, the second term in the approximation for $x > 3$ may be dropped. For very large x, when $\frac{1}{\pi x}$ becomes negligible, $S(x) \simeq \frac{1}{2}$. However there will be considerable difficulties in calculating $\cos\left(\frac{\pi}{2}x^2\right)$ accurately before this final limiting value can be used. Since $\cos\left(\frac{\pi}{2}x^2\right)$ is periodic, its value is essentially determined by the fractional part of x^2. If $x^2 = N + \theta$ where N is an integer and $0 \leq \theta < 1$, then $\cos\left(\frac{\pi}{2}x^2\right)$ depends on θ and on N modulo 4. By exploiting this fact, it is possible to retain significance in the calculation of $\cos\left(\frac{\pi}{2}x^2\right)$ either all the way to the very large x limit, or at least until the integer part of $\frac{x}{2}$ is equal to the maximum integer allowed on the machine.

4 References

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

5 Parameters

5.1 Compulsory Input Parameters

1: **x** – REAL (KIND=nag_wp)

The argument x of the function.

5.2 Optional Input Parameters

None.

5.3 Output Parameters

1: **result**

The result of the function.

2: **ifail** – INTEGER

ifail $= 0$ unless the function detects an error (see Section 5).

6 Error Indicators and Warnings

There are no failure exits from nag_specfun_fresnel_s (s20ac). The argument **ifail** has been included for consistency with other functions in this chapter.

7 Accuracy

Let δ and ϵ be the relative errors in the argument and result respectively.

If δ is somewhat larger than the ***machine precision*** (i.e., if δ is due to data errors etc.), then ϵ and δ are approximately related by:

$$\epsilon \simeq \left|\frac{x\sin\left(\frac{\pi}{2}x^2\right)}{S(x)}\right|\delta.$$

Figure 1 shows the behaviour of the error amplification factor $\left|\frac{x\sin\left(\frac{\pi}{2}x^2\right)}{S(x)}\right|$.

However if δ is of the same order as the ***machine precision***, then rounding errors could make ϵ slightly larger than the above relation predicts.

For small x, $\epsilon \simeq 3\delta$ and hence there is only moderate amplification of relative error. Of course for very small x where the correct result would underflow and exact zero is returned, relative error-control is lost.

For moderately large values of x,

$$|\epsilon| \simeq \left|2x\sin\left(\frac{\pi}{2}x^2\right)\right||\delta|$$

and the result will be subject to increasingly large amplification of errors. However the above relation breaks down for large values of x (i.e., when $\frac{1}{x^2}$ is of the order of the ***machine precision***); in this region the relative error in the result is essentially bounded by $\frac{2}{\pi x}$.

Hence the effects of error amplification are limited and at worst the relative error loss should not exceed half the possible number of significant figures.

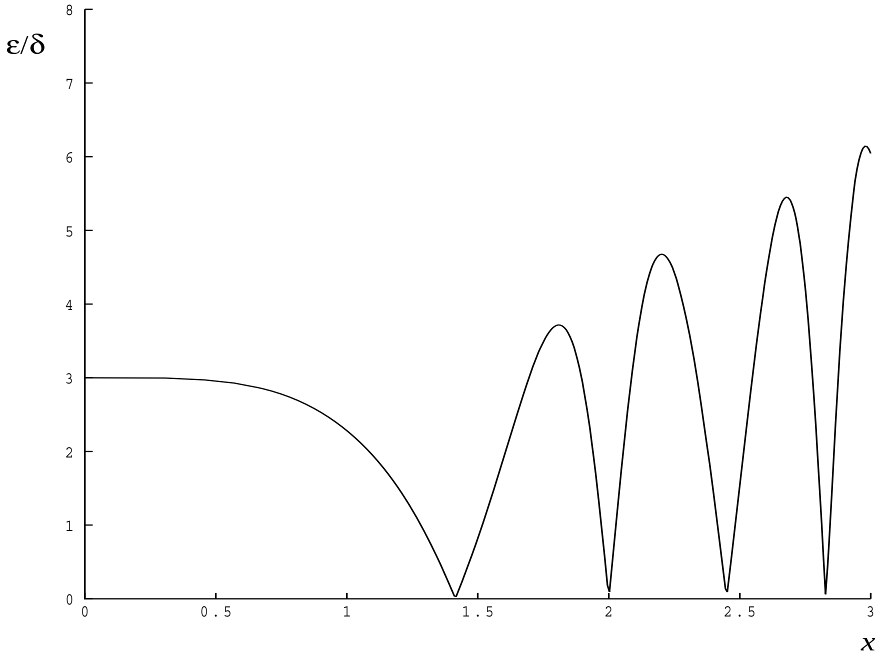

Figure 1

8 Further Comments

None.

9 Example

This example reads values of the argument x from a file, evaluates the function at each value of x and prints the results.

9.1 Program Text

```
     function s20ac_example

fprintf('s20ac example results\n\n');

x = [0   0.5   1   2   4   5   6   8   10   -1   1000];
n = size(x,2);
result = x;

for j=1:n
  [result(j), ifail] = s20ac(x(j));
end

disp('      x          S(x)');
fprintf('%12.3e%12.3e\n',[x; result]);

s20ac_plot;

function s20ac_plot
  x = [-10:0.02:10];
  for j = 1:numel(x)
    [S(j), ifail] = s20ac(x(j));
  end

  fig1 = figure;
  plot(x,S,'-r');
```

```
xlabel('x');
ylabel('S(x)');
title('Fresnel Integral S(x)');

% print(fig1,'-dpng','-r75','s20ac_fig1.png');
% print(fig1,'-deps','-r75','s20ac_fig1.eps');
```

9.2 Program Results

```
    s20ac example results

     x           S(x)
  0.000e+00   0.000e+00
  5.000e-01   6.473e-02
  1.000e+00   4.383e-01
  2.000e+00   3.434e-01
  4.000e+00   4.205e-01
  5.000e+00   4.992e-01
  6.000e+00   4.470e-01
  8.000e+00   4.602e-01
  1.000e+01   4.682e-01
 -1.000e+00  -4.383e-01
  1.000e+03   4.997e-01
```