NAG Toolbox for Matlab

s17ae

1 Purpose
s17ae returns the value of the Bessel Function $J_0(x)$, via the function name.

2 Syntax

*[result, ifail] = s17ae(x)*

3 Description
s17ae evaluates an approximation to the Bessel Function of the first kind $J_0(x)$.

**Note:** $J_0(-x) = J_0(x)$, so the approximation need only consider $x \geq 0$.

The function is based on three Chebyshev expansions:

For $0 < x \leq 8$,

$$J_0(x) = \sum_{r=0}^{\infty} a_r T_r(t), \quad \text{with } t = 2 \left(\frac{x}{8}\right)^2 - 1.$$

For $x > 8$,

$$J_0(x) = \sqrt{2 \pi x} \left\{ P_0(x) \cos\left(x - \frac{\pi}{4}\right) - Q_0(x) \sin\left(x - \frac{\pi}{4}\right) \right\},$$

where $P_0(x) = \sum_{r=0}^{\infty} b_r T_r(t)$,

and $Q_0(x) = \frac{8}{x} \sum_{r=0}^{\infty} c_r T_r(t)$,

with $t = 2 \left(\frac{x}{8}\right)^2 - 1$.

For $x$ near zero, $J_0(x) \approx 1$. This approximation is used when $x$ is sufficiently small for the result to be correct to machine precision.

For very large $x$, it becomes impossible to provide results with any reasonable accuracy (see Section 7), hence the function fails. Such arguments contain insufficient information to determine the phase of oscillation of $J_0(x)$; only the amplitude, $\sqrt{\frac{2}{\pi|x|}}$, can be determined and this is returned on soft failure.

The range for which this occurs is roughly related to machine precision; the function will fail if $|x| \geq \frac{1}{\text{machine precision}}$.

4 References

Clenshaw C W (1962) Chebyshev Series for Mathematical Functions *Mathematical tables* HMSO

5 Parameters

5.1 Compulsory Input Parameters

1:  $x$ – double scalar

   The argument $x$ of the function.
5.2 Optional Input Parameters

None.

5.3 Input Parameters Omitted from the MATLAB Interface

None.

5.4 Output Parameters

1: result – double scalar

The result of the function.

2: ifail – int32 scalar

ifail = 0 unless the function detects an error (see Section 6).

6 Error Indicators and Warnings

Errors or warnings detected by the function:

ifail = 1

x is too large. On soft failure the function returns the amplitude of the \( J_0 \) oscillation, \( \sqrt{\frac{2}{\pi|x|}} \).

7 Accuracy

Let \( \delta \) be the relative error in the argument and \( E \) be the absolute error in the result. (Since \( J_0(x) \) oscillates about zero, absolute error and not relative error is significant.)

If \( \delta \) is somewhat larger than the machine precision (e.g., if \( \delta \) is due to data errors etc.), then \( E \) and \( \delta \) are approximately related by:

\[ E \simeq |xJ_1(x)|\delta \]

(provided \( E \) is also within machine bounds). Figure 1 displays the behaviour of the amplification factor \( |xJ_1(x)| \).

However, if \( \delta \) is of the same order as machine precision, then rounding errors could make \( E \) slightly larger than the above relation predicts.

For very large \( x \), the above relation ceases to apply. In this region, \( J_0(x) \simeq \sqrt{\frac{2}{\pi|x|}} \cos\left(x - \frac{\pi}{4}\right) \). The amplitude \( \sqrt{\frac{2}{\pi|x|}} \) can be calculated with reasonable accuracy for all \( x \), but \( \cos\left(x - \frac{\pi}{4}\right) \) cannot. If \( x - \frac{\pi}{4} \) is written as \( 2N\pi + \theta \) where \( N \) is an integer and \( 0 \leq \theta < 2\pi \), then \( \cos\left(x - \frac{\pi}{4}\right) \) is determined by \( \theta \) only. If \( x \gtrsim \delta^{-1} \), \( \theta \) cannot be determined with any accuracy at all. Thus if \( x \) is greater than, or of the order of, the inverse of the machine precision, it is impossible to calculate the phase of \( J_0(x) \) and the function must fail.
8 Further Comments

None.

9 Example

```matlab
x = 0;
[result, ifail] = s17ae(x)
result = 1
ifail = 0
```