

# NAG C Library

## Library Contents

\* This function will be withdrawn at Mark 8.

### Chapter a00 – Library Identification

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### Chapter a02 – Complex Arithmetic

a02bac nag\_complex  
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a02bbc nag\_complex\_real  
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a02bcc nag\_complex\_imag  
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a02cac nag\_complex\_add  
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a02cbc nag\_complex\_subtract  
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a02ccc nag\_complex\_multiply  
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a02cdc nag\_complex\_divide  
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a02cfc nag\_complex\_conjg  
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a02cgc nag\_complex\_equal  
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a02dac nag\_complex\_arg  
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a02ddc nag\_complex\_i\_power  
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a02dec nag\_complex\_r\_power  
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a02dfc nag\_complex\_c\_power  
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a02dgc nag\_complex\_log  
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a02dhc nag\_complex\_exp  
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a02dkc nag\_complex\_cos  
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a02dlc nag\_complex\_tan  
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- c02afc nag\_zeros\_complex\_poly  
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- c02agc nag\_zeros\_real\_poly  
Zeros of a polynomial with real coefficients
- c02akc nag\_cubic\_roots  
Zeros of a cubic polynomial with real coefficients
- c02alc nag\_quartic\_roots  
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**Chapter c05 – Roots of One or More Transcendental Equations**

- c05adc nag\_zero\_cont\_func\_bd  
Zero of a continuous function of one variable
- c05nbc nag\_zero\_nonlin\_eqns  
Solution of a system of nonlinear equations (function values only)
- c05pbc nag\_zero\_nonlin\_eqns\_deriv  
Solution of a system of nonlinear equations (using first derivatives)
- c05sdc nag\_zero\_cont\_func\_bd\_1  
Zero of a continuous function of one variable, thread-safe
- c05tbc nag\_zero\_nonlin\_eqns\_1  
Solution of a system of nonlinear equations (function values only), thread-safe
- c05ubc nag\_zero\_nonlin\_eqns\_deriv\_1  
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- c05zbc nag\_check\_deriv  
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- c05zcc nag\_check\_deriv\_1  
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- c06eac nag\_fft\_real  
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- c06ebc nag\_fft\_hermitian  
Single 1-D Hermitian discrete Fourier transform
- c06ecc nag\_fft\_complex  
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- c06ekc nag\_convolution\_real  
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- c06fpc nag\_fft\_multiple\_real  
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- c06fqc nag\_fft\_multiple\_hermitian  
Multiple 1-D Hermitian discrete Fourier transforms
- c06frc nag\_fft\_multiple\_complex  
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- c06fuc nag\_fft\_2d\_complex  
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- c06gbc nag\_conjugate\_hermitian  
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- c06gcc nag\_conjugate\_complex  
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- c06gqc nag\_multiple\_conjugate\_hermitian  
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- c06gsc nag\_multiple\_hermitian\_to\_complex  
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- c06gzc nag\_fft\_init\_trig  
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c06hac nag\_fft\_multiple\_sine  
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c06hcc nag\_fft\_multiple\_qtr\_sine  
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d01ajc nag\_1d\_quad\_gen  
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d01akc nag\_1d\_quad\_osc  
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d01alc nag\_1d\_quad\_brkpts  
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d01amc nag\_1d\_quad\_inf  
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d01anc nag\_1d\_quad\_wt\_trig  
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d01apc nag\_1d\_quad\_wt\_alglog  
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d01aqc nag\_1d\_quad\_wt\_cauchy  
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d01asc nag\_1d\_quad\_inf\_wt\_trig  
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d01bac nag\_1d\_quad\_guass  
1-D Gaussian quadrature rule evaluation  
d01fcc nag\_multid\_quad\_adapt  
Multi-dimensional adaptive quadrature  
d01gac nag\_1d\_quad\_vals  
1-D integration of a function defined by data values only  
d01gbc nag\_multid\_quad\_monte\_carlo  
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d01sjc nag\_1d\_quad\_gen\_1  
1-D adaptive quadrature, allowing for badly-behaved integrands, thread-safe  
d01skc nag\_1d\_quad\_osc\_1  
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d01slc nag\_1d\_quad\_brkpts\_1  
1-D adaptive quadrature, allowing for singularities at specified points, thread-safe  
d01smc nag\_1d\_quad\_inf\_1  
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d01snc nag\_1d\_quad\_wt\_trig\_1  
1-D adaptive quadrature, finite interval, sine or cosine weight functions, thread-safe  
d01spc nag\_1d\_quad\_wt\_alglog\_1  
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d01sqc nag\_1d\_quad\_wt\_cauchy\_1  
1-D adaptive quadrature, weight function  $1/(x - c)$ , Cauchy principal value, thread-safe  
d01ssc nag\_1d\_quad\_inf\_wt\_trig\_1  
1-D adaptive quadrature, semi-infinite interval, sine or cosine weight function, thread-safe  
d01tac nag\_1d\_quad\_guass\_1  
1-D Gaussian quadrature rule evaluation, thread-safe  
d01wcc nag\_multid\_quad\_adapt\_1  
Multi-dimensional adaptive quadrature, thread-safe

d01xbc nag\_multid\_quad\_monte\_carlo\_1  
Multi-dimensional quadrature, using Monte Carlo method, thread-safe

## Chapter d02 – Ordinary Differential Equations

d02cjc nag\_ode\_ivp\_adams\_gen  
Ordinary differential equation solver using a variable-order variable-step Adams method (Black Box)

d02ejc nag\_ode\_ivp\_bdf\_gen  
Ordinary differential equations solver, stiff, initial value problems using the Backward Differentiation Formulae

d02gac nag\_ode\_bvp\_fd\_nonlin\_fixedbc  
Ordinary differential equations solver, for simple nonlinear two-point boundary value problems, using a finite difference technique with deferred correction

d02gbc nag\_ode\_bvp\_fd\_lin\_gen  
Ordinary differential equations solver, for general linear two-point boundary value problems, using a finite difference technique with deferred correction

d02pcc nag\_ode\_ivp\_rk\_range  
Ordinary differential equations solver, initial value problems over a range using Runge–Kutta methods

d02pdc nag\_ode\_ivp\_rk\_onestep  
Ordinary differential equations solver, initial value problems, one time step using Runge–Kutta methods

d02ppc nag\_ode\_ivp\_rk\_free  
Freeing function for use with the Runge–Kutta suite (d02p functions)

d02pvc nag\_ode\_ivp\_rk\_setup  
Set-up function for use with nag\_ode\_ivp\_rk\_range (d02pcc) and/or nag\_ode\_ivp\_rk\_onestep (d02pdc)

d02pwc nag\_ode\_ivp\_rk\_reset\_tend  
A function to re-set the end point following a call to nag\_ode\_ivp\_rk\_onestep (d02pdc)

d02pxc nag\_ode\_ivp\_rk\_interp  
Ordinary differential equations solver, computes the solution by interpolation anywhere on an integration step taken by nag\_ode\_ivp\_rk\_onestep (d02pdc)

d02pzc nag\_ode\_ivp\_rk\_errass  
A function to provide global error assessment during an integration with either nag\_ode\_ivp\_rk\_range (d02pcc) or nag\_ode\_ivp\_rk\_onestep (d02pdc)

d02qfc nag\_ode\_ivp\_adams\_roots  
Ordinary differential equation solver using Adams method (sophisticated use)

d02qwc nag\_ode\_ivp\_adams\_setup  
Set-up function for nag\_ode\_ivp\_adams\_roots (d02qfc)

d02qyc nag\_ode\_ivp\_adams\_free  
Freeing function for use with nag\_ode\_ivp\_adams\_roots (d02qfc)

d02qzc nag\_ode\_ivp\_adams\_interp  
Interpolation function for use with nag\_ode\_ivp\_adams\_roots (d02qfc)

d02rac nag\_ode\_bvp\_fd\_nonlin\_gen  
Ordinary differential equations solver, for general nonlinear two-point boundary value problems, using a finite difference technique with deferred correction

## Chapter e01 – Interpolation

e01bac nag\_ld\_spline\_interpolant  
Interpolating function, cubic spline interpolant, one variable

e01bec nag\_monotonic\_interpolant  
Interpolating function, monotonicity-preserving, peicewise cubic Hermite, one variable

e01bfc nag\_monotonic\_evaluate  
Evaluation of interpolant computed by nag\_monotonic\_interpolant (e01bec), function only

e01bgc	nag_monotonic_deriv	Evaluation of interpolant computed by nag_monotonic_interpolant (e01bec), function and first derivative
e01bhc	nag_monotonic_intg	Evaluation of interpolant computed by nag_monotonic_interpolant (e01bec), definite integral
e01dac	nag_2d_spline_interpolant	Interpolating function, bicubic spline interpolant, two variables
e01sac	nag_2d_scatter_interpolant	A function to generate a two-dimensional surface interpolating a set of data points, using either the method of Renka and Cline or using the modified Shepard's method
e01sbc	nag_2d_scatter_eval	A function to evaluate, at a set of points, the two-dimensional interpolant function generated by nag_2d_scatter_interpolant (e01sac)
e01szc	nag_2d_scatter_free	Freeing function for use with nag_2d_scatter_eval (e01sbc)

## Chapter e02 – Curve and Surface Fitting

e02adc	nag_1d_cheb_fit	Computes the coefficients of a Chebyshev series polynomial for arbitrary data
e02aec	nag_1d_cheb_eval	Evaluates the coefficients of a Chebyshev series polynomial
e02afc	nag_1d_cheb_interp_fit	Computes the coefficients of a Chebyshev series polynomial for interpolated data
e02bac	nag_1d_spline_fit_knots	Least-squares curve cubic spline fit (including interpolation), one variable
e02bbc	nag_1d_spline_evaluate	Evaluation of fitted cubic spline, function only
e02bcc	nag_1d_spline_deriv	Evaluation of fitted cubic spline, function and derivatives
e02bdc	nag_1d_spline_intg	Evaluation of fitted cubic spline, definite integral
e02bec	nag_1d_spline_fit	Least-squares cubic spline curve fit, automatic knot placement, one variable
e02dcc	nag_2d_spline_fit_grid	Least-squares bicubic spline fit with automatic knot placement, two variables (rectangular grid)
e02ddc	nag_2d_spline_fit_scatter	Least-squares bicubic spline fit with automatic knot placement, two variables (scattered data)
e02dec	nag_2d_spline_eval	Evaluation of bicubic spline, at a set of points
e02dfc	nag_2d_spline_eval_rect	Evaluation of bicubic spline, at a mesh of points

## Chapter e04 – Minimizing or Maximizing a Function

e04abc	nag_opt_one_var_no_deriv	Minimizes a function of one variable, using function values only
e04bbc	nag_opt_one_var_deriv	Minimizes a function of one variable, requires first derivatives
e04ccc	nag_opt_simplex	Unconstrained minimization using simplex algorithm
e04dgc	nag_opt_conj_grad	Unconstrained minimization using conjugate gradients
e04fcc	nag_opt_lsqr_no_deriv	Unconstrained nonlinear least squares (no derivatives required)
e04gbc	nag_opt_lsqr_deriv	Unconstrained nonlinear least squares (first derivatives required)

e04hcc	nag_opt_check_deriv	Checks 1st derivatives of a user-defined function
e04hdc	nag_opt_check_2nd_deriv	Checks 2nd derivatives of a user-defined function
* e04jbc	nag_opt_bounds_no_deriv	Bound constrained nonlinear minimization (no derivatives required)
* e04kbc	nag_opt_bounds_deriv	Bound constrained nonlinear minimization (first derivatives required)
e04lbc	nag_opt_bounds_2nd_deriv	Solves bound constrained problems. 1st and 2nd derivatives are required
e04mfc	nag_opt_lp	Linear programming
e04myc	nag_opt_sparse_mps_free	Free memory allocated by nag_opt_sparse_mps_read (e04mzc)
e04mzc	nag_opt_sparse_mps_read	Read MPSX data for sparse LP or QP problem from a file
e04ncc	nag_opt_lin_lsq	Solves linear least-squares and convex quadratic programming problems (non-sparse)
e04nfc	nag_opt_qp	Quadratic programming
e04nkc	nag_opt_sparse_convex_qp	Solves sparse linear programming or convex quadratic programming problems
e04ucc	nag_opt_nlp	Minimization with nonlinear constraints using a sequential QP method
e04ugc	nag_opt_nlp_sparse	NLP problem (sparse)
e04unc	nag_opt_nlin_lsq	Solves nonlinear least-squares problems using the sequential QP method
e04xac	nag_opt_estimate_deriv	Computes an approximation to the gradient vector and/or the Hessian matrix for use with nag_opt_nlp (e04ucc) and other nonlinear optimization functions
e04xxc	nag_opt_init	Initialisation function for option setting
e04xyc	nag_opt_read	Read options from a text file
e04xzc	nag_opt_free	Memory freeing function for use with option setting
e04yac	nag_opt_lsq_check_deriv	Least-squares derivative checker for use with nag_opt_lsq_deriv (e04gbc)
e04ycc	nag_opt_lsq_covariance	Covariance matrix for nonlinear least-squares

## Chapter f – Linear Algebra

f01bnc	nag_complex_cholesky	$UU^H$ factorization of complex Hermitian positive-definite matrix
f01mcc	nag_real_cholesky_skyline	$LDL^T$ factorization of real symmetric positive-definite variable-bandwidth (skyline) matrix
f01qcc	nag_real_qr	$QR$ factorization of real $m$ by $n$ matrix ( $m \geq n$ )
f01qdc	nag_real_apply_q	Compute $QB$ or $Q^TB$ after factorization by nag_real_qr (f01qcc)
f01qec	nag_real_form_q	Form columns of $Q$ after factorization by nag_real_qr (f01qcc)
f01rcc	nag_complex_qr	$QR$ factorization of complex $m$ by $n$ matrix ( $m \geq n$ )
f01rdc	nag_complex_apply_q	Compute $QB$ or $Q^HB$ after factorization by nag_complex_qr (f01rcc)

f01rec	nag_complex_form_q	Form columns of $Q$ after factorization by nag_complex_qr (f01rcc)
f02aac	nag_real_symm_eigenvalues	All eigenvalues of real symmetric matrix
f02abc	nag_real_symm_eigensystem	All eigenvalues and eigenvectors of real symmetric matrix
f02adc	nag_real_symm_general_eigenvalues	All eigenvalues of generalized real symmetric-definite eigenproblem
f02aec	nag_real_symm_general_eigensystem	All eigenvalues and eigenvectors of generalized real symmetric-definite eigenproblem
f02afc	nag_real_eigenvalues	All eigenvalues of real matrix
f02agc	nag_real_eigensystem	All eigenvalues and eigenvectors of real matrix
f02awc	nag_hermitian_eigenvalues	All eigenvalues of complex Hermitian matrix
f02axc	nag_hermitian_eigensystem	All eigenvalues and eigenvectors of complex Hermitian matrix
f02bjc	nag_real_general_eigensystem	All eigenvalues and optionally eigenvectors of real generalized eigenproblem, by $QZ$ algorithm
f02ecc	nag_real_eigensystem_sel	Computes selected eigenvalues and eigenvectors of a real general matrix
f02gcc	nag_complex_eigensystem_sel	Computes selected eigenvalues and eigenvectors of a complex general matrix
f02wec	nag_real_svd	SVD of real matrix
f02xec	nag_complex_svd	SVD of complex matrix
f03aec	nag_real_cholesky	$LL^T$ factorization and determinant of real symmetric positive-definite matrix
f03afc	nag_real_lu	$LU$ factorization and determinant of real matrix
f03ahc	nag_complex_lu	$LU$ factorization and determinant of complex matrix
f04adc	nag_complex_lin_eqn_mult_rhs	Approximate solution of complex simultaneous linear equations with multiple right-hand sides
f04agc	nag_real_cholesky_solve_mult_rhs	Approximate solution of real symmetric positive-definite simultaneous linear equations (coefficient matrix already factorized by nag_real_cholesky (f03aec))
f04ajc	nag_real_lu_solve_mult_rhs	Approximate solution of real simultaneous linear equations (coefficient matrix already factorized by nag_real_lu (f03afc))
f04akc	nag_complex_lu_solve_mult_rhs	Approximate solution of complex simultaneous linear equations (coefficient matrix already factorized by nag_complex_lu (f03ahc))
f04arc	nag_real_lin_eqn	Approximate solution of real simultaneous linear equations, one right-hand side
f04awc	nag_hermitian_lin_eqn_mult_rhs	Approximate solution of complex Hermitian positive-definite simultaneous linear equations (coefficient matrix already factorized by nag_complex_cholesky (f01bnc))
f04mcc	nag_real_cholesky_skyline_solve	Approximate solution of real symmetric positive-definite variable-bandwidth simultaneous linear equations (coefficient matrix already factorized by nag_real_cholesky_skyline (f01mcc))

## Chapter f06 – Linear Algebra Support Functions

f06pac	dgemv	Matrix-vector product, real rectangular matrix
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f06pbc	dgbmv	Matrix-vector product, real rectangular band matrix
f06pcc	dsymv	Matrix-vector product, real symmetric matrix
f06pdc	dsbmv	Matrix-vector product, real symmetric band matrix
f06pec	dspmv	Matrix-vector product, real symmetric packed matrix
f06pfc	dtrmv	Matrix-vector product, real triangular matrix
f06pgc	dtbmv	Matrix-vector product, real triangular band matrix
f06phc	dtpmv	Matrix-vector product, real triangular packed matrix
f06pjc	dtrsv	System of equations, real triangular matrix
f06pkc	dtbsv	System of equations, real triangular band matrix
f06plc	dtpsv	System of equations, real triangular packed matrix
f06pmc	dger	Rank-1 update, real rectangular matrix
f06ppc	dsyr	Rank-1 update, real symmetric matrix
f06pqc	dspr	Rank-1 update, real symmetric packed matrix
f06prc	dsyr2	Rank-2 update, real symmetric matrix
f06psc	dspr2	Rank-2 update, real symmetric packed matrix
f06sac	zgemv	Matrix-vector product, complex rectangular matrix
f06sbc	zgbmv	Matrix-vector product, complex rectangular band matrix
f06scc	zhemv	Matrix-vector product, complex Hermitian matrix
f06sdc	zhbmv	Matrix-vector product, complex Hermitian band matrix
f06sec	zhpmv	Matrix-vector product, complex Hermitian packed matrix
f06sfc	ztrmv	Matrix-vector product, complex triangular matrix
f06sgc	ztbmv	Matrix-vector product, complex triangular band matrix
f06shc	ztpmv	Matrix-vector product, complex triangular packed matrix
f06sjc	ztrsv	System of equations, complex triangular matrix
f06skc	ztbsv	System of equations, complex triangular band matrix
f06slc	ztpsv	System of equations, complex triangular packed matrix
f06smc	zgeru	Rank-1 update, complex rectangular matrix, unconjugated vector
f06snc	zgerc	Rank-1 update, complex rectangular matrix, conjugated vector
f06spc	zher	Rank-1 update, complex Hermitian matrix

f06sqc	zhpr	Rank-1 update, complex Hermitian packed matrix
f06src	zher2	Rank-2 update, complex Hermitian matrix
f06ssc	zhpr2	Rank-2 update, complex Hermitian packed matrix
f06yac	dgemm	Matrix-matrix product, two real rectangular matrices
f06ycc	dsymm	Matrix-matrix product, one real symmetric matrix, one real rectangular matrix
f06yfc	dtrmm	Matrix-matrix product, one real triangular matrix, one real rectangular matrix
f06yjc	dtrsm	Solves a system of equations with multiple right-hand sides, real triangular coefficient matrix
f06ypc	dsyrk	Rank- $k$ update of a real symmetric matrix
f06yrc	dsyr2k	Rank- $2k$ update of a real symmetric matrix
f06zac	zgemm	Matrix-matrix product, two complex rectangular matrices
f06zcc	zhemm	Matrix-matrix product, one complex Hermitian matrix, one complex rectangular matrix
f06zfc	ztrmm	Matrix-matrix product, one complex triangular matrix, one complex rectangular matrix
f06zjc	ztrsm	Solves system of equations with multiple right-hand sides, complex triangular coefficient matrix
f06zpc	zherk	Rank- $k$ update of a complex Hermitian matrix
f06zrc	zher2k	Rank- $2k$ update of a complex Hermitian matrix
f06ztc	zsymm	Matrix-matrix product, one complex symmetric matrix, one complex rectangular matrix
f06zuc	zsyrk	Rank- $k$ update of a complex symmetric matrix
f06zwc	zsyr2k	Rank- $2k$ update of a complex symmetric matrix

## Chapter f11 – Sparse Linear Algebra

f11dac	nag_sparse_nsym_fac	Incomplete $LU$ factorization (nonsymmetric)
f11dcc	nag_sparse_nsym_fac_sol	Solver with incomplete $LU$ preconditioning (nonsymmetric)
f11dec	nag_sparse_nsym_sol	Solver with Jacobi, SSOR or no preconditioning (nonsymmetric)
f11jac	nag_sparse_sym_chol_fac	Incomplete Cholesky factorization (symmetric)
f11jcc	nag_sparse_sym_chol_sol	Solver with incomplete Cholesky preconditioning (symmetric)
f11jec	nag_sparse_sym_sol	Solver with Jacobi, SSOR, or no preconditioning (symmetric)
f11zac	nag_sparse_nsym_sort	Sparse sort (nonsymmetric)
f11zbc	nag_sparse_sym_sort	Sparse sort (symmetric)

**Chapter g01 – Simple Calculations on Statistical Data**

g01aac	nag_summary_stats_lvar	Mean, variance, skewness, kurtosis etc, one variable, from raw data
g01aec	nag_frequency_table	Frequency table from raw data
g01alc	nag_5pt_summary_stats	Five-point summary (median, hinges and extremes)
g01bjc	nag_binomial_dist	Binomial distribution function
g01bkc	nag_poisson_dist	Poisson distribution function
g01blc	nag_hypergeom_dist	Hypergeometric distribution function
g01cec	nag_deviates_normal_dist	Deviate of Normal distribution function
g01ddc	nag_shapiro_wilk_test	Shapiro and Wilk's $W$ test for Normality
g01dhc	nag_ranks_and_scores	Ranks, Normal scores, approximate Normal scores or exponential (Savage) scores
g01eac	nag_prob_normal	Probabilities for the standard Normal distribution
g01ebc	nag_prob_students_t	Probabilities for Student's $t$ -distribution
g01ecc	nag_prob_chi_sq	Probabilities for $\chi^2$ distribution
g01edc	nag_prob_f_dist	Probabilities for $F$ -distribution
g01eec	nag_prob_beta_dist	Upper and lower tail probabilities and probability density function for the beta distribution
g01efc	nag_gamma_dist	Probabilities for the gamma distribution
g01fac	nag_deviates_normal	Deviates for the Normal distribution
g01fbc	nag_deviates_students_t	Deviates for Student's $t$ -distribution
g01fcc	nag_deviates_chi_sq	Deviates for the $\chi^2$ distribution
g01fdc	nag_deviates_f_dist	Deviates for the $F$ -distribution
g01fec	nag_deviates_beta	Deviates for the beta distribution
g01ffc	nag_deviates_gamma_dist	Deviates for the gamma distribution
g01gbc	nag_prob_non_central_students_t	Computes probabilities for the non-central Student's $t$ -distribution
g01gcc	nag_prob_non_central_chi_sq	Computes probabilities for the non-central $\chi^2$ distribution
g01gdc	nag_prob_non_central_f_dist	Computes probabilities for the non-central $F$ -distribution
g01gec	nag_prob_non_central_beta_dist	Computes probabilities for the non-central beta distribution
g01hac	nag_bivariate_normal_dist	Probability for the bivariate Normal distribution
g01hbc	nag_multi_normal	Computes probabilities for the multivariate Normal distribution

## Chapter g02 – Correlation and Regression Analysis

g02brc	nag_ken_spe_corr_coeff	Kendall and/or Spearman non-parametric rank correlation coefficients, allows variables and observations to be selectively disregarded
g02bxc	nag_corr_cov	Product-moment correlation, unweighted/weighted correlation and covariance matrix, allows variables to be disregarded
g02byc	nag_partial_corr	Computes partial correlation/variance-covariance matrix from correlation/variance-covariance matrix computed by nag_corr_cov (g02bxc)
g02cac	nag_simple_linear_regression	Simple linear regression with or without a constant term, data may be weighted
g02cbc	nag_regress_confid_interval	Simple linear regression confidence intervals for the regression line and individual points
g02dac	nag_regsn_mult_linear	Fits a general (multiple) linear regression model
g02dcc	nag_regsn_mult_linear_addrm_obs	Add/delete an observation to/from a general linear regression model
g02ddc	nag_regsn_mult_linear_upd_model	Estimates of regression parameters from an updated model
g02dec	nag_regsn_mult_linear_add_var	Add a new independent variable to a general linear regression model
g02dfc	nag_regsn_mult_linear_delete_var	Delete an independent variable from a general linear regression model
g02dgc	nag_regsn_mult_linear_newyvar	Fits a general linear regression model to new dependent variable
g02dkc	nag_regsn_mult_linear_tran_model	Estimates of parameters of a general linear regression model for given constraints
g02dnc	nag_regsn_mult_linear_est_func	Estimate of an estimable function for a general linear regression model
g02fac	nag_regsn_std_resid_influence	Calculate standardized residuals and influence statistics
g02gac	nag_glm_normal	Fits a generalized linear model with Normal errors
g02gbc	nag_glm_binomial	Fits a generalized linear model with binomial errors
g02gcc	nag_glm_poisson	Fits a generalized linear model with Poisson errors
g02gdc	nag_glm_gamma	Fits a generalized linear model with gamma errors
g02gkc	nag_glm_tran_model	Estimates and standard errors of the parameters of a general linear model for given constraints
g02gnc	nag_glm_est_func	Estimable function and the standard error of a generalized linear model
g02hac	nag_robust_m_regsn_estim	Robust regression, standard $M$ -estimates
g02hkc	nag_robust_corr_estim	Robust estimation of a correlation matrix, Huber's weight function

## Chapter g03 – Multivariate Methods

g03aac	nag_mv_prin_comp	Principal component analysis
g03acc	nag_mv_canon_var	Canonical variate analysis
g03adc	nag_mv_canon_corr	Canonical correlation analysis

g03bac	nag_mv_orthomax Orthogonal rotations for loading matrix
g03bcc	nag_mv_procrustes Procrustes rotations
g03cac	nag_mv_factor Maximum likelihood estimates of parameters
g03ccc	nag_mv_fac_score Factor score coefficients, following nag_mv_factor (g03cac)
g03dac	nag_mv_discrim Test for equality of within-group covariance matrices
g03dbc	nag_mv_discrim_mahaldist Mahalanobis squared distances, following nag_mv_discrim (g03dac)
g03dcc	nag_mv_discrim_group Allocates observations to groups, following nag_mv_discrim (g03dac)
g03eac	nag_mv_distance_mat Compute distance (dissimilarity) matrix
g03ecc	nag_mv_hierar_cluster_analysis Performs hierarchical cluster analysis
g03efc	nag_mv_kmeans_cluster_analysis K-means
g03ehc	nag_mv_dendrogram Construct dendrogram following nag_mv_hierar_cluster_analysis (g03ecc)
g03ejc	nag_mv_cluster_indicator Construct clusters following nag_mv_hierar_cluster_analysis (g03ecc)
g03fac	nag_mv_prin_coord_analysis Principal co-ordinate analysis
g03fcc	nag_mv_ordinal_multidimscale Multidimensional scaling
g03xzc	nag_mv_dend_free Frees memory allocated to the dendrogram array in nag_mv_dendrogram (g03ehc)
g03zac	nag_mv_z_scores Standardize values of a data matrix

## Chapter g04 – Analysis of Variance

g04bbc	nag_anova_random General block design or completely randomized design
g04bcc	nag_anova_row_col Analysis of variance, general row and column design, treatment means and standard errors
g04cac	nag_anova_factorial Complete factorial design
g04czc	nag_anova_factorial_free Memory freeing function for nag_anova_factorial (g04cac)
g04dbc	nag_anova_confid_interval Computes confidence intervals for differences between means computed by nag_anova_random (g04bbc) or nag_anova_row_col (g04bcc)
g04eac	nag_dummy_vars Computes orthogonal polynomials or dummy variables for factor/classification variable

## Chapter g05 – Random Number Generators

g05cac	nag_random_continuous_uniform Pseudo-random real number, uniform distribution over (0,1)
g05cbc	nag_random_init_repeatable Initialise random number generating functions to give repeatable sequence
g05ccc	nag_random_init_nonrepeatable Initialise random number generating functions to give non-repeatable sequence

g05cfc	nag_save_random_state	Save state of random number generating functions
g05cgc	nag_restore_random_state	Restore state of random number generating functions
g05dac	nag_random_continuous_uniform_ab	Pseudo-random real number, uniform distribution over $(a, b)$
g05dbc	nag_random_exp	Pseudo-random real number, (negative) exponential distribution
g05ddc	nag_random_normal	Pseudo-random real number, Normal distribution
g05dyc	nag_random_discrete_uniform	Pseudo-random integer from uniform distribution
g05eac	nag_ref_vec_multi_normal	Set up reference vector for multivariate Normal distribution
g05ecc	nag_ref_vec_poisson	Set up reference vector for generating pseudo-random integers, Poisson distribution
g05edc	nag_ref_vec_binomial	Set up reference vector for generating pseudo-random integers, binomial distribution
g05ehc	nag_ran_permut_vec	Pseudo-random permutation of a vector of integers
g05ejc	nag_ran_sample_vec	Pseudo-random sample without replacement from an integer vector
g05exc	nag_ref_vec_discrete_pdf_cdf	Set up reference vector from supplied cumulative distribution function or probability distribution function
g05eyc	nag_return_discrete	Pseudo-random integer from reference vector
g05ezc	nag_return_multi_normal	Pseudo-random multivariate Normal vector from reference vector
g05fec	nag_random_beta	Pseudo-random real numbers from the beta distribution
g05ffc	nag_random_gamma	Pseudo-random real numbers from the gamma distribution
g05hac	nag_arma_time_series	ARMA time series of $n$ terms
g05hkc	nag_generate_agarchI	Univariate time series, generate $n$ terms of either a symmetric GARCH process or a GARCH process with asymmetry of the form $(\epsilon_{t-1} + \gamma)^2$
g05hlc	nag_generate_agarchII	Univariate time series, generate $n$ terms of a GARCH process with asymmetry of the form $( \epsilon_{t-1}  + \gamma\epsilon_{t-1})^2$
g05hmc	nag_generate_garchGJR	Univariate time series, generate $n$ terms of an asymmetric Glosten, Jagannathan and Runkle (GJR) GARCH process

## Chapter g07 – Univariate Estimation

g07cac	nag_2_sample_t_test	$t$ -test statistic, for a difference in means between two Normal populations, confidence interval
g07dac	nag_median_lvar	Robust estimation, median, median absolute deviation, robust standard deviation
g07dbc	nag_robust_m_estim_lvar	Robust estimation, $M$ -estimate of location and scale parameters, standard weight function
g07ddc	nag_robust_trimmed_lvar	Trimmed and winsorized mean of a sample with estimates of the variances of the two means

**Chapter g08 – Nonparametric Statistics**

- g08aac nag\_sign\_test  
Sign test on two paired samples
- g08acc nag\_median\_test  
Median test on two samples of unequal size
- g08aec nag\_friedman\_test  
Friedman two-way analysis of variance on  $k$  matched samples
- g08afc nag\_kruskal\_wallis\_test  
Kruskal–Wallis one-way analysis of variance on  $k$  samples of unequal size
- g08agc nag\_wilcoxon\_test  
Performs the Wilcoxon one-sample (matched pairs) signed rank test
- g08amc nag\_mann\_whitney  
Performs the Mann–Whitney  $U$  test on two independent samples
- g08cbc nag\_1\_sample\_ks\_test  
Performs the one-sample Kolmogorov–Smirnov test for standard distributions
- g08cdc nag\_2\_sample\_ks\_test  
Performs the two-sample Kolmogorov–Smirnov test
- g08cgc nag\_chi\_sq\_goodness\_of\_fit\_test  
Performs the  $\chi^2$  goodness of fit test, for standard continuous distributions
- g08eac nag\_runs\_test  
Performs the runs up or runs down test for randomness
- g08ebc nag\_pairs\_test  
Performs the pairs (serial) test for randomness
- g08ecc nag\_triplets\_test  
Performs the triplets test for randomness
- g08edc nag\_gaps\_test  
Performs the gaps test for randomness

**Chapter g10 – Smoothing in Statistics**

- g10abc nag\_smooth\_spline\_fit  
Fit cubic smoothing spline, smoothing parameter given
- g10acc nag\_smooth\_spline\_estim  
Fit cubic smoothing spline, smoothing parameter estimated
- g10bac nag\_kernel\_density\_estim  
Kernel density estimate using Gaussian kernel
- g10cac nag\_running\_median\_smoother  
Smoothed data sequence using running median smoother
- g10zac nag\_order\_data  
Reorder data to give ordered distinct observations

**Chapter g11 – Contingency Table Analysis**

- g11aac nag\_chi\_sq\_2\_way\_table  
 $\chi^2$  statistic for two-way contingency table
- g11bac nag\_tabulate\_stats  
Computes multiway table from set of classification factors using selected statistic
- g11bbc nag\_tabulate\_percentile  
Computes multiway table from set of classification factors using given percentile/quantile

**Chapter g12 – Survival Analysis**

- g12aac nag\_prod\_limit\_surviv\_fn  
Kaplan–Meier (product-limit) estimates of survival probabilities
- g12bac nag\_surviv\_cox\_model  
Fits Cox’s proportional hazard model

**Chapter g13 – Time Series Analysis**

- g13abc nag\_tsa\_auto\_corr  
Sample autocorrelation function
- g13acc nag\_tsa\_auto\_corr\_part  
Partial autocorrelation function
- g13asc nag\_tsa\_resid\_corr  
Univariate time series, diagnostic checking of residuals, following  
nag\_tsa\_multi\_inp\_model\_estim (g13bec)
- g13bec nag\_tsa\_multi\_inp\_model\_estim  
Estimation for time series models
- g13bjc nag\_tsa\_multi\_inp\_model\_forecast  
Forecasting function
- g13bxc nag\_tsa\_options\_init  
Initialisation function for option setting
- g13byc nag\_tsa\_transf\_orders  
Allocates memory to transfer function model orders
- g13bzc nag\_tsa\_trans\_free  
Freeing function for the structure holding the transfer function model orders
- g13cbc nag\_tsa\_spectrum\_univar  
Univariate time series, smoothed sample spectrum using spectral smoothing by the trapezium  
frequency (Daniell) window
- g13cdc nag\_tsa\_spectrum\_bivar  
Multivariate time series, smoothed sample cross spectrum using spectral smoothing by the  
trapezium frequency (Daniell) window
- g13cec nag\_tsa\_cross\_spectrum\_bivar  
Multivariate time series, cross amplitude spectrum, squared coherency, bounds, univariate and  
bivariate (cross) spectra
- g13cfc nag\_tsa\_gain\_phase\_bivar  
Multivariate time series, gain, phase, bounds, univariate and bivariate (cross) spectra
- g13cgc nag\_tsa\_noise\_spectrum\_bivar  
Multivariate time series, noise spectrum, bounds, impulse response function and its standard  
error
- g13eac nag\_kalman\_sqrt\_filt\_cov\_var  
One iteration step of the time-varying Kalman filter recursion using the square root covariance  
implementation
- g13ebc nag\_kalman\_sqrt\_filt\_cov\_invar  
One iteration step of the time-invariant Kalman filter recursion using the square root covariance  
implementation with  $(A, C)$  in lower observer Hessenberg form
- g13ecc nag\_kalman\_sqrt\_filt\_info\_var  
One iteration step of the time-varying Kalman filter recursion using the square root information  
implementation
- g13edc nag\_kalman\_sqrt\_filt\_info\_invar  
One iteration step of the time-invariant Kalman filter recursion using the square root information  
implementation with  $(A^{-1}, A^{-1}B)$  in upper controller Hessenberg form
- g13ewc nag\_trans\_hessenberg\_observer  
Unitary state-space transformation to reduce  $(A, C)$  to lower or upper observer Hessenberg form
- g13exc nag\_trans\_hessenberg\_controller  
Unitary state-space transformation to reduce  $(B, A)$  to lower or upper controller Hessenberg form
- g13fac nag\_estimate\_agarchI  
Univariate time series, parameter estimation for either a symmetric GARCH process or a  
GARCH process with asymmetry of the form  $(\epsilon_{t-1} + \gamma)^2$
- g13fbc nag\_forecast\_agarchI  
Univariate time series, forecast function for either a symmetric GARCH process or a GARCH  
process with asymmetry of the form  $(\epsilon_{t-1} + \gamma)^2$
- g13fcc nag\_estimate\_agarchII  
Univariate time series, parameter estimation for a GARCH process with asymmetry of the form  
 $(|\epsilon_{t-1}| + \gamma\epsilon_{t-1})^2$

- g13fdc nag\_forecast\_agarchII  
Univariate time series, forecast function for a GARCH process with asymmetry of the form  $(|\epsilon_{t-1}| + \gamma\epsilon_{t-1})^2$
- g13fec nag\_estimate\_garchGJR  
Univariate time series, parameter estimation for an asymmetric Glosten, Jagannathan and Runkle (GJR) GARCH process
- g13ffc nag\_forecast\_garchGJR  
Univariate time series, forecast function for an asymmetric Glosten, Jagannathan and Runkle (GJR) GARCH process
- g13xzc nag\_tsa\_free  
Freeing function for use with g13 option setting

## Chapter h – Operations Research

- h02bbc nag\_ip\_bb  
Solves integer programming problems using a branch and bound method
- h02buc nag\_ip\_mps\_read  
Read MPSX data for IP, LP or QP problem from a file
- h02bvc nag\_ip\_mps\_free  
Free memory allocated by nag\_ip\_mps\_read (h02buc)
- h02xxc nag\_ip\_init  
Initialise option structure to null values
- h02xyc nag\_ip\_read  
Read optional parameter values from a file
- h02xzc nag\_ip\_free  
Free NAG allocated memory from option structures
- h03abc nag\_transport  
Classical transportation algorithm

## Chapter m01 – Sorting

- m01cac nag\_double\_sort  
Quicksort of set of values of data type double
- m01csc nag\_quicksort  
Quicksort of set of values of arbitrary data type
- m01ctc nag\_stable\_sort  
Stable sort of set of values of arbitrary data type
- m01cuc nag\_chain\_sort  
Chain sort of linked list
- m01dsc nag\_rank\_sort  
Rank sort of set of values of arbitrary data type
- m01esc nag\_reorder\_vector  
Reorders set of values of arbitrary data type into the order specified by a set of indices
- m01fsc nag\_search\_vector  
Searches a vector for either the first or last match to a given value
- m01zac nag\_make\_indices  
Inverts a permutation converting a rank vector to an index vector or vice versa

## Chapter s – Approximations of Special Functions

- s10aac nag\_tanh  
Hyperbolic tangent,  $\tanh x$
- s10abc nag\_sinh  
Hyperbolic sine,  $\sinh x$
- s10acc nag\_cosh  
Hyperbolic cosine,  $\cosh x$
- s11aac nag\_arctanh  
Inverse hyperbolic tangent,  $\operatorname{arctanh} x$

s11abc	nag_arcsinh	Inverse hyperbolic sine, $\operatorname{arcsinh} x$
s11acc	nag_arccosh	Inverse hyperbolic cosine, $\operatorname{arccosh} x$
s13aac	nag_exp_integral	Exponential integral $E_1(x)$
s13acc	nag_cos_integral	Cosine integral $\operatorname{Ci}(x)$
s13adc	nag_sin_integral	Sine integral $\operatorname{Si}(x)$
s14aac	nag_gamma	Gamma function $\Gamma(x)$
s14abc	nag_log_gamma	Log Gamma function $\ln(\Gamma(x))$
s14aec	nag_real_polygamma	Derivative of the psi function $\psi(x)$
s14afc	nag_complex_polygamma	Derivative of the psi function $\psi(z)$
s14bac	nag_incomplete_gamma	Incomplete gamma functions $P(a, x)$ and $Q(a, x)$
s15abc	nag_cumul_normal	Cumulative normal distribution function, $P(x)$
s15acc	nag_cumul_normal_complem	Complement of cumulative normal distribution function, $Q(x)$
s15adc	nag_erfc	Complement of error function, $\operatorname{erfc} x$
s15aec	nag_erf	Error function, $\operatorname{erf} x$
s17acc	nag_bessel_y0	Bessel function $Y_0(x)$
s17adc	nag_bessel_y1	Bessel function $Y_1(x)$
s17aec	nag_bessel_j0	Bessel function $J_0(x)$
s17afc	nag_bessel_j1	Bessel function $J_1(x)$
s17agc	nag_airy_ai	Airy function $\operatorname{Ai}(x)$
s17ahc	nag_airy_bi	Airy function $\operatorname{Bi}(x)$
s17ajc	nag_airy_ai_deriv	Airy function $\operatorname{Ai}'(x)$
s17akc	nag_airy_bi_deriv	Airy function $\operatorname{Bi}'(x)$
s17alc	nag_bessel_zeros	Zeros of Bessel functions $J_\alpha(x)$ , $J'_\alpha(x)$ , $Y_\alpha(x)$ or $Y'_\alpha(x)$
s18acc	nag_bessel_k0	Modified Bessel function $K_0(x)$
s18adc	nag_bessel_k1	Modified Bessel function $K_1(x)$
s18aec	nag_bessel_i0	Modified Bessel function $I_0(x)$
s18afc	nag_bessel_i1	Modified Bessel function $I_1(x)$
s18ccc	nag_bessel_k0_scaled	Scaled modified Bessel function $e^x K_0(x)$
s18cdc	nag_bessel_k1_scaled	Scaled modified Bessel function $e^x K_1(x)$

s18cec	nag_bessel_i0_scaled	Scaled modified Bessel function $e^{- x }I_0(x)$
s18cfc	nag_bessel_i1_scaled	Scaled modified Bessel function $e^{- x }I_1(x)$
s18ecc	nag_bessel_i_nu_scaled	Scaled modified Bessel function $e^{-x}I_{\nu/4}(x)$
s18edc	nag_bessel_k_nu_scaled	Scaled modified Bessel function $e^xK_{\nu/4}(x)$
s18eec	nag_bessel_i_nu	Modified Bessel function $I_{\nu/4}(x)$
s18efc	nag_bessel_k_nu	Modified Bessel function $K_{\nu/4}(x)$
s18egc	nag_bessel_k_alpha	Modified Bessel functions $K_{\alpha+n}(x)$ for real $x > 0$ , selected values of $\alpha \geq 0$ and $n = 0, 1, \dots, N$
s18ehc	nag_bessel_k_alpha_scaled	Scaled modified Bessel functions $e^xK_{\alpha+n}(x)$ for real $x > 0$ , selected values of $\alpha \geq 0$ and $n = 0, 1, \dots, N$
s18ejc	nag_bessel_i_alpha	Modified Bessel functions $I_{\alpha+n-1}(x)$ or $I_{\alpha-n+1}(x)$ for real $x \neq 0$ , non-negative $\alpha < 1$ and $n = 1, 2, \dots,  N  + 1$
s18ekc	nag_bessel_j_alpha	Bessel functions $J_{\alpha+n-1}(x)$ or $J_{\alpha-n+1}(x)$ for real $x \neq 0$ , non-negative $\alpha < 1$ and $n = 1, 2, \dots,  N  + 1$
s19aac	nag_kelvin_ber	Kelvin function ber $x$
s19abc	nag_kelvin_bei	Kelvin function bei $x$
s19acc	nag_kelvin_ker	Kelvin function ker $x$
s19adc	nag_kelvin_kei	Kelvin function kei $x$
s20acc	nag_fresnel_s	Fresnel integral $S(x)$
s20adc	nag_fresnel_c	Fresnel integral $C(x)$
s21bac	nag_elliptic_integral_rc	Degenerate symmetrised elliptic integral of 1st kind $R_C(x, y)$
s21bbc	nag_elliptic_integral_rf	Symmetrised elliptic integral of 1st kind $R_F(x, y, z)$
s21bcc	nag_elliptic_integral_rd	Symmetrised elliptic integral of 2nd kind $R_D(x, y, z)$
s21bdc	nag_elliptic_integral_rj	Symmetrised elliptic integral of 3rd kind $R_J(x, y, z, r)$
s21cbc	nag_jacobian_elliptic	Jacobian elliptic functions sn, cn and dn with complex arguments
s21ccc	nag_jacobian_theta	Jacobian theta functions with real arguments
s21dac	nag_elliptic_integral_f	Elliptic integrals of the second kind with complex arguments
s22aac	nag_legendre_p	Legendre and associated Legendre functions of the first kind with real arguments

**Chapter x01 – Mathematical Constants**

X01AAC nag\_pi  
 $\pi$   
X01ABC nag\_euler\_constant  
Euler's constant,  $\gamma$

**Chapter x02 – Machine Constants**

X02AHC nag\_max\_sine\_argument  
Largest permissible argument for `sin` and `cos` functions  
X02AJC nag\_machine\_precision  
Machine precision  
X02AKC nag\_real\_smallest\_number  
Smallest positive model number  
X02ALC nag\_real\_largest\_number  
Largest positive model number  
X02AMC nag\_real\_safe\_small\_number  
Safe range of floating-point arithmetic  
X02ANC nag\_complex\_safe\_small\_number  
Safe range of NAG complex floating-point arithmetic  
X02BBC nag\_max\_integer  
Largest representable integer  
X02BEC nag\_decimal\_digits  
Maximum number of decimal digits that can be represented  
X02BHC nag\_real\_base  
Parameter  $b$  of model of floating-point arithmetic  
X02BJC nag\_real\_base\_digits  
Parameter  $p$  of model of floating-point arithmetic  
X02BKC nag\_real\_min\_exponent  
Parameter  $e_{\min}$  of model of floating-point arithmetic  
X02BLC nag\_real\_max\_exponent  
Parameter  $e_{\max}$  of model of floating-point arithmetic  
X02DAC nag\_underflow\_flag  
Switch for taking precautions to avoid underflow  
X02DJC nag\_real\_arithmetic\_rounds  
Parameter `ROUNDS` of model of floating-point arithmetic