Computer Programs by Chapter and Section

1.0	`flmoon`	calculate phases of the moon by date
1.1	`julday`	Julian Day number from calendar date
1.1	`badluk`	Friday the 13th when the moon is full
1.1	`caldat`	calendar date from Julian day number
2.1	`gaussj`	Gauss-Jordan matrix inversion and linear equation solution
2.3	`ludcmp`	linear equation solution, LU decomposition
2.3	`lubksb`	linear equation solution, backsubstitution
2.4	`tridag`	solution of tridiagonal systems
2.4	`banmul`	multiply vector by band diagonal matrix
2.4	`bandec`	band diagonal systems, decomposition
2.4	`banbks`	band diagonal systems, backsubstitution
2.5	`mprove`	linear equation solution, iterative improvement
2.6	`svbksb`	singular value backsubstitution
2.6	`svdcmp`	singular value decomposition of a matrix
2.6	`pythag`	calculate $(a^2 + b^2)^{1/2}$ without overflow
2.7	`cyclic`	solution of cyclic tridiagonal systems
2.7	`sprsin`	convert matrix to sparse format
2.7	`sprsax`	product of sparse matrix and vector
2.7	`sprstx`	product of transpose sparse matrix and vector
2.7	`sprstp`	transpose of sparse matrix
2.7	`sprspm`	pattern multiply two sparse matrices
2.7	`sprstm`	threshold multiply two sparse matrices
2.7	`linbcg`	biconjugate gradient solution of sparse systems
2.7	`snrm`	used by `linbcg` for vector norm
2.7	`atimes`	used by `linbcg` for sparse multiplication
2.7	`asolve`	used by `linbcg` for preconditioner
2.8	`vander`	solve Vandermonde systems
2.8	`toeplz`	solve Toeplitz systems
2.9	`choldc`	Cholesky decomposition
2.9	`cholsl`	Cholesky backsubstitution
2.10	`qrdcmp`	QR decomposition
2.10	`qrsolv`	QR backsubstitution
2.10	`rsolv`	right triangular backsubstitution
2.10	`qrupdt`	update a QR decomposition
2.10	`rotate`	Jacobi rotation used by `qrupdt`
3.1	`polint`	polynomial interpolation
3.2	`ratint`	rational function interpolation
3.3	`spline`	construct a cubic spline
3.3	`splint`	cubic spline interpolation
3.4	`locate`	search an ordered table by bisection

3.4	`hunt`	search a table when calls are correlated
3.5	`polcoe`	polynomial coefficients from table of values
3.5	`polcof`	polynomial coefficients from table of values
3.6	`polin2`	two-dimensional polynomial interpolation
3.6	`bcucof`	construct two-dimensional bicubic
3.6	`bcuint`	two-dimensional bicubic interpolation
3.6	`splie2`	construct two-dimensional spline
3.6	`splin2`	two-dimensional spline interpolation
4.2	`trapzd`	trapezoidal rule
4.2	`qtrap`	integrate using trapezoidal rule
4.2	`qsimp`	integrate using Simpson's rule
4.3	`qromb`	integrate using Romberg adaptive method
4.4	`midpnt`	extended midpoint rule
4.4	`qromo`	integrate using open Romberg adaptive method
4.4	`midinf`	integrate a function on a semi-infinite interval
4.4	`midsql`	integrate a function with lower square-root singularity
4.4	`midsqu`	integrate a function with upper square-root singularity
4.4	`midexp`	integrate a function that decreases exponentially
4.5	`qgaus`	integrate a function by Gaussian quadratures
4.5	`gauleg`	Gauss-Legendre weights and abscissas
4.5	`gaulag`	Gauss-Laguerre weights and abscissas
4.5	`gauher`	Gauss-Hermite weights and abscissas
4.5	`gaujac`	Gauss-Jacobi weights and abscissas
4.5	`gaucof`	quadrature weights from orthogonal polynomials
4.5	`orthog`	construct nonclassical orthogonal polynomials
4.6	`quad3d`	integrate a function over a three-dimensional space
5.1	`eulsum`	sum a series by Euler–van Wijngaarden algorithm
5.3	`ddpoly`	evaluate a polynomial and its derivatives
5.3	`poldiv`	divide one polynomial by another
5.3	`ratval`	evaluate a rational function
5.7	`dfridr`	numerical derivative by Ridders' method
5.8	`chebft`	fit a Chebyshev polynomial to a function
5.8	`chebev`	Chebyshev polynomial evaluation
5.9	`chder`	derivative of a function already Chebyshev fitted
5.9	`chint`	integrate a function already Chebyshev fitted
5.10	`chebpc`	polynomial coefficients from a Chebyshev fit
5.10	`pcshft`	polynomial coefficients of a shifted polynomial
5.11	`pccheb`	inverse of `chebpc`; use to economize power series
5.12	`pade`	Padé approximant from power series coefficients
5.13	`ratlsq`	rational fit by least-squares method
6.1	`gammln`	logarithm of gamma function
6.1	`factrl`	factorial function
6.1	`bico`	binomial coefficients function
6.1	`factln`	logarithm of factorial function

6.1	`beta`	beta function
6.2	`gammp`	incomplete gamma function
6.2	`gammq`	complement of incomplete gamma function
6.2	`gser`	series used by `gammp` and `gammq`
6.2	`gcf`	continued fraction used by `gammp` and `gammq`
6.2	`erf`	error function
6.2	`erfc`	complementary error function
6.2	`erfcc`	complementary error function, concise routine
6.3	`expint`	exponential integral E_n
6.3	`ei`	exponential integral Ei
6.4	`betai`	incomplete beta function
6.4	`betacf`	continued fraction used by `betai`
6.5	`bessj0`	Bessel function J_0
6.5	`bessy0`	Bessel function Y_0
6.5	`bessj1`	Bessel function J_1
6.5	`bessy1`	Bessel function Y_1
6.5	`bessy`	Bessel function Y of general integer order
6.5	`bessj`	Bessel function J of general integer order
6.6	`bessi0`	modified Bessel function I_0
6.6	`bessk0`	modified Bessel function K_0
6.6	`bessi1`	modified Bessel function I_1
6.6	`bessk1`	modified Bessel function K_1
6.6	`bessk`	modified Bessel function K of integer order
6.6	`bessi`	modified Bessel function I of integer order
6.7	`bessjy`	Bessel functions of fractional order
6.7	`beschb`	Chebyshev expansion used by `bessjy`
6.7	`bessik`	modified Bessel functions of fractional order
6.7	`airy`	Airy functions
6.7	`sphbes`	spherical Bessel functions j_n and y_n
6.8	`plgndr`	Legendre polynomials, associated (spherical harmonics)
6.9	`frenel`	Fresnel integrals $S(x)$ and $C(x)$
6.9	`cisi`	cosine and sine integrals Ci and Si
6.10	`dawson`	Dawson's integral
6.11	`rf`	Carlson's elliptic integral of the first kind
6.11	`rd`	Carlson's elliptic integral of the second kind
6.11	`rj`	Carlson's elliptic integral of the third kind
6.11	`rc`	Carlson's degenerate elliptic integral
6.11	`ellf`	Legendre elliptic integral of the first kind
6.11	`elle`	Legendre elliptic integral of the second kind
6.11	`ellpi`	Legendre elliptic integral of the third kind
6.11	`sncndn`	Jacobian elliptic functions
6.12	`hypgeo`	complex hypergeometric function
6.12	`hypser`	complex hypergeometric function, series evaluation
6.12	`hypdrv`	complex hypergeometric function, derivative of
7.1	`ran0`	random deviate by Park and Miller minimal standard
7.1	`ran1`	random deviate, minimal standard plus shuffle

7.1	`ran2`	random deviate by L'Ecuyer long period plus shuffle
7.1	`ran3`	random deviate by Knuth subtractive method
7.2	`expdev`	exponential random deviates
7.2	`gasdev`	normally distributed random deviates
7.3	`gamdev`	gamma-law distribution random deviates
7.3	`poidev`	Poisson distributed random deviates
7.3	`bnldev`	binomial distributed random deviates
7.4	`irbit1`	random bit sequence
7.4	`irbit2`	random bit sequence
7.5	`psdes`	"pseudo-DES" hashing of 64 bits
7.5	`ran4`	random deviates from DES-like hashing
7.7	`sobseq`	Sobol's quasi-random sequence
7.8	`vegas`	adaptive multidimensional Monte Carlo integration
7.8	`rebin`	sample rebinning used by `vegas`
7.8	`miser`	recursive multidimensional Monte Carlo integration
7.8	`ranpt`	get random point, used by `miser`
8.1	`piksrt`	sort an array by straight insertion
8.1	`piksr2`	sort two arrays by straight insertion
8.1	`shell`	sort an array by Shell's method
8.2	`sort`	sort an array by quicksort method
8.2	`sort2`	sort two arrays by quicksort method
8.3	`hpsort`	sort an array by heapsort method
8.4	`indexx`	construct an index for an array
8.4	`sort3`	sort, use an index to sort 3 or more arrays
8.4	`rank`	construct a rank table for an array
8.5	`select`	find the Nth largest in an array
8.5	`selip`	find the Nth largest, without altering an array
8.5	`hpsel`	find M largest values, without altering an array
8.6	`eclass`	determine equivalence classes from list
8.6	`eclazz`	determine equivalence classes from procedure
9.0	`scrsho`	graph a function to search for roots
9.1	`zbrac`	outward search for brackets on roots
9.1	`zbrak`	inward search for brackets on roots
9.1	`rtbis`	find root of a function by bisection
9.2	`rtflsp`	find root of a function by false-position
9.2	`rtsec`	find root of a function by secant method
9.2	`zriddr`	find root of a function by Ridders' method
9.3	`zbrent`	find root of a function by Brent's method
9.4	`rtnewt`	find root of a function by Newton-Raphson
9.4	`rtsafe`	find root of a function by Newton-Raphson and bisection
9.5	`laguer`	find a root of a polynomial by Laguerre's method
9.5	`zroots`	roots of a polynomial by Laguerre's method with deflation
9.5	`zrhqr`	roots of a polynomial by eigenvalue methods
9.5	`qroot`	complex or double root of a polynomial, Bairstow

9.6	mnewt	Newton's method for systems of equations
9.7	lnsrch	search along a line, used by newt
9.7	newt	globally convergent multi-dimensional Newton's method
9.7	fdjac	finite-difference Jacobian, used by newt
9.7	fmin	norm of a vector function, used by newt
9.7	broydn	secant method for systems of equations
10.1	mnbrak	bracket the minimum of a function
10.1	golden	find minimum of a function by golden section search
10.2	brent	find minimum of a function by Brent's method
10.3	dbrent	find minimum of a function using derivative information
10.4	amoeba	minimize in N-dimensions by downhill simplex method
10.4	amotry	evaluate a trial point, used by amoeba
10.5	powell	minimize in N-dimensions by Powell's method
10.5	linmin	minimum of a function along a ray in N-dimensions
10.5	f1dim	function used by linmin
10.6	frprmn	minimize in N-dimensions by conjugate gradient
10.6	df1dim	alternative function used by linmin
10.7	dfpmin	minimize in N-dimensions by variable metric method
10.8	simplx	linear programming maximization of a linear function
10.8	simp1	linear programming, used by simplx
10.8	simp2	linear programming, used by simplx
10.8	simp3	linear programming, used by simplx
10.9	anneal	traveling salesman problem by simulated annealing
10.9	revcst	cost of a reversal, used by anneal
10.9	revers	do a reversal, used by anneal
10.9	trncst	cost of a transposition, used by anneal
10.9	trnspt	do a transposition, used by anneal
10.9	metrop	Metropolis algorithm, used by anneal
10.9	amebsa	simulated annealing in continuous spaces
10.9	amotsa	evaluate a trial point, used by amebsa
11.1	jacobi	eigenvalues and eigenvectors of a symmetric matrix
11.1	eigsrt	eigenvectors, sorts into order by eigenvalue
11.2	tred2	Householder reduction of a real, symmetric matrix
11.3	tqli	eigensolution of a symmetric tridiagonal matrix
11.5	balanc	balance a nonsymmetric matrix
11.5	elmhes	reduce a general matrix to Hessenberg form
11.6	hqr	eigenvalues of a Hessenberg matrix
12.2	four1	fast Fourier transform (FFT) in one dimension
12.3	twofft	fast Fourier transform of two real functions
12.3	realft	fast Fourier transform of a single real function
12.3	sinft	fast sine transform
12.3	cosft1	fast cosine transform with endpoints
12.3	cosft2	"staggered" fast cosine transform
12.4	fourn	fast Fourier transform in multidimensions

12.5	`rlft3`	FFT of real data in two or three dimensions
12.6	`fourfs`	FFT for huge data sets on external media
12.6	`fourew`	rewind and permute files, used by `fourfs`
13.1	`convlv`	convolution or deconvolution of data using FFT
13.2	`correl`	correlation or autocorrelation of data using FFT
13.4	`spctrm`	power spectrum estimation using FFT
13.6	`memcof`	evaluate maximum entropy (MEM) coefficients
13.6	`fixrts`	reflect roots of a polynomial into unit circle
13.6	`predic`	linear prediction using MEM coefficients
13.7	`evlmem`	power spectral estimation from MEM coefficients
13.8	`period`	power spectrum of unevenly sampled data
13.8	`fasper`	power spectrum of unevenly sampled larger data sets
13.8	`spread`	extirpolate value into array, used by `fasper`
13.9	`dftcor`	compute endpoint corrections for Fourier integrals
13.9	`dftint`	high-accuracy Fourier integrals
13.10	`wt1`	one-dimensional discrete wavelet transform
13.10	`daub4`	Daubechies 4-coefficient wavelet filter
13.10	`pwtset`	initialize coefficients for `pwt`
13.10	`pwt`	partial wavelet transform
13.10	`wtn`	multidimensional discrete wavelet transform
14.1	`moment`	calculate moments of a data set
14.2	`ttest`	Student's t-test for difference of means
14.2	`avevar`	calculate mean and variance of a data set
14.2	`tutest`	Student's t-test for means, case of unequal variances
14.2	`tptest`	Student's t-test for means, case of paired data
14.2	`ftest`	F-test for difference of variances
14.3	`chsone`	chi-square test for difference between data and model
14.3	`chstwo`	chi-square test for difference between two data sets
14.3	`ksone`	Kolmogorov-Smirnov test of data against model
14.3	`kstwo`	Kolmogorov-Smirnov test between two data sets
14.3	`probks`	Kolmogorov-Smirnov probability function
14.4	`cntab1`	contingency table analysis using chi-square
14.4	`cntab2`	contingency table analysis using entropy measure
14.5	`pearsn`	Pearson's correlation between two data sets
14.6	`spear`	Spearman's rank correlation between two data sets
14.6	`crank`	replaces array elements by their rank
14.6	`kendl1`	correlation between two data sets, Kendall's tau
14.6	`kendl2`	contingency table analysis using Kendall's tau
14.7	`ks2d1s`	K–S test in two dimensions, data vs. model
14.7	`quadct`	count points by quadrants, used by `ks2d1s`
14.7	`quadvl`	quadrant probabilities, used by `ks2d1s`
14.7	`ks2d2s`	K–S test in two dimensions, data vs. data
14.8	`savgol`	Savitzky-Golay smoothing coefficients
15.2	`fit`	least-squares fit data to a straight line

15.3	fitexy	fit data to a straight line, errors in both x and y
15.3	chixy	used by fitexy to calculate a χ^2
15.4	lfit	general linear least-squares fit by normal equations
15.4	covsrt	rearrange covariance matrix, used by lfit
15.4	svdfit	linear least-squares fit by singular value decomposition
15.4	svdvar	variances from singular value decomposition
15.4	fpoly	fit a polynomial using lfit or svdfit
15.4	fleg	fit a Legendre polynomial using lfit or svdfit
15.5	mrqmin	nonlinear least-squares fit, Marquardt's method
15.5	mrqcof	used by mrqmin to evaluate coefficients
15.5	fgauss	fit a sum of Gaussians using mrqmin
15.7	medfit	fit data to a straight line robustly, least absolute deviation
15.7	rofunc	fit data robustly, used by medfit
16.1	rk4	integrate one step of ODEs, fourth-order Runge-Kutta
16.1	rkdumb	integrate ODEs by fourth-order Runge-Kutta
16.2	rkqs	integrate one step of ODEs with accuracy monitoring
16.2	rkck	Cash-Karp-Runge-Kutta step used by rkqs
16.2	odeint	integrate ODEs with accuracy monitoring
16.3	mmid	integrate ODEs by modified midpoint method
16.4	bsstep	integrate ODEs, Bulirsch-Stoer step
16.4	pzextr	polynomial extrapolation, used by bsstep
16.4	rzextr	rational function extrapolation, used by bsstep
16.5	stoerm	integrate conservative second-order ODEs
16.6	stiff	integrate stiff ODEs by fourth-order Rosenbrock
16.6	jacobn	sample Jacobian routine for stiff
16.6	derivs	sample derivatives routine for stiff
16.6	simpr	integrate stiff ODEs by semi-implicit midpoint rule
16.6	stifbs	integrate stiff ODEs, Bulirsch-Stoer step
17.1	shoot	solve two point boundary value problem by shooting
17.2	shootf	ditto, by shooting to a fitting point
17.3	solvde	two point boundary value problem, solve by relaxation
17.3	bksub	backsubstitution, used by solvde
17.3	pinvs	diagonalize a sub-block, used by solvde
17.3	red	reduce columns of a matrix, used by solvde
17.4	sfroid	spheroidal functions by method of solvde
17.4	difeq	spheroidal matrix coefficients, used by sfroid
17.4	sphoot	spheroidal functions by method of shoot
17.4	sphfpt	spheroidal functions by method of shootf
18.1	fred2	solve linear Fredholm equations of the second kind
18.1	fredin	interpolate solutions obtained with fred2
18.2	voltra	linear Volterra equations of the second kind
18.3	wwghts	quadrature weights for an arbitrarily singular kernel
18.3	kermom	sample routine for moments of a singular kernel
18.3	quadmx	sample routine for a quadrature matrix

18.3	`fredex`	example of solving a singular Fredholm equation
19.5	`sor`	elliptic PDE solved by successive overrelaxation method
19.6	`mglin`	linear elliptic PDE solved by multigrid method
19.6	`rstrct`	half-weighting restriction, used by `mglin`, `mgfas`
19.6	`interp`	bilinear prolongation, used by `mglin`, `mgfas`
19.6	`addint`	interpolate and add, used by `mglin`
19.6	`slvsml`	solve on coarsest grid, used by `mglin`
19.6	`relax`	Gauss-Seidel relaxation, used by `mglin`
19.6	`resid`	calculate residual, used by `mglin`
19.6	`copy`	utility used by `mglin`, `mgfas`
19.6	`fill0`	utility used by `mglin`
19.6	`maloc`	memory allocation utility used by `mglin`, `mgfas`
19.6	`mgfas`	nonlinear elliptic PDE solved by multigrid method
19.6	`relax2`	Gauss-Seidel relaxation, used by `mgfas`
19.6	`slvsm2`	solve on coarsest grid, used by `mgfas`
19.6	`lop`	applies nonlinear operator, used by `mgfas`
19.6	`matadd`	utility used by `mgfas`
19.6	`matsub`	utility used by `mgfas`
19.6	`anorm2`	utility used by `mgfas`
20.1	`machar`	diagnose computer's floating arithmetic
20.2	`igray`	Gray code and its inverse
20.3	`icrc1`	cyclic redundancy checksum, used by `icrc`
20.3	`icrc`	cyclic redundancy checksum
20.3	`decchk`	decimal check digit calculation or verification
20.4	`hufmak`	construct a Huffman code
20.4	`hufapp`	append bits to a Huffman code, used by `hufmak`
20.4	`hufenc`	use Huffman code to encode and compress a character
20.4	`hufdec`	use Huffman code to decode and decompress a character
20.5	`arcmak`	construct an arithmetic code
20.5	`arcode`	encode or decode a character using arithmetic coding
20.5	`arcsum`	add integer to byte string, used by `arcode`
20.6	`mpops`	multiple precision arithmetic, simpler operations
20.6	`mpmul`	multiple precision multiply, using FFT methods
20.6	`mpinv`	multiple precision reciprocal
20.6	`mpdiv`	multiple precision divide and remainder
20.6	`mpsqrt`	multiple precision square root
20.6	`mp2dfr`	multiple precision conversion to decimal base
20.6	`mppi`	multiple precision example, compute many digits of π