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	
1.1	Caraat	calcilate date from Junaii 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	
		7 1	
3.1	polint	polynomial interpolation	
3.2	ratint	rational function interpolation	
3.3	spline	construct a cubic spline	
3.3	${ t splint}$	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	San Cop Perr reac visit
3.6	splin2	two-dimensional spline interpolation	ηple yrigl niss fable web
			pagi nt (C ion i file site
4.2	trapzd	trapezoidal rule	e fro) 19 s gr s (in http
4.2	qtrap	integrate using trapezoidal rule	m N 186-: ante Icluc
4.2	qsimp	integrate using Simpson's rule	IUM 1992 Ing Ww.
4.3	qromb	integrate using Romberg adaptive method	ERI 2 by r int r int this
4.4	${\tt midpnt}$	extended midpoint rule	CAL Car erne erne one
4.4	qromo	integrate using open Romberg adaptive method	RE nbrid t us t us or ca
4.4	midinf	integrate a function on a semi-infinite interval	CIPI dge ers: any any
4.4	midsql	integrate a function with lower square-root singularity	ES I Unix to m serv 800.
4.4	midsqu	integrate a function with upper square-root singularity	N Fi /ersi ake /er c
4.4	midexp	integrate a function that decreases exponentially	ORT ty P one omp
4.5	qgaus	integrate a function by Gaussian quadratures	RA/ ress par pute oute
4.5	gauleg	Gauss-Legendre weights and abscissas	N 77 s. Pr per c r, is Nort
4.5	gaulag	Gauss-Laguerre weights and abscissas	ogra ogra opy stric h Ar
4.5	gauher	Gauss-Hermite weights and abscissas	iff A for for the first th
4.5	gaujac	Gauss-Jacobi weights and abscissas	Cop thei broh
4.5	gaucof	quadrature weights from orthogonal polynomials	OF yrig r ow ibite nly)
4.5	orthog	construct nonclassical orthogonal polynomials	SCI ht (0 n pe d. T
4.6	quad3d	integrate a function over a three-dimensional space	Sample page from NUMERICAL RECIPES IN FORTRAN 77: THE ART OF SCIENTIFIC COMPUTING (ISBN 0-521-43064-X) Copyright (C) 1986-1992 by Cambridge University Press. Programs Copyright (C) 1986-1992 by Numerical Recipes Software. Permission is granted for internet users to make one paper copy for their own personal use. Further reproduction, or any copying of machine-readable files (including this one) to any server computer, is strictly prohibited. To order Numerical Recipes books, diskettes, or CDROMs visit website http://www.nr.com or call 1-800-872-7423 (North America only), or send email to trade@cup.cam.ac.uk (outside North America).
5.1	eulsum	sum a series by Euler-van Wijngaarden algorithm	FIC C 36-19 1 us er Nu er Nu
5.3	ddpoly	evaluate a polynomial and its derivatives	CON 992 I e. Fu ime
5.3	poldiv	divide one polynomial by another	IPUI by N urthe rical rrade
5.3	ratval	evaluate a rational function	TING Prre Rec
5.7	dfridr	numerical derivative by Ridders' method	e (IS prica proc proc sipes
5.8	chebft	fit a Chebyshev polynomial to a function	BN I Re
5.8	chebev	Chebyshev polynomial evaluation	0-52 cipe on, o oks, oks,
5.9	chder	derivative of a function already Chebyshev fitted	21-4: brar disk k (o
5.9	chint	integrate a function already Chebyshev fitted	306, oftw. ny cr cette utsic
5.10	chebpc	polynomial coefficients from a Chebyshev fit	4-X) are. opyi opyi s, o
5.10	pcshft	polynomial coefficients of a shifted polynomial	ng c r CE lorth
5.11	pccheb	inverse of chebpc; use to economize power series	of ma DRO
5.12	pade	Padé approximant from power series coefficients	achir Ms Peric
5.13	ratlsq	rational fit by least-squares method	ne- a).
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_1 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		complex hypergeometric function, derivative of
0.12	hypdrv	complex hypergeometric function, derivative of
7.1	ran0	random deviate by Park and Miller minimal standard
7.1	ran1	random deviate by Faix and Whitei minimal standard random deviate, minimal standard plus shuffle
/ . 1	Lanı	random deviate, iniminai standard pius snume

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
7.0	ranpt	get fandom 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 N th largest in an array
8.5	hpsel	find M largest values, without altering an array
8.6	eclass	determine equivalence classes from list
8.6	eclass	determine equivalence classes from procedure
0.0	eciazz	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
	± ' ' ' '	T

	Computer Pi	rograms by	Chapter	and Section
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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	revest	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
10.5	amooba	evaluate a trial point, used by amound
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	< 7
13.4	\mathtt{spctrm}	power spectrum estimation using FFT	eada isit v
13.6	memcof	evaluate maximum entropy (MEM) coefficients	able web
13.6	fixrts	reflect roots of a polynomial into unit circle	file: site
13.6	predic	linear prediction using MEM coefficients	s (in
13.7	evlmem	power spectral estimation from MEM coefficients	cluc ://w
13.8	period	power spectrum of unevenly sampled data	ww.
13.8	fasper	power spectrum of unevenly sampled larger data sets	this nr.c
13.8	spread	extirpolate value into array, used by fasper	om e
13.9	dftcor	compute endpoint corrections for Fourier integrals	or c
13.9	dftint	high-accuracy Fourier integrals	any
13.10	wt1	one-dimensional discrete wavelet transform	' ser -800
13.10	daub4	Daubechies 4-coefficient wavelet filter	ver)-87
13.10	pwtset	initialize coefficients for pwt	com 2-72
13.10	pwt	partial wavelet transform	123 123 .
13.10	wtn	multidimensional discrete wavelet transform	(Nor
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14.1	moment	calculate moments of a data set	mer ctly
14.2	ttest	Student's t-test for difference of means	proh ica d
14.2	avevar	calculate mean and variance of a data set	nibit
14.2	tutest	Student's t-test for means, case of unequal variances	ed.
14.2	tptest	Student's t-test for means, case of paired data	To c
14.2	ftest	F-test for difference of variances	orde nd ei
14.3	chsone	chi-square test for difference between data and model	mail mail
14.3	chstwo	chi-square test for difference between two data sets	mer to t
14.3	ksone	Kolmogorov-Smirnov test of data against model	ical rade
14.3	kstwo	Kolmogorov-Smirnov test between two data sets	Rec @c
14.3	probks	Kolmogorov-Smirnov probability function	up.o
14.4	cntab1	contingency table analysis using chi-square	s bo am
14.4	cntab2	contingency table analysis using entropy measure	oks,
14.5	pearsn	Pearson's correlation between two data sets	dis Jk (o
14.6	spear	Spearman's rank correlation between two data sets	kett outs
14.6	crank	replaces array elements by their rank	es, de
14.6	kendl1	correlation between two data sets, Kendall's tau	Nort C
14.6	kendl2	contingency table analysis using Kendall's tau	h A
14.7	ks2d1s	K-S test in two dimensions, data vs. model	OMs meri
14.7	quadct	count points by quadrants, used by ks2d1s	ica).
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	

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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
15.7	1014110	ne data robustry, ased by modern
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	${\tt sphfpt}$	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	сору	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	${\tt mpsqrt}$	multiple precision square root
20.6	mp2dfr	multiple precision conversion to decimal base
20.6	mppi	interpolate and add, used by mglin solve on coarsest grid, used by mglin Gauss-Seidel relaxation, used by mglin calculate residual, used by mglin utility used by mglin, mgfas utility used by mglin, mgfas utility used by mglin memory allocation utility used by mglin, mgfas nonlinear elliptic PDE solved by multigrid method Gauss-Seidel relaxation, used by mgfas solve on coarsest grid, used by mgfas applies nonlinear operator, used by mgfas utility used by mgfas diagnose computer's floating arithmetic Gray code and its inverse cyclic redundancy checksum, used by icrc cyclic redundancy checksum decimal check digit calculation or verification construct a Huffman code append bits to a Huffman code, used by hufmak use Huffman code to encode and decompress a character use Huffman code to decode and decompress a character construct an arithmetic code encode or decode a character using arithmetic coding add integer to byte string, used by arcode multiple precision arithmetic, simpler operations multiple precision multiply, using FFT methods multiple precision reciprocal multiple precision divide and remainder multiple precision square root multiple precision conversion to decimal base multiple precision example, compute many digits of π

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