

References

The references collected here are those of general usefulness, usually cited in more than one section of this book. More specialized sources, usually cited in a single section, are not repeated here.

We first list a small number of books that form the nucleus of a recommended personal reference collection on numerical methods, numerical analysis, and closely related subjects. These are the books that we like to have within easy reach.

- Abramowitz, M., and Stegun, I.A. 1964, *Handbook of Mathematical Functions*, Applied Mathematics Series, Volume 55 (Washington: National Bureau of Standards; reprinted 1968 by Dover Publications, New York)
- Acton, F.S. 1970, *Numerical Methods That Work*; 1990, corrected edition (Washington: Mathematical Association of America)
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- Bratley, P., Fox, B.L., and Schrage, E.L. 1983, *A Guide to Simulation* (New York: Springer-Verlag)
- Dahlquist, G., and Bjorck, A. 1974, *Numerical Methods* (Englewood Cliffs, NJ: Prentice-Hall)
- Delves, L.M., and Mohamed, J.L. 1985, *Computational Methods for Integral Equations* (Cambridge, U.K.: Cambridge University Press)
- Dennis, J.E., and Schnabel, R.B. 1983, *Numerical Methods for Unconstrained Optimization and Nonlinear Equations* (Englewood Cliffs, NJ: Prentice-Hall)
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- Ralston, A., and Rabinowitz, P. 1978, *A First Course in Numerical Analysis*, 2nd ed. (New York: McGraw-Hill)
- Sedgewick, R. 1988, *Algorithms*, 2nd ed. (Reading, MA: Addison-Wesley)
- Stoer, J., and Bulirsch, R. 1980, *Introduction to Numerical Analysis* (New York: Springer-Verlag)
- Wilkinson, J.H., and Reinsch, C. 1971, *Linear Algebra*, vol. II of *Handbook for Automatic Computation* (New York: Springer-Verlag)

We next list the larger collection of books, which, in our view, should be included in any serious research library on computing, numerical methods, or analysis.

- Bevington, P.R. 1969, *Data Reduction and Error Analysis for the Physical Sciences* (New York: McGraw-Hill)
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- Devroye, L. 1986, *Non-Uniform Random Variate Generation* (New York: Springer-Verlag)
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Index of Programs and Dependencies

The following table lists, in alphabetical order, all the routines in *Numerical Recipes*. When a routine requires subsidiary routines, either from this book or else user-supplied, the full dependency tree is shown: A routine calls directly all routines to which it is connected by a solid line in the column immediately to its right; it calls indirectly the connected routines in all columns to its right. Typographical conventions: Routines from this book are in typewriter font (e.g., `eu1sum`, `gamm1n`). The smaller, slanted font is used for the second and subsequent occurrences of a routine in a single dependency tree. (When you are getting routines from the *Numerical Recipes* diskettes, or their archive files, you need only specify names in the larger, upright font.) User-supplied routines are indicated by the use of text font and square brackets, e.g., `[funcv]`. Consult the text for individual specifications of these routines. The right-hand side of the table lists section and page numbers for each program.

addint	— interp	§19.6 (p. 871)
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amebsa	┌ ran1	§10.9 (p. 445)
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		└ ran1	
	┌ [funk]		
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	└ [funk]		
amotry	— [funk]	§10.4 (p. 405)
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	└ revcst		
	└ revers		
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	└ flmoon		
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banmul	§2.4 (p. 44)
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bessi0	§6.6 (p. 230)
bessi1	§6.6 (p. 231)
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bessj — $\left\{ \begin{array}{l} \text{bessj0} \\ \text{bessj1} \end{array} \right.$	§6.5 (p. 228)
bessj0	§6.5 (p. 225)
bessj1	§6.5 (p. 226)
bessjy — beschb — chebev	§6.7 (p. 236)
bessk — $\left\{ \begin{array}{l} \text{bessk0 — bessi0} \\ \text{bessk1 — bessi1} \end{array} \right.$	§6.6 (p. 232)
bessk0 — bessi0	§6.6 (p. 231)
bessk1 — bessi1	§6.6 (p. 232)
bessy — $\left\{ \begin{array}{l} \text{bessy1 — bessj1} \\ \text{bessy0 — bessj0} \end{array} \right.$	§6.5 (p. 227)
bessy0 — bessj0	§6.5 (p. 226)
bessy1 — bessj1	§6.5 (p. 227)
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betacf	§6.4 (p. 221)
betai — $\left\{ \begin{array}{l} \text{gammln} \\ \text{betacf} \end{array} \right.$	§6.4 (p. 220)
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bksub	§17.3 (p. 761)
bnldev — $\left\{ \begin{array}{l} \text{ran1} \\ \text{gammln} \end{array} \right.$	§7.3 (p. 285)
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broydn — $\left\{ \begin{array}{l} \text{fmin} \\ \text{fdjac — [funcv]} \\ \text{qrdcmp} \\ \text{qrupdt — rotate} \\ \text{rsolv} \\ \text{lnsrch — fmin — [funcv]} \end{array} \right.$	§9.7 (p. 383)
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chder		§5.9 (p. 189)
chebev		§5.8 (p. 187)
chebft — [func]		§5.8 (p. 186)
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dawson		§6.10 (p. 253)
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	└─┬─ realft ── four1	
	└─┬─ polint	
	└─┬─ dftcor	
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dpythag		DOUBLE PRECISION version of pythag, <i>q.v.</i>
drealft		DOUBLE PRECISION version of realft, <i>q.v.</i>
dsprsax		DOUBLE PRECISION version of sprsax, <i>q.v.</i>
dsprstx		DOUBLE PRECISION version of sprstx, <i>q.v.</i>
dsvbksb		DOUBLE PRECISION version of svbksb, <i>q.v.</i>
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fit	— gammq	└─ gser	└─ gammln	§15.2 (p. 659)
		└─ gcf		
fitexy	└─ avevar			§15.3 (p. 662)
	└─ fit	└─ gammq	└─ gser	
		└─ gcf	└─ gammln	
	└─ chixy			
	└─ mnbrak			
	└─ brent			
	└─ gammq	└─ gser	└─ gammln	
		└─ gcf		
	└─ zbrent	└─ chixy		
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	└─ ludcmp			
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	└─ [g]			
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gammp	└─ gser	└─ gammln		§6.2 (p. 211)
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julday		§1.1 (p. 13)
kendl1	— erfcc	§14.6 (p. 638)
kendl2	— erfcc	§14.6 (p. 639)
kermom		§18.3 (p. 792)

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ks2d1s	quadct	§14.7 (p. 642)
	├── quadvl	
	├── pearsn ── betai ── gammln	
	│ └── betacf	
	└── probks	
ks2d2s	quadct	§14.7 (p. 643)
	├── quadvl	
	├── pearsn ── betai ── gammln	
	│ └── betacf	
	└── probks	
ksone	sort	§14.3 (p. 619)
	├── [func]	
	└── probks	
kstwo	sort	§14.3 (p. 619)
	└── probks	
laguer	. . . . .	§9.5 (p. 366)
lfit	[funcs]	§15.4 (p. 668)
	├── gaussj	
	└── covsrt	
linbcg	atimes	§2.7 (p. 79)
	├── snrm	
	└── asolve	
linmin	mnbrak ── f1dim ── [func]	§10.5 (p. 412)
	└── brent	
lnsrch	[func]	§9.7 (p. 378)
locate	. . . . .	§3.4 (p. 111)
lop	. . . . .	§19.6 (p. 879)
lubksb	. . . . .	§2.3 (p. 39)
ludcmp	. . . . .	§2.3 (p. 38)
machar	. . . . .	§20.1 (p. 884)
maloc	. . . . .	§19.6 (p. 873)
matadd	. . . . .	§19.6 (p. 879)
matsub	. . . . .	§19.6 (p. 879)
medfit	─ rofunc ── select	§15.7 (p. 699)
memcof	. . . . .	§13.6 (p. 561)
metrop	─ ran3	§10.9 (p. 443)
mgfas	maloc	§19.6 (p. 877)
	├── rstruct	
	├── slvsm2 ── fill0	
	├── interp	
	├── copy	
	├── relax2	
	├── lop	
	└── matsub	

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└─ anorm2		
└─ matadd		
mglin ── malloc	§19.6 (p. 869)	
└─ rstrct		
└─ slvsml ── fill0		
└─ interp		
└─ copy		
└─ relax		
└─ resid		
└─ fill0		
└─ addint ── interp		
midinf ── [func]	§4.4 (p. 138)	
midpnt ── [func]	§4.4 (p. 136)	
miser ── ranpt ── ran1	§7.8 (p. 316)	
└─ [func]		
mmid ── [derivs]	§16.3 (p. 717)	
mnbrak ── [func]	§10.1 (p. 393)	
mnewt ── [usrfun]	§9.6 (p. 374)	
└─ ludcmp		
└─ lubksb		
moment	§14.1 (p. 607)	
mp2dfr ── mpops	§20.6 (p. 913)	
mpdiv ── mpinv ── mpmul ── drealft ── dfour1	§20.6 (p. 911)	
└─ mpops		
└─ mpmul ── drealft ── dfour1		
└─ mpops		
mpinv ── mpmul ── drealft ── dfour1	§20.6 (p. 911)	
└─ mpops		
mpmul ── drealft ── dfour1	§20.6 (p. 910)	
mpops	§20.6 (p. 907)	
mppi ── mpsqrt ── mpmul ── drealft ── dfour1	§20.6 (p. 913)	
└─ mpops		
└─ mpops		
└─ mpmul ── drealft ── dfour1		
└─ mpinv ── mpmul ── drealft ── dfour1		
└─ mp2dfr ── mpops		
mprove ── lubksb	§2.5 (p. 48)	
mpsqrt ── mpmul ── drealft ── dfour1	§20.6 (p. 912)	
└─ mpops		
mrqcof ── [funcs]	§15.5 (p. 681)	
mrqmin ── mrqcof ── [funcs]	§15.5 (p. 680)	
└─ gaussj		
└─ covsrt		

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newt	├── fmin	├── fdjac ── [funcv]	├── ludcmp	├── lubksb	└── lnsrch ── <i>fmin</i> ── [funcv]	§9.7 (p. 379)
odeint	├── [derivs]	├── rkqs ── [derivs]	└── rkck ── [derivs]			§16.2 (p. 714)
orthog						§4.5 (p. 153)
pade	├── ludcmp	├── lubksb	└── mprove ── <i>lubksb</i>			§5.12 (p. 196)
pccheb						§5.11 (p. 193)
pcshft						§5.10 (p. 192)
pearsn	├── betai	├── gammln	└── betacf			§14.5 (p. 632)
period	├── avevar					§13.8 (p. 572)
piksr2						§8.1 (p. 322)
piksrt						§8.1 (p. 321)
pinvs						§17.3 (p. 762)
plgndr						§6.8 (p. 247)
poidev	├── ran1	└── gammln				§7.3 (p. 284)
polcoe						§3.5 (p. 114)
polcof	├── polint					§3.5 (p. 115)
poldiv						§5.3 (p. 169)
polin2	├── polint					§3.6 (p. 118)
polint						§3.1 (p. 103)
powell	├── [func]	├── linmin	├── mnbrak	├── brent	└── f1dim ── [func]	§10.5 (p. 411)
predic						§13.6 (p. 562)
probks						§14.3 (p. 620)
psdes						§7.5 (p. 293)
pwt						§13.10 (p. 589)
pwtset						§13.10 (p. 589)
pythag						§2.6 (p. 62)
pzextr						§16.4 (p. 724)
qgaus	├── [func]					§4.5 (p. 141)
qrdcmp						§2.10 (p. 92)

qromb	└─ trapzd — [func]	. . . . .	§4.3 (p. 134)
	└─ polint		
qromo	└─ midpnt — [func]	. . . . .	§4.4 (p. 137)
	└─ polint		
qroot	— poldiv	. . . . .	§9.5 (p. 371)
qrsolv	— rsolv	. . . . .	§2.10 (p. 93)
qrupdt	— rotate	. . . . .	§2.10 (p. 94)
qsimp	— trapzd — [func]	. . . . .	§4.2 (p. 133)
qtrap	— trapzd — [func]	. . . . .	§4.2 (p. 131)
quad3d	— qgaus — [func]	. . . . .	§4.6 (p. 157)
	└─ [y1]		
	└─ [y2]		
	└─ [z1]		
	└─ [z2]		
quadct		. . . . .	§14.7 (p. 642)
quadmx	— wghts — kermom	. . . . .	§18.3 (p. 793)
quadvl		. . . . .	§14.7 (p. 643)
ran0		. . . . .	§7.1 (p. 270)
ran1		. . . . .	§7.1 (p. 271)
ran2		. . . . .	§7.1 (p. 272)
ran3		. . . . .	§7.1 (p. 273)
ran4	— psdes	. . . . .	§7.5 (p. 294)
rank		. . . . .	§8.4 (p. 333)
ranpt	— ran1	. . . . .	§7.8 (p. 318)
ratint		. . . . .	§3.2 (p. 106)
ratlsq	└─ [fn]	. . . . .	§5.13 (p. 200)
	└─ dsvecmp — dpythag		
	└─ dsvbksb		
	└─ ratval		
ratval		. . . . .	§5.3 (p. 170)
rc		. . . . .	§6.11 (p. 259)
rd		. . . . .	§6.11 (p. 257)
realft	— four1	. . . . .	§12.3 (p. 507)
rebin		. . . . .	§7.8 (p. 314)
red		. . . . .	§17.3 (p. 763)
relax		. . . . .	§19.6 (p. 872)
relax2		§19.6 (p. 878)
resid		§19.6 (p. 872)
revcst		§10.9 (p. 441)
revers		§10.9 (p. 442)
rf		§6.11 (p. 257)

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<ul style="list-style-type: none"> <ul style="list-style-type: none"> rc rf 	§6.11 (p. 258)
rk4 — [derivs]	§16.1 (p. 706)
rkck — [derivs]	§16.2 (p. 713)
<ul style="list-style-type: none"> <ul style="list-style-type: none"> [derivs] <ul style="list-style-type: none"> rk4 — [derivs] 	§16.1 (p. 707)
rkqs — rkck — [derivs]	§16.2 (p. 712)
rlft3 — fourn	§12.5 (p. 522)
rofunc — select	§15.7 (p. 700)
rotate	§2.10 (p. 95)
rsolv	§2.10 (p. 93)
rstrct	§19.6 (p. 870)
rtbis — [func]	§9.1 (p. 347)
rtflsp — [func]	§9.2 (p. 349)
rtnewt — [funcd]	§9.4 (p. 358)
rtsafe — [funcd]	§9.4 (p. 359)
rtsec — [func]	§9.2 (p. 350)
rzextr	§16.4 (p. 725)
<ul style="list-style-type: none"> <ul style="list-style-type: none"> ludcmp lubksb 	§14.8 (p. 646)
scrsho — [func]	§9.0 (p. 342)
select	§8.5 (p. 334)
selip — shell	§8.5 (p. 335)
<ul style="list-style-type: none"> <ul style="list-style-type: none"> plgnr <ul style="list-style-type: none"> solvde <ul style="list-style-type: none"> difeq pinvs red bksub 	§17.4 (p. 768)
shell	§8.1 (p. 323)
<ul style="list-style-type: none"> <ul style="list-style-type: none"> [load] <ul style="list-style-type: none"> odeint <ul style="list-style-type: none"> [derivs] rkqs — rkck — [derivs] [score] 	§17.1 (p. 750)
<ul style="list-style-type: none"> <ul style="list-style-type: none"> [load1] <ul style="list-style-type: none"> odeint <ul style="list-style-type: none"> [derivs] rkqs — rkck — [derivs] [score] [load2] 	§17.2 (p. 752)
simp1	§10.8 (p. 434)
simp2	§10.8 (p. 434)
simp3	§10.8 (p. 435)

simplx	├─ simp1	§10.8 (p. 432)
	├─ simp2	
	└─ simp3	
simpr	├─ ludcmp	§16.6 (p. 736)
	├─ lubksb	
	└─ [derivs]	
sinft	├─ realft ── four1	§12.3 (p. 511)
slvsm2	├─ fill0	§19.6 (p. 878)
slvsm1	├─ fill0	§19.6 (p. 872)
sncndn	. . . . .	§6.11 (p. 262)
snrm	. . . . .	§2.7 (p. 81)
sobseq	. . . . .	§7.7 (p. 302)
solvde	├─ difeq	§17.3 (p. 760)
	├─ pinvs	
	├─ red	
	└─ bksub	
sor	. . . . .	§19.5 (p. 860)
sort	. . . . .	§8.2 (p. 324)
sort2	. . . . .	§8.2 (p. 326)
sort3	├─ indexx	§8.4 (p. 332)
spctrm	├─ four1	§13.4 (p. 550)
spear	├─ sort2	§14.6 (p. 635)
	├─ crank	
	├─ erfcc	
	└─ betai ── gammln	
	└─ betacf	
sphbes	├─ bessjy ── beschb ── chebev	§6.7 (p. 245)
sphfpt	├─ newt ── fdjac ── shootf (q.v.)	§17.4 (p. 772)
	├─ lnsrch ── shootf (q.v.)	
	├─ fmin ── shootf (q.v.)	
	├─ ludcmp	
	└─ lubksb	
sphoot	├─ newt ── fdjac ── shoot (q.v.)	§17.4 (p. 771)
	├─ lnsrch ── shoot (q.v.)	
	├─ fmin ── shoot (q.v.)	
	├─ ludcmp	
	└─ lubksb	
splie2	├─ spline	§3.6 (p. 121)
splin2	├─ splint	§3.6 (p. 121)
	└─ spline	
spline	§3.3 (p. 109)
splint	§3.3 (p. 110)
spread	§13.8 (p. 576)

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spr sax	§2.7 (p. 72)
spr sin	§2.7 (p. 72)
spr spm	§2.7 (p. 75)
spr stm	§2.7 (p. 76)
spr stp — iindexx	§2.7 (p. 73)
spr stx	§2.7 (p. 73)
stif bs — jacobn	§16.6 (p. 737)
— simpr — ludcmp	
— lubksb	
— [derivs]	
— pzextr	
stiff — jacobn	§16.6 (p. 732)
— ludcmp	
— lubksb	
— [derivs]	
stoerm — [derivs]	§16.5 (p. 726)
svb ksb	§2.6 (p. 56)
svd cmp — pythag	§2.6 (p. 59)
svd fit — [funcs]	§15.4 (p. 672)
— svd cmp — pythag	
— svb ksb	
svd var	§15.4 (p. 673)
toeplz	§2.8 (p. 88)
tptest — avevar	§14.2 (p. 612)
— betai — gammln	
— betacf	
tqli — pythag	§11.3 (p. 473)
trapzd — [func]	§4.2 (p. 131)
tred2	§11.2 (p. 467)
tridag	§2.4 (p. 43)
trncst	§10.9 (p. 442)
trnspt	§10.9 (p. 442)
ttest — avevar	§14.2 (p. 610)
— betai — gammln	
— betacf	
tutest — avevar	§14.2 (p. 611)
— betai — gammln	
— betacf	
twofft — four1	§12.3 (p. 505)
vander	§2.8 (p. 84)

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vegas	└─ rebin	§7.8 (p. 311)
	└─ ran2	
	└─ [fxn]	
voltra	└─ [g]	§18.2 (p. 787)
	└─ [ak]	
	└─ ludcmp	
	└─ lubksb	
wt1	— daub4	§13.10 (p. 587)
wtn	— daub4	§13.10 (p. 595)
wghts	— kermom	§18.3 (p. 791)
zbrac	— [func]	§9.1 (p. 345)
zbrak	— [func]	§9.1 (p. 345)
zbrent	— [func]	§9.3 (p. 354)
zrhqr	└─ balanc	§9.5 (p. 368)
	└─ hqr	
zridr	— [func]	§9.2 (p. 351)
zroots	— laguer	§9.5 (p. 367)

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