

## Index

---

### A

adjusted vegas 146  
Alternating Direction Implicit (ADI)  
  method 168, 308  
American barriers 31  
American digitals 342–4  
Andersen, L. and J. Andreasen (1999) 305  
Andersen, L., J. Andreasen and D. Eliezer  
  (2000) 329  
Andersen, L. and R. Brotherton-Ratcliffe  
  (1997) 10  
  (1997/98) 115, 118  
  (1998) 100, 108, 252, 254  
Andersen, L.B.G. (1996) 181, 203  
Andreasen, J. (1997) 317, 318, 320  
Andreasen's Gaussian Exchange Rate and  
  Term Structure model 318–20  
  extension to multiple factors 323–4  
  one-factor-model 320–2  
antithetic variables 177–8  
antithetic variates 210  
arithmetic average model 149–63  
arithmetic spot, determination of parameters  
  154–6  
Asian options 149, 156–8  
at-the-money volatility 24

### B

backward Kolmogorov equation 105–6  
backward (pricing) equation 117  
backward variables 117  
backwardation 5  
barrier contracts, effect on market 35  
barrier mis-specification error 229  
barrier options 29–36, 98, 99, 180–2, 229,  
  262, 328  
  1994–6 crisis 30  
  determination of breaching 33–4  
  hedging methods 34–5  
  monitoring 33  
  and Partial Differential Equation 41  
  popularity 29–30  
  types 31–3  
barrier-delta 128, 131  
barrier-gamma 128, 131  
basket options 149, 158–63

quasi-random numbers for computation  
  200–1  
  on a series of forwards 161–3  
  stochastic Taylor expansion 160–1  
Bates, D.  
  (1988) 8  
  (1991) 8  
Belledin, M. and C. Schlag (1999) 272  
best-of call and worst-of put 71–2  
best-of and worst-of currencies forwards  
  69–70  
binary options 334–5  
binomial trees 227–33, 242  
  one-step model 227  
  convergence 229  
  in two dimensions 229–32  
Black, F. (1976) 121  
Black, F. and M. Scholes (1973) 209, 210,  
  249, 305  
Black formula 121  
Black–Scholes formula 4, 21, 249, 254,  
  283  
Black–Scholes framework 104, 165–6  
Black–Scholes model 3, 15, 16, 127  
  and European Foreign Exchange vanilla  
  options 25–6  
  and Finite Difference Methods (FDMs)  
  165–6  
Black–Scholes Partial Differential Equation  
  (PDE) 3, 132, 332, 333, 335, 337  
Bloomberg 97  
Bouchard, A.N. and N. Touzi (1999) 329  
Bowie, J. and P. Carr (1994) 8, 329  
Box–Muller algorithm 176  
Boyle, P.P. (1977) 210  
Boyle, P.P. *et al* (1997) 182  
Boyle, P.P., M. Broadie and P. Glasserman  
  (1997) 210, 215  
Bratley, P. and B. Fox (1988) 216  
Broadie, M., J. Cvitanić and H.M. Soner  
  (1998) 328, 332, 333, 334  
Broadie, M. and P. Glasserman  
  (1996) 129  
  (1998) 184  
Broadie, M., P. Glasserman and S.G. Kou  
  (1999) 202, 206

- Brown, H.M., D. Hobson and L.C.G. Rogers (2001) 329  
 Brownian bridge 181, 202  
 Brownian motion 143, 149  
 Burden, R.L. and J.D. Faires (1993) 237  
 butterflies 19–20
- C**  
 càdlàg process 306  
 calibration 272–9  
   jump-diffusion model 311–5  
 calls on forwards 121  
 CantorSpeed 90 17  
 Carr, P.  
   (1994) 8  
   (2001) 129  
 Carr, P. and D.B. Madan (1999) 21  
 Central Processing Unit (CPU) times 177, 243  
 Champney, R. (2000) 209  
 charm 5, 13, 128  
 Chebyshev polynomials 223  
 Chesney, M., M. Jeanblanc-Picqué and M. Yor (1997) 328  
 Cholesky decomposition 69, 73, 158, 200, 237  
 Clewlow, L. and C. Strickland (1998) 168, 171  
 cliquet options 60  
 colour 6, 13, 128  
 compound options 68–9, 79–80, 264  
   Greeks of 94–5  
   hedging 85–6  
   for no-arbitrage bounds 80–4  
   for put-call parity 80–4  
   rho risk 93–4  
   static hedging 79–96, 86–94  
   value in the Black–Scholes model 84–5  
   vega risk 92–3  
   volga risk 93  
 computational time 192  
 contango 5  
 Control Variate technique 178–9  
 Cooley, J.W.C. and J.W. Tukey (1965) 236  
 correlation 143, 167  
   of term structure 145  
 correlation coefficients 145  
   for a four currency market 144  
 correlation risk 143–6  
   and cross gamma 133  
   hedging 145–6  
 corridors 50  
 cost of carry 116, 120  
 Cox, D.R. and H.D. Miller (1965) 105, 106, 107, 109  
 Cox, J.C., J.E. Ingersoll and S.A. Ross (1985) 267, 285  
 Cox–Ingersoll–Ross (CIR) process 108, 182, 277  
 Cox–Ross–Rubinstein model 227  
 Crank–Nicholson scheme 166, 260–62, 288  
 cross-gamma-correlation-risk relationship 133  
 currency spots 149  
 Cvitanić, J., H. Pham and N. Touzi (1999) 329  
 Cvitanić J. and I. Karatzas (1993) 328, 329, 331, 332
- D**  
 dangerous derivatives 327–48  
 dates, differing 25–6, 44–5  
 delta 11–14, 19, 34–5, 39–40, 46, 59, 99, 100, 128, 139, 253  
   strike 11  
   volatility 11  
 delta-hedging 15  
 delta-rho relationship 133  
 delta-symmetric strike 7  
 Derman, E., D. Ergener and I. Kani (1994) 329  
 Dewynne, J., S. Howison and P. Wilmott (1996) 105, 108, 109  
 diagonalisation 200–201  
 differing dates 25–6, 44–5  
 digital options 42, 334–5  
   corridor of 50  
   foreign–domestic symmetry 43  
   Greeks 42–3  
   pricing 45  
 Dirac Delta function 106  
 Dirichlet boundary 295  
 discounted forward price 119  
 discrepancy, quantitative description 192–4  
 dispersion coefficient 252  
 Dixit, A.K. and R.S. Pindyck (1994) 105  
 domestic money market account 116  
 double barrier options 51–3  
 double no-touch options 49–50  
 driftless delta 5, 128  
 dual Black–Scholes Partial Differential Equation (PDE) 10  
 dual delta 6, 11–12, 13, 43  
 dual gamma 6, 13, 43  
 dual theta 3, 6, 13, 128  
 Duffie, D. (1996) 103  
 Dumas, B., J. Fleming and R.E. Whaley (1998) 115, 116, 119, 120, 253, 259  
 Dupire, B. (1994) 10, 115, 250, 251, 252  
 Dupire formula 249, 254  
 Dynkin's equation 110
- E**  
 eigenvalues 324  
 Eisenberg, L.K. and R.A. Jarrow (1991) 104  
 El Karoui, N. and M.C. Quenez (1995) 328, 329, 332  
 Engeler, M. (1998) 85  
 Euro 130  
 Euro-related symmetries of value, delta and leverage 9  
 European barriers 31

- European options, in a Black–Scholes model 132–4
- exchange options, numerical results 240–5
- exchange rate spot 25
- exotic options 37–73, 235, 302–3, 308, 327  
   first generation 37–56  
   second generation 57–73
- expiry and delivery dates, differing 25–6
- exponential barriers 41
- exponential model 23
- F**
- face-lifting procedure 332, 333, 334
- fade-in-out options 54
- Fast Fourier Transforms (FFT) method 235–48, 245, 246, 308  
   comparison with Sobol’ method 244–5
- Faure, H. (1982) 210
- Faure sequence 188–91, 195, 203, 223
- Feynman–Kac Theorem 4
- filtered probability space 116
- final time value 136
- finite difference grid 171
- Finite Difference Methods (FDMs) 165, 249, 272, 283, 284, 327  
   in Black–Scholes model 165–6
- finite differences 165–73
- Finite Element Methods (FEMs) 272, 283–303, 286–94  
   errors 299–301  
   finite element system of equations 297–8  
   mesh and basis functions 295–7  
   numerical solution 295  
   results 299  
   semi-discretisation in the time direction 288  
   solution 287–8
- first generation exotics 37–56
- first-order classical log-normal model 158
- Fishman, G.S. (1997) 179
- fixed-strike Asian vanilla 156–7
- Flannery, B. *et al* (1992) 172, 176, 191, 192, 245, 246, 269
- fluffy barriers 32
- Fokker–Planck (diffusion) equation 105
- Föllmer, H. and P. Leukert (1999) 329
- Foreign Exchange Committee 33–4
- Foreign Exchange market model 143–4
- foreign-domestic symmetry 8, 43, 136
- forward and backward Partial Differential Equations (PDEs) 115–24
- forward contract 4
- forward correlation 278–9
- forward delta 5, 12, 128
- forward Kolmogorov equation 106–8
- forward price 4
- forward (pricing) equation 117
- Forward Rate Curve (FRC) 324
- forward variables 117
- forward volatilities of variance 278
- forward-start options 57–60, 69
- Greeks 59–60  
   pricing 58
- forward-start strategy 68–9
- forwards 97
- forwards on options on forwards 118–9
- Fox, B. (1986) 216
- fully explicit scheme 166
- fully implicit scheme 166
- futures contract 5
- G**
- gamma 5, 12, 34–5, 40, 42, 46, 59, 99, 100, 128, 140
- gamma–vega relationship 134
- Garman, M.B. and S.W. Kohlagen (1983) 236
- Garman–Kohlhagen adaptation 103
- Gauss–Laguerre algorithm 269
- Gauss–Legendre integration 242
- Gaussian Exchange Rate and Term Structure model 318–24
- gearing 128, 330
- generalised options on the minimum/maximum 72–3
- Generally Accepted Accounting Principles (GAAP) 100
- Gentle, D. (1993) 159
- geometric Brownian motion 3, 57, 305
- geometric mirror 8
- Geske, R. (1979) 84
- Girsanov’s theorem 329
- Glasserman, P. and X. Zhao (1999) 129
- Greeks 59–60, 100, 127–42, 171–2, 341  
   in a binomial tree 129  
   calculating 183–5  
   calculating for a plain vanilla call 185  
   of compound options 94–5  
   computation 129  
   forward-start options 59–60  
   relations among 135  
   in a static hedge 44  
   in terms of deltas 11–14  
   and vanilla options 11–13  
   of vanilla options, Heston’s stochastic volatility model 270
- Gulko, L. (1999) 283
- H**
- Halton, J. (1960) 210, 213, 216
- Halton sequence 188, 191, 223
- Hämmerlin, G. and K.–H. Hoffmann (1992) 223
- Hardy–Krause 198, 213
- Hart, I. and M. Ross (1994) 328
- Haug, E.G. (1997) 98
- heat equation 4, 107, 290–9
- Heath, D., R. Jarrow and A. Morton (1992) 319, 324
- hedging  
   compound options 85–6  
   correlation risk 145–6

- Heston, S. (1993) 104, 141, 167, 183, 267, 279, 299
- Heston's stochastic volatility model 167, 169, 170, 182, 267–82, 283, 285–6  
 calibration 272–9  
 derivation of value functions 279–82  
 Foreign Exchange setting 267–8  
 Greeks of vanilla options 270  
 volatility smile 273–5, 276
- Heynen, R. and H. Kat (1994) 146
- hindsight options 205
- historic volatility 16–17
- hit options 342–4
- Hlawka, E. (1961) 191, 192, 213
- homogeneity properties 116, 127
- homogeneity relations 128
- homogeneity of time 127, 129
- Hopscotch method 284
- Hui, C.H. and C.F. Lo (2000) 21, 99
- Hull, J.C. and A. White 283  
 (1987) 104, 249
- Hull–White model 168, 169
- I**
- implied volatility 10–11, 16–17, 18, 99
- importance sampling 179, 182
- independent quasi-random numbers 195
- installment options 62–3, 264
- integral method 158
- integral pricing 158–9
- interest rate risk and gamma 133
- interest rates 143
- International Accounting Standards (IAS) 100
- International Currency Options Master Agreement (ICOM) 34
- interpolation method 256–9
- iteration 22
- Itô process 103
- Itô's rule 346
- Itô–Taylor expansion 149, 151
- J**
- James, F., J. Hoogland and R. Klein (1997) 194
- Johnson, H. (1987) 210, 235
- Joy, C., P.P. Boyle and K.S. Tan (1996) 210, 214
- jump-diffusion model 305–16  
 calibration to Foreign Exchange markets 311–5  
 shape of volatility smile 309–11
- K**
- kappa 128, 137, 140
- Karatzas, I. (1997) 252
- Karatzas, I. and S. Kou  
 (1996) 329  
 (1998) 329
- Karatzas, I. and S. Shreve  
 (1991) 346  
 (1994) 153, 251  
 (1998) 331, 332
- kernel approach 256–8
- kernel interpolation 253
- Kloeden, P.E. and E. Platen (1992) 151, 153
- knock-in barriers 98
- Knuth, D.E. (1997) 176, 177
- Koksama, J.F. (1942/43) 213
- Kolmogorov equations 105, 115, 117
- Kolmogorov backward equation 165
- Kolmogorov forward equation 251, 252, 253
- Kolmogorov's forward and backward PDEs 115
- Kufner, A. (1980) 284
- Kufner, A. and A.M. Sändig (1987) 284
- Kurpiel, A. and T. Roncalli (2000) 284
- L**
- lambdas 259
- Lamberton, D. and B. Lapeyre (1996) 307
- Laurent expansions 190
- law of cosine in a tetrahedron 145
- Lebesgue measure 251
- Lemma of Lax and Milgram 293
- leverage 9, 35, 330
- leverage-constrained pricing theory 327
- leverage/gearing 128
- Lévy processes 21
- L'Hôpital's rule 341
- LIBOR rates 320
- Lie-algebraic approach 21, 99
- Likelihood Ratio (LR) method 184, 185
- Linetsky, V. (1997) 328
- Lipton, A. (2001) 104
- local volatility 99, 100
- local volatility function 116, 119, 120
- local volatility surfaces 249–66
- log-normal pricing 159–60
- long-run variance 167, 275
- long-term Foreign Exchange options model 317–25
- long-term variance 267
- lookback options  
 quasi-random numbers for computation 202–3  
 valuation in closed form 204–7  
 Greeks 206
- low-discrepancy sequences 187–8, 210, 213–4
- M**
- margin accounts 5
- Margrabe, W. (1978) 210, 235, 240
- market price of volatility risk 167, 267
- market risk of Foreign Exchange options 15–16
- MATLAB 299
- Matsumoto, M. and T. Nishimura (1998) 176, 195
- maximum principle 346
- mean reversion 267, 272, 275, 276–7
- Melino, A. and S.M. Turnbull (1990) 283

- Mersenne Twister (MT) 195  
 Mersenne Twister (MT) algorithm 176  
 Merton, R.C.  
   (1973) 81, 124  
   (1976) 305  
 moment matching 149–51  
 Monte Carlo integration, with quasi-random numbers 195–8  
 Monte Carlo simulations 72, 128, 129, 175–86, 187, 214–6, 217  
   method 175–6  
   path dependent derivatives 176–7  
 moving strike options 60  
 multi-asset options 143, 209
- N**
- Nahum, E. (1998) 207  
 Nelken, I. (1996) 235  
 Newton Raphson method 10–11, 84, 88  
 Niederreiter, H. (1998) 188, 190, 199  
 Niederreiter sequence 191–2, 194, 203, 204  
 no-arbitrage bounds, for compound options 80–84  
 no-arbitrage pricing theory 228  
 no-touch options, corridor of 50  
 non-business days, impact on pricing of options 27–8  
 numerical results  
   exchange options 240–5  
   spread options 241–2
- O**
- occupation time derivatives 32  
 one-step model, binomial trees 227  
 one-touch digitals 342–4  
 one-touch options 45–8, 279  
   Greeks 46–7  
   knock-out probability 47  
   pricing 46  
   properties of first hitting time 47–8  
 option price sensitivities 127–42  
   *see also* Greeks  
 options with discontinuous payoffs 327  
 options on forwards 118  
 options on the minimum/maximum 69–70  
 options on several correlated currencies 235–48  
 Ornstein–Uhlenbeck process 109  
 Oztukel, A. and P. Wilmott (2000) 104, 108
- P**
- Papageorgiou, A. and J. Traub (1998) 204  
 Papanicolaou, G.C. and K.R. Sircar (1999) 249  
 parasian barriers 32–3  
 parisian barriers 32–3, 328  
 partial barriers 32  
 Partial Differential Equations (PDEs) 99, 105, 127, 165, 170, 283  
   and barrier options 41  
   forward and backward 115–24  
   for general contingent claim 270–1  
   for option prices 259–60  
 path-dependence at discrete points in time 170–1  
 path-dependent derivatives, Monte Carlo simulations 176–7  
 path-independent derivatives 176  
 pathwise method 184  
 Pelsser, A. and T. Vorst (1994) 129  
 physical deliveries 98  
 Plackett, R.L. (1954) 132  
 Plackett's Identity 132  
 plain vanilla call, calculating Greeks 185  
 plain vanilla options 97  
 Poisson process 306  
 power model 23  
 power options 60–1  
 premium value date 25  
 Press, W.H. *et al* (1992) 346  
 pricing options 76  
 pricing of options, impact of non-business days 27–8  
 Probability Density Function (PDF) 103–13  
 put–call delta parity 7  
 put–call parity 7  
   for compound options 80–4  
   put–call symmetry 8
- Q**
- quanto barriers 33  
 quanto European plain vanilla 76  
 quanto forward 76  
 quanto forward-start plain vanilla 77  
 quanto options 75–7, 209  
 quanto power option 77  
 quasi-Monte Carlo integration, convergence 198–9  
 quasi-Monte Carlo techniques 209–25, 242  
 quasi-random numbers 187–208  
   with Monte Carlo integration 195–8  
   types and description 188–92  
 quasi-random numbers for computation  
   basket options 200–1  
   lookback options 202–3  
   vanilla options 196–8
- R**
- Radon–Nikodym derivative 179, 332  
 rainbow options 127, 137  
 range binaries 344–6  
 ratchet options 60  
 rate of mean reversion 267, 272, 275, 276–7  
 rates symmetry 8  
 Ravindran, K. (1993) 241  
 rebates 31–2, 338–9  
 Rebonato, R.  
   (1998) 318  
   (1999) 99, 100, 108, 324  
 regular barriers 31  
 Reiner, E. (1992) 209  
 Rendelman, R. and B. Bartter (1979) 224

- resetable barriers 33  
 reverse barriers 31, 34–5, 335–42  
   joint formulae for 339–41  
 reverse up-and-out call 329–30  
 Revuz, D. and M. Yor (1995) 49  
 rho 6, 13, 15–16, 43, 128, 129, 140  
 rho risk, compound options 93–4  
 rho-delta relationship 136  
 rhoq 128  
 Riccati differential equation 281  
 Richtmyer sequence 188, 189, 195, 203  
 risk reversals 19–20, 305, 311  
 risk-neutral valuation 210  
 Ritchken, P. 229  
 Rogers, L.G.C. and D. Williams (1987)  
   182  
 RSFPage FXMOX 17  
 Rubinstein, M.  
   (1991) 84  
   (1994) 229  
 running extremum 136
- S**
- Savitzky–Golay smoothing filter 172  
 scale-invariance of prices 130–2  
 scale-invariance of time 129–30  
 Schmock, U., S.E. Shreve and U. Wystup  
   (2001) 328, 329, 333  
 Schuss, Z. (1980) 109, 110  
 second generation exotics 57–73  
 Sewell, G. (2000) 110  
 Shadwick, B.A. and W.F. Shadwick (2001)  
   100, 104  
 Shaw, W. (1998) 134  
 Shreve, S.  
   (1996) 39  
   (1997) 117, 118, 136  
   (1998) 179  
 single barrier options  
   in Black–Scholes model 37–8  
   Greeks 39  
 single, double and outside barriers 31  
 skew 19  
 slide-in corridor 54–6  
 Sobol' method, comparison with Fast  
   Fourier method 244–5  
 Sobol', I.M. 191, 192, 213  
 Sobol' points 215–16, 217  
 Sobol' sequence 192, 195, 203, 204, 223  
 Sobolev spaces 284  
 soft barrier options 328  
 Soner, H.M. and N Touzi (2000) 329  
 space-homogeneity 7  
 speed 5, 12, 128  
 speed of mean reversion 167  
 spot delta 5, 11, 12, 42  
 stairs option 63  
   last period functionals 63–5  
   price 68  
   within period functionals 65–7
- static hedge  
   Greeks in 44  
   using vertical spreads 44  
 static hedging, compound options 86–94  
 steady-state distributions 108–9  
 Stein, E.M. and J.C. Stein (1991) 104  
 step options 328  
 step and soft barriers 32  
 step-up 171  
 stochastic Taylor expansion 151, 158, 161–2  
 stochastic volatility 182–3  
 stochastic volatility models 167–70, 283  
 strangles 305, 311  
 strike, delta-symmetric 7  
 strike given delta 11  
 strike-delta 128, 130–1  
 strike-gamma 128, 130–1  
 strikes 253  
 Stulz, R. (1982) 139, 210, 232, 235  
 super-replication 328, 330–4
- T**
- Taleb, N. (1996) 134  
 Telerate 4720 17  
 temperature model 23  
 term structure  
   of correlation 145  
   of volatility at-the-money 23–4  
 term structure models and formulae 21  
 theoretical Black–Scholes values 35–6  
 Theoretical Value (TV) 37, 57, 279  
 theta 5, 12, 34, 39–40, 42, 46, 59, 100, 128,  
   129, 141  
 Thomas, B. (1996) 85  
 time-dependent volatility 121  
 time-homogeneity 7–8  
 Tompkins, R.G. (1997) 85  
 Topper, J.  
   (1999) 100  
   (2000) 103  
   (2001) 108  
   (2002) 106  
 trader's gamma 12  
 trader's rule of thumb method 267, 279  
 transformed forward and backward  
   transition densities 122–4  
 triangular FX market 143–4  
 tridiagonal scheme 166  
 trinomial trees 229
- U**
- uncoupled systems 104  
 underlying options 75  
 up-and-out call option 335–8
- V**
- value 12  
 value in the Black–Scholes model,  
   compound options 84–5  
 vanilla options 3–14, 263  
   Greeks 5–6, 11–13

- market data 17
  - pricing 319–20
  - quasi-random numbers for computation 196–8
  - quotation 9
  - vanilla volatility retriever 22
  - vanna 6, 13, 20, 128
  - variance gamma processes 21
  - variance reduction techniques 175–86
  - Vasicek, O.A. (1998) 210
  - vega 6, 13, 15–16, 20, 34, 35, 40–1, 42, 44, 47, 59, 99, 128, 129, 140, 146
  - vega given delta 13–14
  - vega matrix 14
  - vega risk, compound options 92–3
  - vol of vol 267, 274, 277
  - volatilities 143
  - volatility at-the-money, term structure 23–4
  - volatility given delta 11
  - volatility management 15–24
  - volatility matrix 18, 19
  - volatility risk and gamma 133
  - volatility smile 17–19, 35, 115, 283
    - Heston's stochastic volatility model 273–5, 276
    - reasons for 20–1
    - shape 20
    - shape in jump-diffusion model 309–11
  - volatility swap 171
  - volatility of variance 167, 267, 272, 274, 277
  - volga 6, 13, 20, 21, 43, 185
  - volga risk, compound options 93
  - vonma/volga 128
- W**
- Wiener processes 84, 209
  - Wilmot, P., J. Dewynne and S. Howison (1994) 250
  - Wilmott, P. (1998) 105, 109, 110, 170
  - Wilmott, P., S. Howison and J. Dewynne (1995) 4
  - window barriers 32
  - wing shifts 22
  - wing volatility 19
  - Wystup, U.
    - (1999) 95, 136
    - (2001) 241, 279
  - Wystup's formula catalogue 136, 138
- X**
- XOR operations 191
- Z**
- zero-cost structures 97–101
  - zero-coupon bonds 318
  - zero-day spot 25
  - Zhang, P. (1997) 329