CERTIFICATE IN QUANTITATIVE FINANCE

CQF

Certificate in Quantitative Finance

Learning Pathway

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CERTIFICATE IN QUANTITATIVE FINANCE

CQF

Welcome to the CQF program

This booklet is designed to guide you through the program content of the CQF. It also includes the core text book reading list, indicating the chapters appropriate for each module.

The program begins with the Mathematics for Quantitative Finance Primer (optional), 12 hours of intensive training covering all the mathematical preliminaries you need to know before commencing the CQF. We strongly advise all delegates to complete the Primer.

The examined part of the CQF program comprises six modules. Each module covers a different aspect of quantitative finance and consists of lectures and discussions. The preparatory reading listed against each module gives you a good introduction to the topics discussed in lectures. The further reading allows you to delve deeper into each topic and are recommended but not required as part of the program.

Our Lifelong Learning library encompasses over 600 hours of lectures on every conceivable finance subject. The Lifelong Learning lectures listed support the core lectures. As the content is ever expanding, it is advisable to check the library regularly.

Contents

Module 1

Building Blocks of Quant Finance

This module introduces the rules of applied Itô calculus as a modeling framework. We build tools in both stochastic calculus and martingale theory and look at simple stochastic differential equations and their associated Fokker-Planck and Kolmogorov equations.

- **The random nature of prices:** Examination of data, unpredictability, the need for probabilistic models, drift and volatility.
- **Probability preliminaries:** Review of discrete and continuous random variables, transition density functions, moments and important distributions, the Central Limit Theorem.
- **Fokker-Planck and Kolmogorov equations:** similarity solutions.
- **Products and strategies:** examination of different asset classes, derivatives products and common trading strategies.
- **Applied Itô calculus:** Discrete-time random walks, continuous Wiener processes via rescaling and passing to the limit, quadratic variation, Itô integrals and Itô's lemma.
- Simulating and manipulating stochastic differential equations.
- **Martingale:** Conditional expectations, change of measure, stochastic processes as a martingale and tools of the trade.
- **The binomial model:** Up and down moves, delta hedging and self-financing replication, no arbitrage, a pricing model and risk-neutral probabilities.

Preparatory reading:

- P. Wilmott, *Paul Wilmott Introduces Quantitative Finance*, second edition, 2007, John Wiley. (Chapters 3,4,5,7)

Further reading:

- J.D. Hamilton, *Time Series Analysis*, 1994, Princeton University Press
- J.A. Rice, *Mathematical Statistics and Data Analysis*, 1988, Wadsworth-BrooksCole
- S.N. Neftci, *An Introduction to the Mathematics of Financial Derivatives*, 1996, Academic Press (general reference)

Lifelong Learning lectures:

(available to Full program and Level II delegates)

- Linear Algebra - Riaz Ahmad
- Stochastic Calculus - Riaz Ahmad
- Differential Equations - Riaz Ahmad
- Methods for Quant Finance I, II - Riaz Ahmad
- Martingales - Riaz Ahmad

Module 2

Quantitative Risk and Regulations

This module deals with the classical portfolio theory of Markowitz, the Capital Asset Pricing Model and more recent developments of these theories. We investigate risk and reward, looking at risk management metrics such as VaR. We also examine current regulation and its impact on the industry from both a trading and investment perspective.

- **Modern Portfolio Theory:** Expected returns, variances and covariances, benefits of diversification, the opportunity set and the efficient frontier, the Sharpe ratio, utility functions and the Black-Litterman Model.
- **Capital Asset Pricing Model:** Single-index model, beta, diversification, optimal portfolios, the multi-index model.
- **Portfolio Optimization:** Formulation, implementation and use of calculus to solve constrained optimization.
- **Value at risk:** Profit and loss for simple portfolios, tails of distributions, Monte Carlo simulations and historical simulations, stress testing and worst-case scenarios.
- **Volatility clustering:** Concept and evidence.
- **Properties of daily asset returns:** Average values, standard deviations, departures from the normal distribution, squared returns.
- **Properties of high-frequency returns:** Five-minute returns contrasted with daily returns, intraday volatility patterns, impact of macroeconomic news, realized variance.
- **Volatility models:** The ARCH framework, why ARCH models are popular, the GARCH model, ARCH models, asymmetric ARCH models and econometric methods.
- **Risk Regulation and Basel III:** Definition of capital, evolution of Basel, Basel III and market risk, key provisions.
- **Impact of Risk Regulation:** Impact of new regualtions on trading activities.
- **Cointegration:** Modeling long term relationships, arbitrage using mean reversion.

Preparatory reading:

- P. Wilmott, *Paul Wilmott Introduces Quantitative Finance*, second edition, 2007, John Wiley. (Chapters 1, 2, 3, 20-22)
- S.J. Taylor, *Asset Price Dynamics, Volatility and Prediction*, 2007, Princeton University Press. (Chapters 2,4, 9-10, 12)

Further reading:

- E.J. Elton & M.J. Gruber, *Modern Portfolio Theory and Investment Analysis*, 1995, John Wiley
- R.C. Merton, *Continuous Time Finance*, 1992, Blackwell
- N. Taleb, *Dynamic Hedging*, 1996, John Wiley
- David G. Luenberger, *Investment Science*, Oxford University Press, June 1997 (Chapters 6 & 7)
- Jonathan E Ingersoll, *Theory of Financial Decision Making*, Rowman & Littlefield, 1987 (Chapter 4)
- Elton Gruber, Brown and Goetzmann, *Modern Portfolio Theory and Investment Analysis Part 2* (Chapters 4 to 12)
- S.N. Neftci, *An Introduction to the Mathematics of Financial Derivatives*, 1996, Academic Press (general reference)
- Ruey S. Tsay, *Analysis of Financial Time Series* (Wiley Series in Probability and Statistics)
- Attilio Meucci, *Risk and Asset Allocation,* Springer Finance, 3rd Corrected printing, 2009

Lifelong Learning lectures:

(available to Full program and Level II delegates)

- Fundamentals of Optimization - Riaz Ahmad
- Investment Lessons from Blackjack and Gambling - Paul Wilmott
- Symmetric Downside Sharpe Ratio - William Ziemba
- Beyond Black-Litterman: Views on Generic Markets - Attilio Meucci
- Financial Modeling using Garch Processes - Kyriakos Chourdakis

Module 3

Equities and Currencies

The Black-Scholes theory, built on the principles of delta hedging and no arbitrage, has been very successful and fruitful as a theoretical model and in practice. This module explains the theory and results using different kinds of mathematics to make the delegate familiar with techniques in current use.

- **The Black-Scholes model:** A stochastic differential equation for an asset price, the delta-hedged portfolio and self-financing replication, no arbitrage, the pricing partial differential equation and simple solutions.
- **Martingales:** The probabilistic mathematics underlying derivatives theory, Girsanov, change of measure and Feynman-Kac.
- **Risk-neutrality:** Fair value of an option as an expectation with respect to a risk-neutral density function.
- **Early exercise:** American options, elimination of arbitrage, modifying the binomial method, gradient conditions, formulation as a free-boundary problem.
- **The Greeks:** delta, gamma, theta, vega and rho and their uses in hedging.
- **Numerical analysis:** Monte Carlo simulation and the explicit finite-difference method.
- **Further numerical analysis:** Crank-Nicolson, and Douglas multi-time level methods, convergence, accuracy and stability.
- **Exotic options:** OTC contracts and their mathematical analysis.
- **Derivatives market practice:** Examination of common practices and historical perspective of option pricing.
- **Non-probabilistic models:** Uncertainty in parameter values versus randomness in variables, nonlinear equations.
- **Static hedging:** Hedging exotic target contracts with exchange-traded vanilla contracts, optimal static hedging.
- **Market based valuation of Equity Index Options using Python:** Calibration & simulation with real examples implemented in Python

Preparatory reading:

- P. Wilmott, *Paul Wilmott Introduces Quantitative Finance*, second edition, 2007, John Wiley. (Chapters 6, 8, 27-30)
- P. Wilmott, *Paul Wilmott on Quantitative Finance*, second edition, 2006, John Wiley. (Chapters 14, 22-29, 37, 45-53, 57, 76-83) three volume set.
- E.G. Haug, *Derivatives: Models on Models*, Wiley. (Chapter 1 & 2, and on the CD Know Your Weapon 1 & 2)

Further reading:

- N. Taleb, *Dynamic Hedging*, 1996, John Wiley
- J.C. Hull, Options, *Futures and Other Derivatives* (5th Edition), 2002, Prentice-Hall
- K.W. Morton and D.F. Mayers, *Numerical Solution of Partial Differential Equations: An Introduction*, 1994, Cambridge University Press
- G.D. Smith, *Numerical Solution of Partial Differential Equations*, 1985, Oxford University Press
- Martin Baxter and Andrew Rennie, *Financial Calculus: An Introduction to Derivative Pricing* (general reference)
- Steven E. Shreve, *Stochastic Calculus for Finance II: Continuous – Time Models v.2* (general reference but at least 1-6 and 9)
- Richard L. Burden and J. D. Faires, Numerical Analysis (general reference)

Lifelong Learning lectures:

(available to Full program and Level II delegates)

- Black-Scholes World, Mathematical Methods and Introduction to Numerical Methods - Riaz Ahmad
- Infinite Variance - Nassim Nicholas Taleb
- Introduction to Volatility Trading and Variance Swaps - Sebastien Bossu
- Advanced Equity Models: Pricing, Calibration and Monte Carlo Simulation - Wim Schoutens
- Discrete Hedging and Transaction Costs - Paul Wilmott
- Ten Ways to Derive Black-Scholes - Paul Wilmott
- Volatility Arbitrage and How to Hedge - Paul Wilmott

Module 4

Fixed Income and Commodities

This module reviews the plethora of interest rate models used within the industry. We discuss the implementation and limitations of these models and the need for a more sophisticated framework in order to understand these processes. Many of the ideas seen in the equity-derivatives world are encountered again here but in a more complex form.

- **Fixed-income products:** Fixed and floating rates, bonds, swaps, caps and floors, FRAs and other delta products.
- **Yield, duration and convexity:** Definitions, use and limitations, bootstrapping to build up the yield curve from bonds and swaps.
- **Curve stripping:** reference rates & basis spreads, OIS discounting and dual-curve stripping, cross-currency basis curve, cost of funds and the credit crisis.
- **Interpolation methods:** piece wise constant forwards, piece wise linear, cubic splines, smart quadratics, quartics, monontone convex splines.
- **Current Market Practices:** Money vs. scrip, holiday calendars, business day rules, and schedule generation, day count fractions.
- **Stochastic interest rate models, one and two factors:** Transferring ideas from the equity world, differences from the equity world, popular models, data analysis.
- **Calibration:** Fitting the yield curve in simple models, use and abuse.
- **Data analysis:** Examining interest rate and yield curve data to find the best model.
- Probabilistic methods for interest rates.
- **Heath, Jarrow and Morton model:** Modeling the yield curve.Determining risk factors of yield curve evolution and optimal volatility structure by PCA. Pricing interest rate derivatives by Monte Carlo.
- **The Libor Market Model:** (Also Brace, Gatarek and Musiela). Calibrating the reference volatility structure by fitting to caplet or swaption data.
- **SABR Model:** Managing volatility risks, smiles, local volatility models, using the SABR model and hedging stability.
- **Arbitrage Free SABR model:** Reduction to the effective forward equation, arbitrage free boundary conditions, comparison with historical data and hedging under SABR model.
- **Advanced Monte Carlo techniques:** Low-discrepancy series for numerical quadrature. Use for option pricing, speculation and scenario analysis.
- **Energy Derivatives:** Specualtion using energy derivatives and risk management in energy derivatives.

Preparatory reading:

- P. Wilmott, *Paul Wilmott Introduces Quantitative Finance*, 2007, John Wiley. (Chapters 14-19)
- P. Wilmott, *Paul Wilmott on Quantitative Finance*, second edition, 2006, John Wiley. (Chapters 30-33, 36, 37) three-volume set
- P. Jaeckel, *Monte Carlo Methods in Finance*, 2002, John Wiley (Chapters 1-14)

Further reading:

- N. Taleb, *Dynamic Hedging*, 1996, John Wiley
- J.C. Hull, Options, *Futures and Other Derivatives* (5th Edition), 2002, Prentice-Hall

Lifelong Learning lectures:

(available to Full program and Level II delegates)

- Term Sheets - Paul Wilmott
- Brace, Gatarek and Musiela - Timothy Mills
- Managing Smile Risk - Pat Hagan
- The Market Price of Risk - Paul Wilmott
- Fixed Income Modelling - Claudio Albanese
- Yield Curves via Static Hedging - Yury Rojek
- Tools and Methods for Quantitative Finance - Sebastien Lleo

Module 5

Credit Products and Risk

Credit risk plays an important role in the current financial markets. We see major products and examine the most important models. The modeling approaches include structural and reduced form as well as copulas.

- **Credit risk and credit derivatives:** Products and uses, credit derivatives, qualitative description of instruments, applications.
- Structural and Intensity models used for credit risk.
- **CDS pricing, market approach:** Implied default probability, recovery rate, default time modeling, building a spreadsheet on CDS pricing.
- **Synthetic CDO pricing:** The default probability distribution, default correlation, tranche sensitivity, pricing spread.
- **Implementation:** CDO/copula modeling using spreadsheets.
- **Correlation and state dependence:** correlation, linear correlation, analyzing correlation, sensitivity and state dependence.
- **Valuation Adjustment (CVA):** Valuation adjustments in pricing developing key ideas including calulation of CVA, DVA, FVA and MVA.
- **Risk of default:** The hazard rate, implied hazard rate, stochastic hazard rate and credit rating, capital structure arbitrage.
- **Copulas:** Pricing basket credit instruments by simulation.
- **Statistical methods in estimating default probability:** ratings migration and transition matrices and Markov processes.

Preparatory reading:

- P. Wilmott, *Paul Wilmott on Quantitative Finance*, second edition, 2006, John Wiley. (Chapters 39-42)

Further reading:

- A.K. Dixit and R.S. Pindyck, *Investment Under Uncertainty*, 1994, Princeton University Press
- Darrell Duffie & Kenneth J. Singleton, *Credit Risk: Pricing, Measurement, and Management*, Princeton University Press, 2003
- Gunter Loffler and Peter Posche, *Credit Risk Modeling using Excel and VBA*, Wiley, 2007
- George Chacko et al., *Credit Derivatives: A Primer on Credit Risk, Modeling, and Instruments*, Wharton School Publishing, 2006. (Chapters 3, 5)
- Philipp J. Schoenbucher, *Credit Derivatives Pricing Models: Model, Pricing and Implementation*, Wiley, 2003. (Chapters 2, 4, 5)
- Antulio N. Bomfim, *Understanding Credit Derivatives and Related Instruments*, Academic Press, 2004. (Chapters 15, 16, 17)

Lifelong Learning lectures:

(available to Full program and Level II delegates)

- Jumps in Credit Risk Modeling. Intensity Models: Theory, Cailbration, Pricing - Wim Schouten
- The Pricing of CDOs using Levy Copulas - Wim Schouten
- Introduction to CVA - David Bakstein
- Credit Modelling - Claudio Albanese

Module 6

Advanced Electives

In this module you choose two from the following six online electives to specialize in your area of interest. You will also be required to complete a practical project relating to one of the electives you have chosen.

Algorithmic Trading: The use of algorithms has become an important element of modern-day financial markets, used by both the buy side and sell side. This elective will look into the techniques used by quantitative professionals who work within the area.

- Sample Momentum Strategy
- Introduction to Fetcher - Rebalancing the SP 500 every month
- In-depth with Fundamentals - Piotroski Score
- Incorporating new sources of data - Accern and StockTwits
- Simple Stat Arbs - Pairs Trading
- More in-depth Stat Arbs - Looking at Baskets of Stocks

Who is it for: Trading, Asset Management, Hedges Funds professionals

Advanced Computational Methods: One key skill for anyone who works within quantitative finance is how to use technology to solve complex mathematical problems. This elective will look into advanced computational techniques for solving and implementing math in an efficient and succinct manner, ensuring that the right techniques are used for the right problems.

- Finite Difference Methods (algebraic approach) and application to BVP
- Root finding
- Interpolation
- Numerical Integration

Who is it for: IT, Quant Analytics, Derivatives, Valuation, Actuarial, Model Validation professionals

Advanced Risk Management and Regulation: Post-global financial crisis, risk has become a key issue in every financial organisation. Organisations need good measures and techniques to manage risk and to be able to show this to the regulators. This elective will look at the techniques used within the industry to manage risk and discuss how these are useful for an organisation and how they satisfy the regulatory landscape.

- Risk Management: A Helicopter View
- Multivariate Risk Models – Risk mapping, Copulas, Correlation and Covariance and PCA
- Portfolio VAR
- Measuring Risk Using Extreme Value Theory
- The Basel Accords

Who is it for: Risk Management, Trading, Fund Management professionals

Advanced Volatility Modeling: Volatility and being able to model volatility is a key element to any quant model. This elective will look into the common techniques used to model volatility throughout the industry. It will provide the mathematics and numerical methods for solving problems in stochastic volatility.

- Fourier Transforms
- Functions of a Complex Variable
- Stochastic Volatility
- Jump Diffusion

Who is it for: Derivatives, Structuring, Trading, Valuations, Actuarial, Model Validation professionals

Advanced Portfolio Management: As quantitative finance becomes more important in today's financial markets, many buy-side firms are using quantitative techniques to improve their returns and better manage client capital. This elective will look into the latest techniques used by the buy side in order to achieve these goals.

- Perform a dynamic portfolio optimization, using stochastic control
- Combine views with market data using filtering to determine the necessary parameters
- Understand the importance of behavioural biases and be able to address them
- Understand the implementation issues
- Develop new insights into portfolio risk management

Who is it for: Trading, Fund Management, Asset Management professionals

Counterparty Credit Risk Modeling: Post-global financial crisis, counterparty credit risk and other related risks have become much more pronounced and need to be taken into account during the pricing and modeling stages. This elective will go through all the risks associated with the counterparty and how they are included in any modeling frameworks.

- Credit Risk to Credit Derivatives
- Counterparty Credit Risk: CVA, DVA, FVA
- Interest Rates for Counterparty Risk – dynamic models and modeling
- Interest Rate Swap CVA and implementation of dynamic model

Who is it for: Risk Management, Structuring, Valuations, Actuarial, Model Validation professionals

Certificate in Quantitative Finance Reading List

Books in bold are supplied. Further Reading books are recommended but not required.

Numbers as column headings refer to the module for which the books are relevant.

Numbers underneath ● refer to chapters.

Substantial discounts are available on most of these books from the wilmott.com bookshop.

We recommend you try and get the latest editions of these books, many of them are updated quite frequently.

CORE TEXT BOOKS	1	2	3	4	5	6
P. Wilmott, *Paul Wilmott Introduces Quantitative Finance*, John Wiley	● 3,4,5,7	● 1, 2, 3, 20-22	● 6, 8, 27-30	● 14-19		
E.G. Haug, *Derivatives: Models on Models*, Wiley (Chapter 1 & 2 and on the CD Know Your Weapon 1 and 2)			●			
P. Wilmott, *Paul Wilmott on Quantitative Finance*, John Wiley			● 12, 49, 50	● 4 to 30-33, 36, 37	● 39-42	● 22-29, 37, 45-48, 50-53, 57, 76-83
P. Jaeckel, *Monte Carlo Methods in Finance*, John Wiley				1-14		
Paul Wilmott, *Frequently Asked Questions in Quantitative Finance* (general reference)	●	●	●	●	●	●
S.J. Taylor, *Asset Price Dynamics, Volatility and Prediction*, Princeton University Press		● 2, 4, 9-10, 12, 15-16				
J.D. Hamilton, *Time Series Analysis*, Princeton University Press		●			●	
J.A. Rice, *Mathematical Statistics and Data Analysis*, Wadsworth-BrooksCole	●					
E.J. Elton & M.J. Gruber, *Modern Portfolio Theory and Investment Analysis*, John Wiley		●				
S.N. Neftci, *An Introduction to the Mathematics of Financial Derivatives*, 1996, Academic Press (general reference)	●	●				
R.C. Merton, *Continuous Time Finance*, Blackwell		●				
N. Taleb, *Dynamic Hedging*, John Wiley		●	●	●		
J.C. Hull, *Options, Futures and Other Derivatives*, Prentice-Hall		●	●	●	●	

Further Reading

FURTHER READING	1	2	3	4	5	6
K.W. Morton and D.F. Mayers, *Numerical Solution of Partial Differential Equations: An Introduction*, Cambridge University Press	●			●		
David G. Luenberger, *Investment Science Oxford University Press*, June 1997 (chapters 6 & 7)				●		
Jonathan E. Ingersoll, *Theory of Financial Decision Making*, Rowman & Littlefield, 1987 (chapter 4)		●				
Elton Gruber, Brown and Goetzmann, *Modern Portfolio Theory and Investment Analysis* (Part 2 - Chapters 4 to 12)		●				
Martin Baxter and Andrew Rennie, *Financial Calculus: An Introduction to Derivative Pricing* (general reference)			●			
Steven E Shreve, *Stochastic Calculus for Finance I: The Binomial Asset Pricing Model v.1* (Chapters 1 and 5)	●					
Steven E Shreve , *Stochastic Calculus for Finance II: Continuous – Time Models v.2* (General Reference but at least 1-6 and 9)	●		●			
Darrell Duffie & Kenneth J. Singleton, *Credit Risk: Pricing, Measurement, and Management*, Princeton University Press, 2003 (General reference)					●	
Ruey S. Tsay, *Analysis of Financial Time Series* (Wiley Series in Probability and Statistics)		●				
David F Hendry and Bent Neilsen, Econometric Modeling: A Likelihood Approach, Princeton University Press, 2007		●				
Greg Davies & Arnaud de Servigny, Behavioral Investment Management: An Efficient Alternative to Modern Portfolio Theory, 2012, McGraw-Hill (discusses where classical portfolio theory breaks down)		●				
Attilio Meucci, Risk and Asset Allocation, Springer Finance, 3rd corrected printing, 2009		●			●	●

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