Certificate in Quantitative Finance

Syllabus

Module 1: Foundations of Quantitative Finance

- What is quantitative finance
- Quantitative finance versus financial engineering versus data science
- Role of a quant in banks, hedge funds, prop desks, and fintechs
- Micro and macroeconomic concepts relevant to quant modelling
- The quantitative finance workflow
- Careers in quantitative finance
- Tools and languages
- Ethics and professional conduct for quants

Module 2: Mathematics for Quantitative Finance

- Foundations: symbols, rules, sequences, series, exponents, logarithms
- Equations, inequalities, functions, and graphs
- Differential calculus and higher-order derivatives
- Financial applications of second derivatives
- Optimization: constrained and unconstrained
- Linear algebra: matrices, determinants, eigenvalues, eigenvectors
- Numerical optimization techniques
- Real analysis concepts for finance

Module 3: Probability and Statistics for Finance

- Probability foundations: axioms, conditional probability, Bayes' theorem
- Random variables: discrete and continuous
- Probability distributions: normal, lognormal, binomial, Poisson, t-distribution
- Moments of distributions: mean, variance, skewness, kurtosis
- Measures of dispersion and central tendency

- Joint distributions and covariance
- Law of large numbers and central limit theorem
- Descriptive versus inferential statistics

Module 4: Regression and Econometrics

- Simple linear regression
- Multiple linear regression
- Assumptions of OLS and diagnostics
- Confidence intervals and hypothesis testing
- Random walks and mean reversion
- Maximum likelihood estimation
- Time-series concepts: stationarity, autocorrelation, cointegration
- Panel data and cross-sectional analysis
- Multicollinearity, heteroskedasticity, autocorrelation

Module 5: Stochastic Processes and Calculus

- Introduction to stochastic processes
- Brownian motion and geometric Brownian motion
- Markov chains and Markov processes
- Ito's lemma
- Stochastic differential equations
- Poisson processes and jump diffusion
- Mean-reverting processes: Ornstein-Uhlenbeck
- Monte Carlo simulation

Module 6: Derivatives and Option Pricing

- Forwards, futures, and swaps
- Option payoffs and strategies
- Put-call parity
- Binomial option pricing model
- Black-Scholes-Merton model
- Greeks: delta, gamma, vega, theta, rho
- Implied volatility and volatility surfaces
- Exotic options: barrier, Asian, lookback
- Interest rate derivatives: caps, floors, swaptions

Module 7: Fixed Income and Interest Rate Modelling

- Bond pricing and yield conventions
- Yield to maturity, spot rates, and forward rates
- Term structure of interest rates
- Duration, convexity, and immunization
- Short-rate models: Vasicek, CIR, Hull-White
- Heath-Jarrow-Morton framework
- Credit risk and credit spreads
- Credit default swaps and CDOs

Module 8: Portfolio Theory and Optimization

- Modern portfolio theory
- Markowitz mean-variance optimization
- Efficient frontier and capital market line
- Sharpe ratio and risk-adjusted returns
- Sharpe's single-index model
- Black-Litterman model
- Risk parity and factor-based allocation
- Constraints, transaction costs, and practical implementation

Module 9: Risk Management and Quantitative Risk

- Types of risk: market, credit, liquidity, operational
- Value at Risk (VaR): historical, parametric, Monte Carlo
- Expected shortfall (CVaR)
- Stress testing and scenario analysis
- Risk factor models and covariance estimation
- Extreme value theory
- Counterparty credit risk and CVA
- Basel framework and regulatory capital

Module 10: Algorithmic Trading and Execution

- Market microstructure: order books, liquidity, spreads
- Types of orders and execution algorithms
- VWAP, TWAP, and implementation shortfall

- High-frequency trading concepts
- Backtesting: methodology, pitfalls, and biases
- Look-ahead bias, survivorship bias, and overfitting
- Transaction cost modelling
- Signal generation and alpha research

Module 11: Machine Learning and AI in Finance

- Machine learning fundamentals: supervised, unsupervised, reinforcement learning
- Feature engineering for financial data
- Overfitting and regularization
- Tree-based models: random forests, gradient boosting
- Neural networks and deep learning
- Natural language processing for financial text
- Reinforcement learning for trading
- Explainable AI and model risk

Module 12: Quantitative Investment Strategies

- Factor investing: value, momentum, quality, size, low volatility
- Statistical arbitrage and pairs trading
- Market-neutral strategies
- Trend following and managed futures
- Volatility trading and variance risk premium
- Event-driven and merger arbitrage
- Multi-strategy portfolio construction
- Capacity, crowding, and decay of alpha

Module 13: Data Science and Financial Data

- Sources of financial data: market, fundamental, alternative
- Data cleaning, alignment, and quality
- Time-series data handling
- Panel data and cross-sectional data
- Big data tools and platforms
- Alternative data: satellite, social, transaction
- Data governance and compliance
- Data visualization and dashboards

Module 14: Programming and Computational Finance

- Python for quantitative finance
- NumPy, pandas, SciPy, scikit-learn
- Object-oriented programming for finance
- Vectorization and performance optimization
- C++ and low-latency computing
- APIs and market data feeds
- Version control and reproducibility
- Cloud computing for quant research

Module 15: Model Risk, Validation and Governance

- Model risk management frameworks
- Model validation and independent review
- Backtesting and benchmarking
- Model documentation and governance
- Regulatory expectations
- Explainability and interpretability
- Model monitoring and performance decay
- AI governance and responsible AI

Module 16: Market Microstructure and Trading Systems

- Market structure
- Order types and matching engines
- Liquidity and market impact
- Latency and colocation
- Smart order routing
- Exchange connectivity and protocols
- Risk controls in trading systems
- Regulatory considerations

Module 17: Quantitative Finance in India

- Indian capital markets structure
- SEBI regulations relevant to quant strategies
- Derivatives markets in India

- Algorithmic trading regulations in India
- GIFT City and IFSCA framework for quant funds
- Indian market microstructure
- Data availability and challenges in India
- Career paths for quants in India

Module 18: Emerging Trends in Quantitative Finance

- Machine learning and deep learning advances
- Reinforcement learning in trading
- Quantum computing for finance
- Decentralized finance and blockchain
- ESG and climate risk modelling
- Digital assets and crypto quant strategies
- Alternative data and AI-driven alpha
- The future of quant finance careers