School of Sciences
Bachelor of Quantitative Finance

SISTER NIVEDITA UNIVERSITY

SYLLABUS

FOR

THREE YEARS BACHELOR DEGREE COURSE

IN

QUANTITATIVE FINANCE

UNDER

UGC-CBCS SYSTEM

2022

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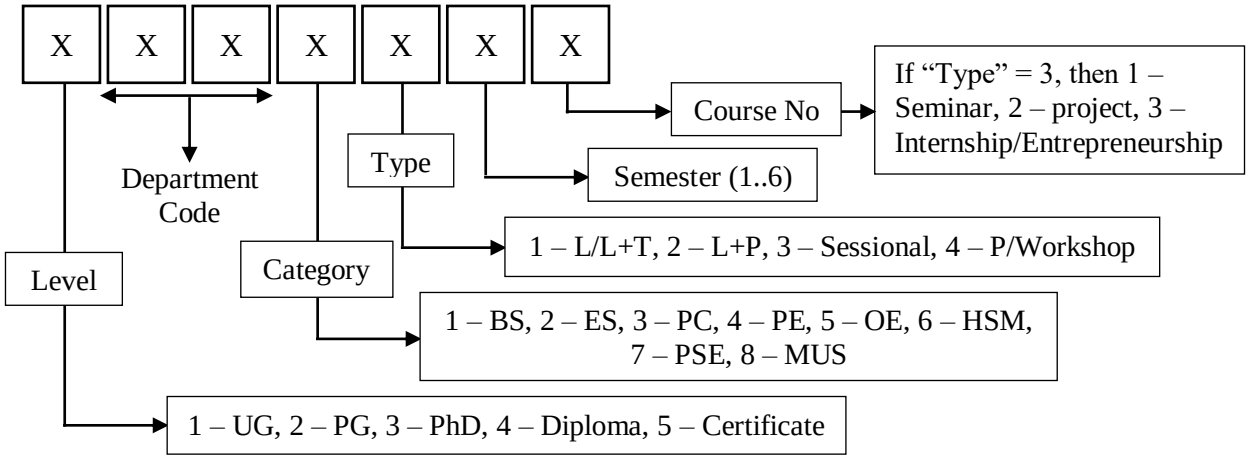
Credit Definition

Type	Duration (in Hour)	Credit
Lecture (L)	1	1
Tutorial (T)	1	1
Practical (P)	2	1

Subject Codification Nomenclature



CC: Core Courses; GE: General Elective; AECC: Ability Enhancement Compulsory Course; SEC: Skill Enhancement Courses; DSE: Discipline Specific Elective; USC: University specified course

First Year

Mandatory Induction Program – Duration 3 weeks

- Physical Activity
- Creative Arts
- Universal Human Values
- Literary
- Proficiency Modules
- Lectures by Eminent People
- Visits to Local Areas
- Familiarization to Department/Branch & Innovations

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SEMESTER: I

Category	Course Title	Code	Credit	Type		
				L	T	P
CC-1	Finance Primer: Financial Instruments and Financial Markets		4	3	1	0
CC-2	Mathematics Primer : Calculus, Probability and Probability distributions, Stochastic Differential Equations		6	4	2	0
DSE-1	Introduction to Python		4	3	1	0
GE-1	Generic Elective		4	3	1	0
AECC-1	Communicative English-I		2	2	0	0
USC-1	Foreign Language – I (German /Spanish /Japanese)		2	2	0	0
Total Credit			24			

SEMESTER: II

Category	Course Title	Code	Credit	Type		
				L	T	P
CC-3	Fundamentals of Quantitative Finance		4	3	1	0
CC-4	Quantitative Risk and Return: Portfolio management and Markowitz Theory		6	4	2	
DSE-2	Fundamentals of Economics		4	3	1	0
GE-2	Generic Elective		4	3	1	0
SEC-1	Mentored Seminar – I		1	1	0	0
USC-2	Foreign Language – II (German /Spanish /Japanese)		2	2	0	0
Total Credit			21			

SEMESTER: III

Category	Course Title	Code	Credit	Type		
				L	T	P
CC-5	Financial Economics		6	4	2	0
CC-6	Equities and Currencies: Pricing Model		6	4	2	0
DSE-3	Time Series Econometrics and applications		4	3	1	0
GE-3	Generic Elective		4	3	1	0
AECC-2	Environmental Science		2	2	0	0
SEC-2	Mentored Seminar – II		1	1	0	0
USC-3	Foreign Language – III (German /Spanish /Japanese)		2	2	0	0
Total Credit			25			

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SEMESTER: IV

Category	Course Title	Code	Credit	Type		
				L	T	P
CC-7	Data Science and Machine Learning 1		6	4	2	0
CC-8	Brownian Motion		6	4	2	0
DSE-4	Numerical Analysis		4	4	0	0
GE-4	Generic Elective		4	3	1	0
SEC-3	Mentored Seminar – III		1	1	0	0
USC-4	Foreign Language – IV (German /Spanish /Japanese)		2	2	0	0
Total Credit		23				

SEMESTER: V

Category	Course Title	Code	Credit	Type		
				L	T	P
CC-9	Interest Rate Models		6	4	2	0
CC-10	Data Science and Machine Learning 2		6	4	2	0
CC-11	Behavioral Finance		4	3	1	0
CC-12	Elective I		4	3	1	0
Total Credit		22				

SEMESTER:VI

Sl No	Course Title	Code	Credit	Type		
				L	T	P
1	Elective II		4	4	0	0
2	Elective III		4	4	0	0
3	Project Work I		13	10	3	0
Total Credit		21				

Elective I:

Elective II:

Elective III:

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SYLLABUS OUTLINE:

SEMESTER I

CC 1 PAPER NAME: Finance Primer: Financial Instruments Financial Markets

- Macro Economics
- Capital Markets in Fundamentals
- Introduction to Money Markets
- Time Value of Money
- Introduction to Equities
- Introduction to Bonds
- Introduction to Swaps
- Introduction to FX
- Introduction to Derivatives
- Introduction to Commodities

CC 2 PAPER NAME: Mathematics Primer : Calculus, Probability and Probability distributions, Stochastic Differential Equations

Calculus:

- Functions and Limits
- Differentiation and Integration
- Complex Numbers
- Functions of Several Variables

Differential Equations:

- First Order Equations
- Second and Higher Order Equations

Probability:

- Probability Distribution Function
- Cumulative Distribution
- Expectation Algebra
- Key Discrete and Continuous Distributions Including the Normal Distribution
- Central Limit Theorem

Statistics:

- General Summary Statistics
- Maximum Likelihood Estimator

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- Regression and Correlation

Linear Algebra:

- Matrices and Vectors
- Systems of Linear Equations
- Eigenvalues and Eigenvectors

Suggested Books:

SEMESTER II

CC 3 PAPER NAME: Fundamentals of Quantitative Finance

The Random Behavior of Assets

- Different types of financial analysis
- Examining time-series data to model returns
- Random nature of prices
- The need for probabilistic models
- The Wiener process, a mathematical model of randomness
- The lognormal random walk- The most important model for equities, currencies, commodities and indices

Binomial Model

- A simple model for an asset price random walk
- Delta hedging
- No arbitrage
- The basics of the binomial method for valuing options
- Risk neutrality

PDEs and Transition Density Functions

- Taylor series
- A trinomial random walk
- Transition density functions
- Our first stochastic differential equation
- Similarity reduction to solve partial differential equations
- Fokker-Planck and Kolmogorov equations

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Applied Stochastic Calculus 1

- Moment Generating Function
- Construction of Brownian Motion/Wiener Process
- Functions of a stochastic variable and Itô's Lemma
- Applied Itô calculus
- Stochastic Integration
- The Itô Integral
- Examples of popular Stochastic Differential Equations

Applied Stochastic Calculus 2

- Extensions of Itô's Lemma
- Important Cases - Equities and Interest rates
- Producing standardised Normal random variables
- The steady state distribution

Martingales

- Binomial Model extended
- The Probabilistic System: sample space, filtration, measures
- Conditional and unconditional expectation
- Change of measure and Radon-Nikodym derivative
- Martingales and Itô calculus
- A detour to explore some further Ito calculus
- Exponential martingales, Girsanov and change of measure

CC 4 PAPER NAME: Quantitative Risk and Return: Portfolio management and Markowitz Theory

Portfolio Management

- Measuring risk and return
- Benefits of diversification
- Modern Portfolio Theory and the Capital Asset Pricing Model
- The efficient frontier
- Optimizing your portfolio
- How to analyze portfolio performance
- Alphas and Betas

Fundamentals of Optimization and Application to Portfolio Selection

- Fundamentals of portfolio optimization
- Formulation of optimization problems

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- Solving unconstrained problems using calculus
- Kuhn-Tucker conditions
- Derivation of CAPM

Value at Risk and Expected Shortfall

- Measuring Risk
- VaR and Stressed VaR
- Expected Shortfall and Liquidity Horizons
- Correlation Everywhere
- Frontiers: Extreme Value Theory

Asset Returns: Key, Empirical Stylised Facts

- Volatility clustering: the concept and the evidence
- Properties of daily asset returns
- Properties of high-frequency returns

Volatility Models: The ARCH Framework

- Why ARCH models are popular?
- The original GARCH model
- What makes a model an ARCH model?
- Asymmetric ARCH models
- Econometric methods

Risk Regulation and Basel III

- Definition of capital
- Evolution of Basel
- Basel III and market risk
- Key provisions

Collateral and Margins

- Expected Exposure (EE) profiles for various types of instruments
- Types of Collateral
- Calculation Initial and Variation Margins
- Minimum transfer amount (MTA)
- ISDA / CSA documentation

Suggested Books:

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SEMESTER: III

CC 5 PAPER NAME: Financial Economics

CC 6 PAPER NAME: Equities and Currencies: Pricing Model

Black-Scholes Model

- The assumptions that go into the Black-Scholes equation
- Foundations of options theory: delta hedging and no arbitrage
- The Black-Scholes partial differential equation
- Modifying the equation for commodity and currency options
- The Black-Scholes formulae for calls, puts and simple digitals
- The meaning and importance of the Greeks, delta, gamma, theta, vega and rho
- American options and early exercise
- Relationship between option values and expectations

Martingale Theory - Applications to Option Pricing

- The Greeks in detail
- Delta, gamma, theta, vega and rho
- Higher-order Greeks
- How traders use the Greeks

Martingales and PDEs: Which, When and Why

- Computing the price of a derivative as an expectation
- Girsanov's theorem and change of measures
- The fundamental asset pricing formula
- The Black-Scholes Formula
- The Feynman-K_ac formula
- Extensions to Black-Scholes: dividends and time-dependent parameters
- Black's formula for options on futures

Intro to Numerical Methods

- The justification for pricing by Monte Carlo simulation
- Grids and discretization of derivatives
- The explicit finite-difference method

Exotic Options

- Characterisation of exotic options

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- Time dependence (Bermudian options)
- Path dependence and embedded decisions
- Asian options

Understanding Volatility

- The many types of volatility
- The market prices of options tells us about volatility
- The term structure of volatility
- Volatility skews and smiles
- Volatility arbitrage: Should you hedge using implied or actual volatility?

Further Numerical Methods

- Implicit finite-difference methods including Crank-Nicolson schemes
- Douglas schemes
- Richardson extrapolation
- American-style exercise
- Explicit finite-difference method for two-factor models
- ADI and Hopscotch methods

Derivatives Market Practice

- Option traders now and then
- Put-Call Parity in early 1900
- Options Arbitrage Between London and New York (Nelson 1904)
- Delta Hedging
- Arbitrage in early 1900
- Fat-Tails in Price Data
- Some of the Big Ideas in Finance
- Dynamic Delta Hedging
- Bates Jump-Diffusion

Advanced Greeks

- The names and contract details for basic types of exotic options
- How to classify exotic options according to important features
- How to compare and contrast different contracts
- Pricing exotics using Monte Carlo simulation
- Pricing exotics via partial differential equations and then finite difference methods

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Advanced Volatility Modeling in Complete Markets

- The relationship between implied volatility and actual volatility in a deterministic world
- The difference between 'random' and 'uncertain'
- How to price contracts when volatility, interest rate and dividend are uncertain
- Non-linear pricing equations
- Optimal static hedging with traded options
- How non-linear equations make a mockery of calibration

Suggested Books

SEMESTER: IV

CC 7 PAPER NAME: Data Science and Machine Learning 1

An Introduction to Machine Learning l

- What is mathematical modeling?
- Classic modeling
- How is machine learning different?
- Principal techniques for Machine Learning

An Introduction to Machine Learning II

- Common Machine Learning Jargon
- Intro to Supervised Learning techniques
- Intro to Unsupervised Learning techniques
- Intro Reinforcement Learning techniques

Math Toolbox for Machine Learning

- Maximum Likelihood Estimation
- Cost/Loss Function
- Gradient Descent
- Stochastic Gradient Descent
- Bias and Variance
- Lagrange Multipliers
- Principal Component Analysis

Supervised Learning – Regression Methods

- Linear Regression
- Penalized Regressions: Lasso, Ridge and Elastic Net
- Logistic, Softmax Regression

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Supervised Learning II

- K Nearest Neighbors
- Naïve Bayes Classifier
- Support Vector Machines

Decision Trees and Ensemble Models

- Entropy minimisation and essential math
- Splitting process and pruning criteria
- Random Forests and Extreme Gradient Boosting
- Bagging with Logit and Decision Tree alternatives (PD Case Study)

Practical Machine Learning Case Studies for Finance

- Macro Forecasting the S&P 500 and the Baa-Spread
- Sharpe style regression methods for mutual funds
- Natural Language Processing for Sentiment Analysis of ESG Company Reports

CC 8 PAPER NAME: Brownian Motion

Suggested Books

SEMESTER: V

CC 9 PAPER NAME: Interest Rate Models

Fixed Income Products and Analysis

- Names and properties of the basic and most important Fixed Income Products
- Features commonly found in Fixed Income Products
- Simple ways to analyze the market value of the instruments: yield, duration and convexity
- How to construct yield curves and forward rates
- Swaps
- The relationship between swaps and zero-coupon bonds

Stochastic Interest Rate Modeling

- Stochastic models for interest rates
- How to derive the pricing equation for many Fixed Income Products
- The structure of many popular one-factor interest rate models
- The theoretical framework for multi-factor interest rate modeling
- Popular two-factor models

Calibration and Data Analysis

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- How to choose time-dependent parameters in one-factor models so that today's yield curve is an output of the model
- The advantages and disadvantages of yield curve fitting
- How to analyze short-term interest rates to determine the best model for the volatility and the real drift
- How to analyze the slope of the yield curve to get information about the market price of risk

Probabilistic Methods for Interest Rates

- The pricing of interest rate products on a probabilistic setting
- The equivalent Martingale measures
- The fundamental asset pricing formula for bonds
- Application for popular interest rates models
- The dynamics of bond prices
- The forward measure
- The fundamental asset pricing formula for derivatives on bonds

Heath Jarrow and Morton Model

- The Heath, Jarrow & Morton (HJM) Forward Rate Model
- The relationship between HJM and spot rate models
- The advantages and disadvantages of the HJM approach
- How to decompose the random movements of the forward rate curve into its principal components

The Libor Market Model

- The Libor Market Model
- The market view of the yield curve
- Yield curve discretisation
- Standard Libor market model dynamics
- Numéraire and measure
- The drift
- Factor reduction

Further Monte Carlo

- The Connection to statistics
- The basic Monte Carlo algorithm, standard error and uniform variates
- Non-uniform variates, efficiency ratio and yield
- Co-dependence in multiple dimensions

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- Wiener Path Construction; Poisson Path Construction
- Numerical integration for solving Sdes
- Variance reduction techniques
- Sensitivity calculations
- Weighted Monte Carlo

Co-Integration for Trading

- Multivariate time series analysis
- Stationary and unit root
- Vector Autoregression Model (VAR)
- Co-integrating relationships and their rank
- Vector Error Correction Model (VECM)
- Reduced Rand Model (Regression) Estimation: Johansen Procedure
- Stochastic modeling of autoregression: Orstein-Uhlenbeck Process
- Statistical arbitrage using mean reversion

Credit Derivatives and Structural Models

- Introduction to credit risk
- Modelling credit risk
- Basic structural models: Merton Model, Black and Cox Model
- Advanced structural models

Credit Default Swaps

- An introduction to CDS
- Default modelling toolkit. Inhomogenous Poisson Process
- CDS pricing: basic and advanced models
- Bootstrapping intensity from CDS market quotes
- Accruals and upfront premium in CDS pricing

Intensity Models

- Modelling default by Poisson Process
- Relationship between intensity and arrival time of default
- Risky bond pricing: constant vs. stochastic hazard rate
- Bond pricing with recovery
- Theory of Affine Models
- Affine Intensity Models and use of Feynman-Kac
- Two-factor Affine Intensity Model example: Vasicek

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CDO & Correlation Sensitivity

- CDO market pricing and risk management
- Loss function and CDO pricing equation
- Motivation from loss distribution
- What Is Copula Function?
- Classification of copula functions
- Simulating via Gaussian Copula
- 3 Gaussian Copula Factor Mode
- The meaning of correlation. Intuition and timescale
- Linear correlation and its misuse
- Rank correlation
- Correlation in exotic options
- Uncertain correlation model for Mezzanine Tranche
- Compound (implied) correlation in loss distribution

X-Valuation Adjustment

- Historical development of OTC derivatives and Xva
- Credit and Debt Value Adjustments (CVA and DVA)
- Funding Value Adjustment (FVA)
- Margin and Capital Value Adjustments (MVA and KVA)
- Current market practice and application
- Implementation of Counterparty Credit Valuation Adjustment (CVA)
- Review the numerical methodologies currently used to quantify CVA in terms of exposure and Monte Carlo Simulation and the Libor Market Model
- Illustrate this methodology as well as DVA, FVA and others

CC 10 PAPER NAME: Data Science and Machine Learning 2

Unsupervised Learning |

- K Means Clustering
- Self Organizing Maps
- Strengths and Weaknesses of HAC and SOM
- Applications in Finance

Unsupervised Learning II

- The curse of dimensionality
- t-distributed Stochastic Neighbor Embedding (t-SNE)
- Uniform Manifold Approximation and Projection (UMAP)
- Autoencoders
- Applications in Finance

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Deep Learning and Neural Networks

- What are Artificial Neural Networks and Deep Learning?
- Perceptron Model, Backpropagation
- Neural Network Architectures: Feedforward, Recurrent, Long Short Term Memory, Convolutional, Generative adversarial
- Applications in Finance

Natural Language Processing

- Pre Processing
- Word vectorizations, Word2Vec
- Deep Learning and NLP Tools
- Application in Finance: sentiment change vs forward returns; S&P 500 trends in sentiment change; Earnings calls analysis.
- Code examples

Reinforcement Learning I

- Recap of multi-armed bandit
- The exploitation-exploration trade-off
- Exploration strategies: softmax versus epsilon-greedy
- Risk-sensitivity in Reinforcement-learning

Reinforcement Learning II

- Reinforcement Learning Case Study
- Application of algo trading
- Application in automated market making

AI Based Algo Trading Strategies

- Basic Financial Data Analysis with Python and Pandas
- Creating Features and Label Data from Financial Time Series for Market Prediction
- Application of Classification Algorithms from Machine Learning to Predict Market Movements
- Vectorized Backtesting of Algorithmic Trading Strategies based on the Predictions
- Risk Analysis for the Algorithmic Trading Strategies

Practical Machine Learning Case Studies for Finance

- Asset Price Behaviour and Volatility modeling
- Empirical SDEs with estimated drift and diffusion functions
- Generalized Stoch Vol models, learning dynamical models from data
- Option pricing and hedging using Machine Learning
- Model free pricing of exotic options
- Robust Portfolio Optimization with Machine Learning

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- Denoising and Detoning covariance matrices
- Nested Cluster Optimization

Quantum Computing in Finance

- Define quantum computing
- Review the three key ingredients of quantum computing: qubits, quantum gates and quantum circuits
- Enumerate some of the applications of quantum computing in various fields
- Construct a simple quantum circuit online using the IBM Quantum Experience
- Learn how to write your own quantum program using the Python module Qiskit
- Review some financial applications of quantum computing, in particular European Call Options

Suggested Books

SEMESTER: VI

CC 9 PAPER NAME: Behavioral Finance

Behavioral finance and how human psychology affects our perception of the world, impacts our quantitative models and drives our financial decisions. This elective will equip delegates with tools to identify the key psychological pitfalls, use their mathematical skills to address these pitfalls and build better financial models.

- System 1 Vs System 2
- Behavioural Biases; Heuristic Processes; Framing Effects and Group Processes
- Loss Aversion Vs Risk Aversion; Loss Aversion; SP/A theory
- Linearity and Nonlinearity
- Game Theory

CC 10 PAPER NAME: Introduction to Anaconda

CC 11 PAPER NAME: C++

Intended for those who are completely new to C++ or have very little exposure to the language.

Starting with the basics of simple input via keyboard and output to screen, this elective will work through a number of topics, finishing with simple OOP.

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- Getting Started with the C++ Environment – First Program; Data Types; Simple Debugging
- Control Flow and Formatting – Decision Making; File Management; Formatting Output
- Functions – Writing User Defined Functions; Headers and Source Files
- Intro to OOP – Simple Classes and Objects
- Arrays and Strings

Suggested Books

Elective I: Numerical Methods

Any study in mathematics is incomplete without treatment of numerical analysis. When a closed form solution is not available or the problem to be solved is too complex to make amenable to explicit methods, a numerical/computational solution is sought. The resulting solution is an example of an approximate solution.

This one-day elective will present several basic numerical methods for solving some of the most classic problems in mathematics.

- Basic iteration and convergence
- Bisection method
- Newton-Raphson
- Rates of convergence
- Taylor series and the error term
- Numerical differentiation
- Trapezoidal method
- Simpson's rule
- Error analysis
- Euler
- Runge-Kutta
- Lagrange interpolation
- Cubic splines
- LU decomposition
- SOR methods

Elective II: R for Data Science & Machine Learning

R is a powerful programming language and software environment for statistical computing. It is one of the favorite tools among academicians and is widely used among statisticians and

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data miners for their data analysis. In this workshop, we'll revisit R programming from scratch to solve quant finance and machine learning problems that help in understanding mathematical and computational tools from a quant's perspective.

- Introduction & Installation
- Getting Started with R & RStudio
- Working with Data
- Writing your own Custom Functions
- Visualization & Charting
- Statistics and Probability
- Machine Learning Applications in R

Elective III: 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