Національний технічний університет України
«КИЇВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ
імені ІГОРЯ СІКОРСЬКОГО»

MMCA

Department of Mathematical Methods of System Analysis

COURSE NAME

Work program of the discipline (Syllabus)

System Financial Mathematics

Details of the discipline	
Level of higher education	***Second (Master's)***
Field of knowledge	*12 Information Technology*[1]
Speciality	*124 System Analysis*
Educational program	*System Analysis of Financial Market, System Analysis and Management*
Discipline status	*Normative*
Form of study	*full-time (daytime)/full-time (evening)/part-time/remote/mixed*
Year of preparation, semester	*1st year, autumn semester*
Scope of discipline	*4 Credit Module*
Semester control / control measures	*Differentiated credit*
Timetable	*Tuesday 2 par / Thursday 2 par*
Language of instruction	*Ukrainian/English/*
Information about Course Leader / Instructors	Lecturer: *Doctor of Physical and Mathematical Sciences, Professor, Corresponding Member of the National Academy of Sciences of Ukraine Kasyanov Pavlo Olehovych, kasyanov.pavlo@lll.kpi.ua https://www.facebook.com/pkasyanov https://www.linkedin.com/in/pavlokasyanov/ https://www.researchgate.net/profile/Pavlo_Kasyanov* Practical / Seminar: *Doctor of Physical and Mathematical Sciences, Professor, Corresponding Member of the National Academy of Sciences of Ukraine Kasyanov Pavlo Olehovych, kasyanov.pavlo@lll.kpi.ua https://www.facebook.com/pkasyanov https://www.linkedin.com/in/pavlokasyanov/ https://www.researchgate.net/profile/Pavlo_Kasyanov*
Course Placement	*Training materials are posted on the Sikorsky Platform (se90tq)* https://do.ipo.kpi.ua/enrol/index.php?id=2118

The program of the discipline

1. Description of the discipline, its purpose, subject of study and learning outcomes

The purpose *of the credit module is to form students' abilities to develop and apply models of financial, geophysical and socio-economic processes and fields using the theoretical and methodological foundations of financial and system mathematics, and students must master the following* ***competencies****:*
General: *GC1 Ability to abstract thinking, analysis and synthesis.*
GC3 Ability to search, process and analyze information from various sources.

Professional: *FC4 Ability to assess risks, develop risk management algorithms in complex systems of various nature. FC5 Ability to model, predict and design complex systems and processes based on methods and tools of system analysis.*

FC6 Ability to apply Data Science theory and methods to perform data mining in order to identify new properties and generate new knowledge about complex systems.

Program Learning Outcomes:

PRN 2 Build and investigate models of complex systems and processes using the following methods: system analysis, mathematical, computer and information modeling.

PRN 3 Apply methods of disclosure of uncertainties in the tasks of system analysis,
to reveal situational uncertainties and uncertainties in the tasks of interaction, counteraction and conflict of strategies, to find a compromise in the disclosure of conceptual
Uncertainty.

PRN 5 Use risk assessment measures and apply them in the analysis of multifactorial risks in complex systems.

PRN 6 Apply methods of machine learning and data mining, mathematical apparatus of fuzzy logic, game theory and distributed artificial intelligence
to solve complex problems of system analysis.

PRN 8 Identify and evaluate the parameters of mathematical models
Management Objects

PRN 12 Know the legislative acts to ensure the protection of intellectual property, the requirements for compliance with the established requirements when filing applications for patents for inventions; adhere to academic integrity

1.1. In particular, to acquire the following practical skills:

- *how to code in Python and R;*
- *work with scientific packages such as NumPy, Scirit-Learn, Keras, etc.;*
- *understanding of how to use the Pandas data analysis toolkit;*
- *how to use Python and R to solve real-world problems;*
- *how to get a job as a data scientist;*
- *how to conduct an in-depth analysis of investments;*
- *how to build investment portfolios;*
- *how to calculate the risks and returns of individual securities;*
- *application of best practices for working with financial data;*
- *use of regression analysis;*
- *understanding of the capital pricing model;*
- *comparison of securities by their Sharpe ratio;*
- *simulation using the Monte Carlo method;*
- *ability to evaluate options using the Black-Scholes formula;*
- *how to easily get a job as a developer in a financial institution.*

1.2. The main tasks of the credit module.

Models of financial, geophysical and socio-economic processes and fields.

1.3. The main tasks of the credit module.

According to the requirements of the program of the discipline, students after mastering the credit module must demonstrate the following learning outcomes:

Knowledge*:*

methods and means of modeling financial, geophysical and socio-economic processes and fields.

***Skills**:*

solve real-world problems with the help of financial analytical simulations. In particular, to determine the optimized return and level of risk, to determine which financial indicators can be simulated by random variables and how they are distributed, to determine the datasets available for analytical sampling of these random variables, which financial indicators are highly correlated, which are relatively independent, to determine whether analytical thinking can give the algorithm an advantage over a simple holding strategy when generating transactions.

***Experience**:*

creation of a research financial laboratory (a paradigm of organized cooperation based on the experience of leading national laboratories in the United States), where the role of each team member is to specialize in a particular task in order to become the best in it, while having a holistic view of the entire process.

2. Prerequisites and post-requisites of the discipline (place in the structural and logical scheme of training in the relevant educational program)

The academic discipline belongs to the cycle of professional training. Interdisciplinary relations: the teaching of the discipline "System Financial Mathematics" is preceded by the study of the discipline "Systems and Methods of Decision Support".

3. The content of the discipline

Credit module 1.

Chapter 1. System Financial Mathematics

1. *Introduction to the stock market.*
   - *1.1. The big picture.*
     - *1.1.1. Types and nature of securities.*
     - *1.1.2. Securities market infrastructure.*
     - *1.1.3. Four stages of "macro-wave" investing.*
     - *1.1.4. Four dynamic factors.*
   - *1.2. Three key cycles.*
     - *1.2.1. Tracking market trends.*
     - *1.2.2. Business Cycle and Stock Market Cycle.*
     - *1.2.3. The Four Stages of the Interest Rate Cycle.*
   - *1.3. Selection of strong and weak stocks and sectors.*
     - *1.3.1. Fundamental analysis.*
     - *1.3.2. Technical analysis.*
   - *1.4. Stock trading technique.*
     - *1.4.1. Managing your risks.*
     - *1.4.2. Managing your money.*
     - *1.4.3. Manage your trading operations.*
     - *1.4.4. Execution of trades.*
   - *1.5. "Macro-wave" investment in dynamics.*
     - *1.5.1. Preparation for the investment week.*
     - *1.5.2. Stimulation of portfolio modeling.*
2. *Financial analytics with R and Python. Building a laboratory for data analysis in a laptop.*
   - *2.1. Analytical thinking.*
   - *2.2. R and Python language for statistical calculations.*
   - *2.3. Financial statistics.*
   - *2.4. Financial securities.*
   - *2.5. Database analysis and risk measurement.*
   - *2.6. Time series analysis.*

2.7. Sharpe ratio.
2.8. Markowitz optimization.
2.9. Cluster analysis.
2.10. Market sentiment assessment.
2.11. Simulation of trading strategies.
2.12. Data exploration through fundamental analysis.
2.13. Forecasting with the help of fundamental analysis.
2.14. Binomial model for options.
2.15. Black-Scholes model.
3. Financial Machine Learning.
3.1. Data analysis.
3.2. Modeling.
3.3. Rotational assessment and backtesting.
3.4. Useful financial features.
3.5. Recipes for high-performance computing.

Recommended topics of practical (seminar) classes

The purpose of conducting practical classes is to consolidate the knowledge gained in lectures, to acquire skills to solve real problems with the help of financial analytical simulations.

1. *Introductory lesson. Downloading useful resources. Introduction to programming in Python.*
2. *Variables and data types in Python.*
3. *Basic syntax in Python.*
4. *Conditional transitions. Functions in Python. Sequences in Python. Iterations in Python.*
5. *Additional features in Python.*
6. *Calculate and compare profit margins in Python.*
7. *Assessment of investment risks.*
8. *Using regression for financial analytics.*
9. *Optimization of the Markowitz portfolio.*
10. *Capital pricing model.*
11. *Regression analysis.*
12. *The Monte Carlo Method as a Decision-Making Tool.*
13. *Data preparation in Python and R*
14. *Classification and Clustering in R and Python*
15. *Learning associative rules*
16. *Reinforcement learning*
17. *Natural Language Processing*
18. *Model Selection*

4. Training Materials & Resources

All the necessary materials are contained on the Sikorsky platform (se90tq)
https://do.ipo.kpi.ua/enrol/index.php?id=2118

Basic:

1. Peter Navarro, When the Market Moves, Will You Be Ready? McGraw-Hill Education, 2003.

2. Mark J. Bennett, Dirk L. Hugen, Financial Analytics with R. Building a Laptop Laboratory for Data Science. Cambridge University Press, 2016.

3. Marcos Lopez de Prado, Advances in Financial Machine Learning. John Wiley & Sons, Inc, 2018.

4. https://www.udemy.com/course/python-for-finance-investment-fundamentals-data-analytics

5. https://www.udemy.com/course/machinelearning/

Secondary:

6. Attilio Meucci, Risk and Asset Allocation. (Springer Finance) 1st ed. 2005. Corr. 3rd printing, 2009

7. M.Z. Zgurovsky, V.S. Mel'nik, P.O. Kasyanov Evolution Inclusions and Variation Inequalities for Earth Data Processing I. Heidelberg, Springer, 2011.– 247p.

8. M.Z. Zgurovsky, V.S. Mel'nik, P.O. Kasyanov Evolution Inclusions andVariation Inequalities for Earth Data Processing II. Heidelberg, Springer,2011. – 274p.

9. Zgurovsky M.Z., Kasyanov P.O., Kapustyan O.V., Valero J., Zadoianchuk N.V. Evolution inclusions and variation Inequalities for Earth data processing III. Long-Time Behavior of Evolution Inclusions Solutions in Earth Data Analysis (English) Series: Advances in Mechanics and Mathematics, 27. – Berlin: Springer, 2012. – XLI. – 330 p. – ISBN 978-3-642-28511-0.

10. Zgurovsky M.Z., Kasyanov P.O. Qualitative and Quantitative Analysis of Nonlinear Systems. Theory and Applications / Springer Series: Studies in Systems, Decision and Control. – Berlin, Cham: Springer, 2018. – XXXIII, 240 p. – DOI: 10.1007/978-3-319-59840-6

11. Zgurovsky M. Z., Melnik V. S. Nonlinear Analysis and Control of Physical Processes and Fields. – Springer, Berlin, 2004. – 508p.

Educational content

5. Methods of mastering the discipline (educational component)

4.1. Lectures

Salary No.	*Title of the topic of the lecture and a list of the main questions (list of didactic aids, references to literature and tasks for the SRS)*
1	*The general picture: the types and nature of securities, the infrastructure of the securities market, the four stages of "macro-wave" investment. [1,6] (2 hours)*
2	*The three key cycles are the Market Trend Tracker, the Business Cycle and the Stock Market Cycle, and the four stages of the Interest Rate Cycle. [1,6] (2 hours)*
3	*Selection of Strong and Weak Stocks and Sectors: Fundamental Analysis, technical analysis. [1,6] (2 hours)*
4	*Stock trading techniques: managing your risks, managing your money, managing your trading operations, executing trades. [1,6] (2 hours)*
5	*"Macro-wave" investing in dynamics: preparation for the investment week, stimulation of portfolio modeling. [1,6] (2 hours)*
6	*Analytical thinking. [2,6] (1 year)*
7	*R and Python language for statistical calculations. Financial statistics. [2,6] (1 year)*
8	*Financial securities. Database analysis and risk measurement. [2,6] (1 year)*
9	*Time series analysis. Sharpe ratio. Markowitz optimization. [2,6] (1 year)*
10	*Cluster analysis. Market sentiment assessment. Simulation of trading strategies. [2,6] (2 years)*
11	*Data exploration through fundamental analysis. [2,6] (1 year)*
12	*Forecasting with the help of fundamental analysis. Binomial model for options. Black-Scholes model. [2,6] (Year 3)*
13	*Financial Machine Learning. [3,6] (Year 4)*

14	Data analysis. Modeling. Rotational assessment and backtesting. [3,6] (Year 3)
15	Useful financial features [3,6] (3 hours).
16	Recipes for high-performance computing [3,6] (3 hours).

4.2. Practical exercises

The purpose of conducting practical classes is to consolidate the knowledge gained in lectures, to acquire the ability to solve real problems with the help of financial analytical simulations

Salary No.	Name of the topic of the lesson (list of didactic support, links to literature and tasks for the SRS)
1	Introductory lesson. Downloading useful resources. Introduction to programming in Python. [4-6] (1 year)
2	Variables and data types in Python. [4-6] (1 year)
3	Basic syntax in Python. [4-6] (1 year)
4	Conditional transitions. Functions in Python. Sequences in Python. Iterations in Python. [4-6] (1 year)
5	Additional features in Python. [4-6] (1 year)
6	Calculate and compare profit margins in Python. [4-6] (1 year)
7	Assessment of investment risks. [4-6] (1 year)
8	Using regression for financial analytics. [4-6] (1 year)
9	Optimization of the Markowitz portfolio. [4-6] (1 year)
10	Capital pricing model. [4-6] (1 year)
11	Regression analysis. [4-6] (1 year)
12	The Monte Carlo Method as a Decision-Making Tool. [4-6] (1 year)
13	Data preparation in Python and R [4-6] (1 hour)
14	Classification and Clustering in R and Python [4-6] (1 hour)
15	Learning associative rules [4-6] (1 hour)
16	Reinforcement Learning [4-6] (1 hour)
17	Natural Language Processing [4-6] (1 hour)
18	Model Selection [4-6] (1 hour)

6. Independent work of a student/graduate student

Students' independent work consists in processing materials and completing tasks on the distance learning platform "Sikorsky" (se90tq)
https://do.ipo.kpi.ua/enrol/index.php?id=2118 ; preparation for the test.

Policy & Control

7. Academic discipline policy (educational component)

It is required to properly perform all tasks on the Sikorsky distance learning platform (se90tq) https://do.ipo.kpi.ua/enrol/index.php?id=2118 according to the requirements and individual strategy, which is determined by the student independently or, if necessary, under the scientific guidance of the teacher / supervisor.

8. Types of control and rating system for assessing learning outcomes (CRO)

Current control: each student determines the strategy for completing tasks (independently or, if necessary, under the scientific guidance of the teacher / supervisor), aiming to receive 100 points at the end of the semester.

Types of control:

a) 5 tests on the distance learning platform "Sikorsky" (se90tq) https://do.ipo.kpi.ua/enrol/index.php?id=2118 (there is a limit on the number of attempts and deadline), each of which can be evaluated for a maximum of 4 points;

*b) trading simulation on the Investopedia trading simulator (https://www.investopedia.com/) game **KA3XSAX**. If, as of December 20, 2023, a student has increased their income by 20% - they receive 100 points! If the total income of the group (as of December 20, 2023) exceeds 1,000,000 USD, all members of the group receive 100 points (each student receives 100,000 USD on the Investopedia platform at the beginning of the semester);*

c) recording of two video lectures as part of one of 7 teams, each of which can be evaluated at 20 points by voting other team members in Telegram

d) Incentive points for completing tasks to improve didactic materials in disciplines are awarded from 20 to 40 incentive points.

Calendar control: it is carried out twice a semester as a monitoring of the current state of compliance with the requirements of the syllabus (in proportion to the number of working weeks per semester).

Semester control: differentiated credit (the sum of points for the semester, additional performance of types of work p. v, d)

Conditions for admission to semester control: semester rating of at least 20 points.

Table of correspondence of rating points to grades on the university scale:

Score	*Score*
100-95	Perfectly
94-85	Very good
84-75	Well
74-65	Satisfactory
64-60	Enough
Less than 60	Disappointing
Admission conditions are not met	Not allowed

9. Additional information on the discipline (educational component)

All the necessary materials are contained on the Sikorsky platform (se90tq) https://do.ipo.kpi.ua/enrol/index.php?id=2118

Work program of the discipline (syllabus):

Compiled by Director of IASA, Doctor of Physical and Mathematical Sciences, Professor, Kasyanov Pavel Olegovich

Academician of the National Academy of Sciences of Ukraine, Doctor of Technical Sciences, Prof. Mikhail Zakharovich Zgurovsky

Approved by the Department of Mathematical Methods of System Analysis (Minutes No. 13 dated 05.06.2024)

Approved by the Methodological Commission of the Faculty (Minutes No. 10 of 06/24/24)