Physicist-Engineer BSc
Scientific Data Processing Specialization
Final exam topics

The examinee receives one topic from the CORE SUBJECTS (1–11) and one topic from the SPECIALIZATION SUBJECTS (12–24). The examiners may ask short questions from other topics as well.

A: CORE SUBJECTS

Probability Theory

1 **Foundations of Probability**: Combinatorics, Sample space, events, Definition and properties of probability measure, Inclusion-exclusion/sieve formula, Classical examples.

2 **Conditional Probability**: Conditional probability, Multiplication rule, Total probability, Bayes theorem, Independence.

3 **Discrete Distributions**: Random variables, Bernoulli-, Binomial-, Geometric-, Negative binomial-, Hypergeometric-, Poisson distributions, Expected value, Variance, Poisson approximation of the binomial distribution, Poisson process.

4 **Continuous Distributions**: Cumulative distribution function (CDF), Probability density function (PDF), Uniform-, Exponential-, Normal-, Cauchy distributions, Transformations, Expected value, Variance, Moments.

5 **Joint Distributions**: Joint distribution function, Marginal distribution and density functions, Conditional distribution and density functions, Covariance, Correlation, Conditional expectation, Tower rule, Indicator variables.

6 **Limit Theorems**: Markov-, Chebyshev inequalities, Weak Law of Large Numbers, Central Limit Theorem, Normal approximation of binomial distribution (de Moivre–Laplace Theorem).

Mathematical Methods in Physics

7 **Coordinate Systems and Differential Equations**: Cylindrical and spherical coordinates, Derivatives in curvilinear coordinates, Laplace and Poisson equations, Wave and heat equations, Separation of variables.

8 **Ordinary Differential Equations and Linear Systems**: First- and second-order linear ODEs, Homogeneous vs. inhomogeneous equations, Superposition principle, Systems of ODEs, Physical examples.

9 **Fourier Methods and Orthogonal Functions**: Fourier series, Fourier transform and inverse, Properties (shift, convolution), Orthogonal functions, Physical applications.

10 **Distributions and Green's Functions**: Concept of distributions, Dirac delta function, Operations (derivative, convolution), Fourier and Laplace transforms, Green's functions and solving differential equations.

11 **Basics of statistical physics**: Fundamentals of thermodynamics, entropy, principle of entropy growth, phase changes, principles of statistical physics: micro- and macro-states, the statistical description of entropy.

B: SPECIALIZATION SUBJECTS

Complex Networks

12 **Basic network models**: Erdős-Rényi graph, statistical equivalence of both versions, degree distribution, clustering coefficient, assortativity, distance, percolation, small-world, Milgram experiment, Watts-Strogatz model.

13 **Scale-freeness**: Power law distributions, divergence of moments, Pareto principle, Zipf's law, Barabási–Albert model, degree distribution, clustering, variants.

14 **Robustness**: Errors vs. attacks, link removal percolation, centralities (distance, degree and path based ones), threshold models, Watts' model, cascades.

15 **Diffusion and spreading**: Random walk on graphs, stationary distribution, SIS model on graphs, epidemic threshold, mean field methods.

16 **Communities**: Stochastic Block Model, inference, community types, Modularity, similarity measures, community detection methods categories and algorithms, other mesoscopic structures, Core-periphery, hierarchical organization.

Introduction to Data Science

17 **Data Handling and Similarity**: Data preparation and transformation, Exploratory analysis and visualization, Sampling and aggregation, Distance measures, Similarity measures, Sequence similarity.

18 **Model Evaluation and Generalization**: Train/validation/test setup, Cross-validation, Underfitting vs. overfitting, Bias-variance trade-off, Performance metrics and ROC/AUC, Model selection principles.

19 **Regression and Optimization-Based Learning**: Regression models (linear, nonparametric), Error measures and bias-variance decomposition, Optimization, Regularization, Logistic regression, Support Vector Machines and kernels.

20 **Supervised Learning Methods**: Instance-based learning, Tree-based methods, Probabilistic methods, Model evaluation basics, Neural networks.

21 **Advanced and Unsupervised Methods**: Ensemble learning, Clustering methods and validation, Dimensionality reduction, Recommender systems and association rules.

Neural Networks

22 **Neural Network Fundamentals and Image Models**: Perceptron, Activation functions, Backpropagation, Convolutional neural networks, Pooling, Loss functions, Regularization, Data augmentation, Diffusion models.

23 **Sequence and Text Modeling**: Temporal data in neural networks, LSTM and recurrent models, Text models, Word2Vec embeddings, Attention mechanisms.

24 **Other learning methods**: Reinforcement learning, Q-learning, Genetic algorithms, Pre-trained networks, Autoencoders, Unsupervised learning.