Physics MSc
FINAL EXAM TOPICS

Common topics

1. **Approximation methods in quantum mechanics.** Time-independent degenerate and non-degenerate perturbation theory. Time-dependent perturbation theory.

2. **Description of mixed states in quantum mechanics.** The density operator and its properties. The time evolution operator.

3. **The properties and models of the atomic nucleus.** Binding energy, size, spin, magnetic moment, izospin. Liquid drop model, Fermi-gas model, shell model.

4. **The basics of probability theory.** Modelling random events. Axioms of probability theory. Conditionaly probability, Bayes-theorem. Definition and main characteristics of the expected value, standard deviation.

5. **The principle of maximum entropy in statistical physics.** Microcanonical and canonical ensembles (Shannon-entropy, entropy maximum, macroquantities as constraints, derivation of ensembles from maximum entropy.)

6. **The ideal gas.** Quantummechanical discussion of the high temperature ideal gas based on on the canonical ensemble.

7. **Lattice structure.** Bravais-lattice, basis. Coordination number. Most frequent lattice types. Primitive cell. Wigner─Seitz-cell. Reciprocal-lattice. The first Brillouin-zone.

8. **Lattice vibrations.** The adiabatic (Born-Oppenheimer) approximation. Harmonic approximation. Dispersion relation of the lattice vibrations. Acoustic and optical vibrations.

9. **Statistical hypothesis testing and parameter estimations**. The general method and steps of hypothesis testing. T-tests, Chi-square test for the variance, F-test for comparing two variances. Properties of parameter estimations. The method of maximum likelyhood estimation.

Computational physicist orientation

1. **Information theory 1.:** Noiseless channels, data compression (Shannon-entropy and its main properties. Asymptotic equipartition. Entropy rate of stochastic processes. Expected code length, Huffman-coding, and its optimality.)

2. **Information theory 2.:** Channel capacity (The Kullback-Leibler distance and the properties of the mutual information. Description of noisy channels, channel capacity, and its meaning. Error-correcting codes.)

3. **Operating systems II/1:** Storage devices, file handling in operating systems. Types of file systems, their functions, and their implementation. Organization of storage media: RAID systems, network storage.

4. **Operating systems II/2:** Special operating systems (Specific issues of embedded, real time, multimedia systems (i.e. timing in real-time systems), and specific solutions.)

5. **Signal processing 1.: Basic principles of analog signal processing**. Linear systems, Fourier-transformation, spectrum, convolution theorem, sampling theorem, Laplace transformation, and its usage in analysis and design of systems.

6. **Signal processing 2.: Digital sampling.** Important properties and some simple types of DA and AD converters. Z-transforms and digital filters. The usage of the most essential LabVIEW DAQmx vi-s (presentation of an example vi.)

7. **Application of microcontrollers 1.:** Microcontrollers' architectural classification (CISC, RISC, Neumann, Harvard), the structure of event-based programs, typical peripheries (watchdog, timer, UART, EEPROM, ADC)

8. **Application of microcontrollers 2.:** The typical instructions of assembly codes (arithmetic, logical, data movement, control transfer, special), addressing modes (immediate, register, direct, indirect…), the role of segments in programming x86 type systems, methods of passing parameters to subroutines.

9. **Computer networks:** The layers of network software, presentation of the protocols of the application layer (http, ftp, smtp, pop3, imap, dns), the service models and protocols of the transport layer (TCP, UDP), trusted and not trusted services in the transport layer

10. **Object-oriented programming 1.**: Classes, general description of objects: definition of class and object. Encapsulation. Access control (public, protected, private). Data members, properties, methods. Static members and their applications. Initialization and removal of object instances. Abstract classes and methods.

11. **Object-oriented programming 2.**: Code reuse on OOP basis: Embedding types in other types. Inheritance. Definition and usage of interfaces. Protected members. Base class expansion, function modification. Initialization of the derived class using the constructor of the base class. Polymorphism, its importance, virtual functions (virtual, new, override).

Applied Physicist Orientation

1. Gaussian beams and laser resonator modes. Matrices in geometrical and physical optics.

2. Absorption and emission of light. Absorption and emission cross sections. Amplification coefficient. Saturation. Homogeneous and inhomogeneous broadening of spectral lines.

3. Properties and applications of main laser types.

4. Generation and measurement methods of short and ultrashort laser pulses.

5. Propagation of light in waveguides. Description with geometrical and wave optics. Optical fibers. Fiber lasers.

6. Physical properties of magnetic materials.

7. Nanostructures and their observation.

8. Physical properties of nanostructures.

9. Methods of materials characterization

10. Definition of spectrum. Main features of spectroscopic devices. Presentation of a few devices that apply different principles for measuring the spectrum.