Czech Technical University in Prague
Faculty of Nuclear Sciences and Physical Engineering

STUDY AREAS
for the entrance examination
DOCTORAL STUDIES

Study program: Quantum Technologies
Entrance examination and interview consists of:

1) general part and 2) specific part.

### 1) Study areas for general part

- **Fundamentals of differential and integral calculus:** differential and integral calculus of one and more real variables, power series and their convergence, Taylor polynomial, Taylor series, linear differential equations of nth order, systems of linear differential equations, linear mappings and its matrices, systems of linear algebraic equations, linear operators and square matrices, determinant, eigenvalues, diagonalizability.
- **Probability and mathematical statistics:** basics of mathematical theory of probability and statistics, random variables and processes, distribution functions, probability density.
- **Differential equations:** existence and uniqueness of their solutions, method of variation of constants, boundary value problems for differential equations.
- **Numerical mathematics:** correctness and conditionality of the problem, stability of the numerical method, rounding errors, iterative and gradient methods of solving linear equations, numerical solution of ordinary differential equations with initial conditions and boundary conditions, convergence, Runge-Kutta methods, basic difference schemes.
- **Quantum theory:** states, observable, basic postulates of quantum physics and mechanics, possibilities of description, Copenhagen interpretation of quantum theory, operators of dynamic variables, canonical commutation relations, Heisenberg uncertainty relations.
- **Pure and mixed states, statistical operator and its time evolution, measurements in quantum theory, particle in centrally symmetric potential, particle in Coulomb field, quantization of momentum, spin, Pauli matrices.**
- **Stationary Schrödinger equation, stationary perturbation theory, dynamic development of quantum systems, evolution operator, nonstationary perturbation theory, Schrödinger, Heisenberg and Dirac image.**
- **The problem of two bodies in quantum mechanics, systems of two particles, hydrogen atom, identical particles, indistinguishable particles, Slater's determinant, Pauli's principle, occupancy numbers.**
- **Electromagnetic field in homogeneous medium, macroscopic Maxwell's equations, constitutional relations, Gauss and Stokes theorem, Laplace, wave and Helmholtz equations.**
- **Plane electromagnetic waves, spherical, parabolic waves, Gaussian and Bessel beams, complex refractive index, Poynting vector, light intensity, polarization, phase and group velocity.**
Boundary condition, Snell's laws, Fresnel formulas, coherence, interference and diffraction of light, propagation of electromagnetic radiation in waveguides, nonlinear optics.

Canonical quantization of electromagnetic field, creation and annihilation operators, Fock space, Quantum linear harmonic oscillator, 2nd quantization, basics of quantum electrodynamics.


Absorption, spontaneous and stimulated emission of optical radiation by an atom, Einstein coefficients, resonant and off-resonance transitions, Rayleigh and Raman scattering.


Quantum description of solids, adiabatic approximation, one-electron approximation, Hartree-Fock approximation, Bloch's theory.

Structure, defects and binding forces in condensed matter, quasiparticles in solids, phonons.

Electronic band structure of solids, methods of calculation, dispersion and absorption of electromagnetic radiation in solids, interband and intraband optical transitions in solids, excitons, metals, dielectrics, semiconductors.

Basic characteristics and properties of nanoparticles and nanostructures, quantum constrained nanostructures - quantum wells, quantum wires, and quantum dots.

Methods of preparation (epitaxy, sputtering, evaporation, lithography, deposition,…) and characterization (diffraction analysis, spectroscopic, microscopic methods,…) of solids and nanostructures.

2) Study areas for specific part

The specific part verifies the knowledge and skills required for the research work of the doctoral student on the chosen framework topic of the dissertation, especially in one of the following areas:

(i) Mathematics and mathematical physics
(ii) Quantum physics and quantum information
(iii) Photonics, optics, laser physics, nanostructures
(iv) Solid state physics and engineering