

**Examination Questions for the Final Exam**  
**„Industrial Robot Systems I, II”**  
**(BSC Nappali- angol nyelvű Mechatronika -**  
**Komplex rendszerek szakirány)**  
**(for Summer 2021, refreshed: 14 October 2021)**

1. The concept of „Group” and "Lie Group”;
  
2. Tangent space at the identity element of a Lie group; Generators of Lie Groups, exponential series of constant generators, “transformed generators”, Lie algebra and the Jacobi identity.
  
3. Basis vectors in the tangent space at the identity element, commutation rules, structure coefficients.
  
4. Homogeneous matrices as Lie groups: their generators and the geometric interpretation of the commutator.
  
5. Parametrization of Lie groups with special emphasis on the Orthogonal Group and the Special Euclidean Group in 3D (rotation and shift operators).
  
6. Formulation of the forward and inverse kinematic task for the robots of open kinematic chain: home position, Tool Center Point, rotational “pose” of workpiece;
  
7. Differential solution methods: optimization under constraints: geometric interpretation of the constraints; Newton-Raphson Algorithm, Gradient Descent Algorithm, the Lagrange multipliers and the Reduced Gradient; The Auxiliary Function; Redundancy, kinematic singularities, the Moore-Penrose pseudoinverse; and its deformation to tackle kinematic singularities.
  
8. The basics of Classical Mechanics: space and time, inertial systems of reference, Newton's Postulates;

9. The Variation Principle in Classical Mechanics: generalized coordinates, the Kinetic Energy and the Lagrangian, the Euler-Lagrange equations for isolated systems.
10. The Euler-Lagrange equations for not isolated systems: the physical interpretation of the Generalized Forces.
11. Industrial robots of open kinematic chain: the application of the homogeneous matrices in building the dynamic model of the robot.
12. The „Computed Torque Control” algorithm: the general form of the dynamic model; Kinematic requirements in PD and PID form; Lyapunov equation; Special PID and PD feedback gains made of a single  $\mathcal{N}$  parameter.
13. Lyapunov's 2nd or „Direct Method”: the stability definitions, Lyapunov function, quadratic Lyapunov function, functions of class „ $\kappa$ ”.
14. The Sliding Mode /Variable Structure Robust Controller: error metrics, relative order of the system under control; Chattering and its elimination;
15. Adaptive Inverse Dynamics Controller for Robots;
16. Fixed Point Transformations in adaptive control: Banach's Fixed Point Theorem;
17. The Robust Fixed Point Transformation and its alternative variant for adaptive control, convergence issues.