ETH zürich

# CMM ‘21 – Questions you should have answers to

# Disclaimer

- The following list of questions is neither exhaustive (it does not cover all relevant material) nor representative of the questions that you will find in the exam.

# Kinematics

- What is the relation between point on body in local coordinate part and its world position?
- What kind of joints are there and what distinguishes them?
- What is forward kinematics?
- What is inverse kinematics?
- Hierarchical modeling and coordinate frames

- What is the Jacobian transpose method?
- What is the $J^+$ (Jacobian Pseudo Inverse) method?
- How to write Inverse Kinematics as a minimization problem?
- How to solve that minimization problem?

# Dynamics

- Particle dynamics
- What are generalized coordinates? How do they affect the equations of motion?
- What is an ODE? What aspects are used to distinguish between types of ODEs?
- What is the (high-level) difference between Langrangian and Newtonian mechanics?
- How to solve ODEs numerically?
- What types of ODE solvers are there? What are their properties?
- Stability and stiff ODEs
- What quantities/data is need for explicit/implicit integration?
- What differences are there computationally?

# Constrained Optimization & Sensitivity Analysis

- What is the difference between a minimization and an optimization problem?
- Where do constraints come up (some examples from robotics and animation)
- What are equilibrium-constraints (and why are they interesting)
- What conditions have to hold for (strict local) optimality?
- For first order optimality, what conditions have to hold between objective gradient and constraint gradients?
- Why do we need second order conditions (and what for)?
- What is a quadratic program?
- When is a QP convex?
- What is the difference between equality and inequality constrained problems?

- What is the Lagrangian for an optimization problem?
- How is the Lagrangian related to the first order optimality conditions?
- What is special about the KKT system?
- What ways are there to solve QPs?
- What ways are there to solve nonlinear programs?
- How can we verify whether a candidate solution to an equality constrained QP is a strict optimum?
- What conditions, in addition to the ones that have to hold for equality constrained QPs, have to hold for inequality-constrained problems?
- What is the idea of the active set method?

- What is the idea of Sequential Quadratic Programming?
- What is additionally necessary for SQP compared to QPs?
- What makes line search for SQP challenging?
- What is the basic idea of Sensitivity Analysis (applied to equilibrium constrained problems)?

# Continuum Mechanics & Finite Elements

- What are strain, stress, and energy density?
- What is the relation between conservative forces and corresponding energy?
- What is the relation between work, force, and energy?
- What is the relation between stress and strain?
- What is the strong form of a PDE, what is the weak form?
- What is the deformation gradient? How is it related to/derived from displacement field?
- What is the Green strain? How is it different from the Cauchy Strain?
- What is the Cauchy stress tensor? What do you multiply onto it, whats the result of that multiplication?

- What is the generalized Hookean material, what do the terms correspond to?
- What is the relation between stress, strain, and energy density?
- How to compute the deformation gradient for a triangle element?
- How to solve for static equilibrium?

# 3D Orientations and Rigid Body Dynamics

- How to represent a rigid body?
- What types of motion does a rigid body admit?
- Center of mass
- Local and global coordinate frames
- Map between local and global
- Linear and angular momentum
- Moment of inertia
- Forces and torques
- 3D rotation representations (Euler angles, quaternions, rotation vectors)
- Velocity of a point on rigid body?

- Angular velocity, relation to velocity of point on rigid body?
- What is the time derivative of the rotation matrix?

# Contact Mechanics

- What kind of contact forces are there?
- What are the computational challenges with contact and friction in general?
- Constraints on normal force?
- Constraints of tangential forces?
- What is complementarity, what is it expressing?
- What is an impact law?
- How to integrate contact constraints with time stepping?
- What is the relation between LCP and QP?
- Hard vs. soft constraints? Advantages, disadvantages.
- What is the Coulomb model expressing?

- What is the maximal dissipation principle? What do we need it for?
- What is a friction cone?
- Why do linear approximations of the friction cone and how?

# Trajectory Optimization & Control

- What is a transcription method?
- What is direct transcription?
- What is direct collocation?
- What is the idea of single shooting?
- How is it different from direct transcription?
- How does sensitivity analysis come into play for trajectory optimization?

- What is open loop control?
- What is feedback control – why is it also called closed loop control?
- What is proportional derivative (PD) control?
- What types of gains are used in PD control?
- Why integral gain?
- What are possible controller inputs/outputs for character animation?