TKT 4150 Biomechanics

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Outline

- Practical information
- What is biomechanics?
- Syllabus for this course in biomechanics
- Dynamics
  - Kinematics
  - Material derivative
  - Einstein's summation convention

Practical information for TKT 4150 Biomechanics

- Lectures TKT 4150 Biomechanics
- Schedule (see Timeplan at Innsida)
- Exercises

- Scientific assistants (vit.ass)
    - Jacob Sturdy (TKT 4150)
    - All course information will be available at Blackboard
- Each student must check that you are registered in Blackboard

About the lectures

- All written material part of the syllabus is relevant for the exam
- Please feedback on anything with respect to the lectures
- Only selected parts will be lectured
- Video for clarity/figures and modest pace
- Blackboard for lower pace, notes, and digestion
- The syllabus is comprehensive
- Pepare yourself for the lectures

What is biomechanics?

- Mechanics applied to biology
  - R & D of the mechanics of living organisms
  - Application of engineering principles to and from biological systems.
- Many levels
  - From the atomistic/molecular level for understanding of cell mechanics and mechanotransduction (calcium transients, actin polymerization, and gene expression)
  - To tissue, organ, and body level
- Mechanics
  - Galileo (1638) used mechanics to study force, motion, and strength of materials
  - Analysis of any dynamic system
    - Thermodynamics
    - Heat and mass transfer
    - Cybernetics
    - Computing methods

Why study biomechanics?

- Physiology can no more be understood without biomechanics than an airplane can without aerodynamics
- Helps to understand
  - Normal function
  - Predict changes due to alteration
  - Propose methods for artificial intervention
- Predictive medicine?
  - Simulation based decision making tools in medicine?
  - Integration of physiological modelling with medical imaging technology.

Historical Background

- Aristotle (384-322 B.C.) The heart center for the blood vessels, no notion of arteries and veins. The heart was the center for both the respiratory and the vascular system. No knowledge of valves
- Praxagoras (ca. 300 B.C.) Claimed that the arteries supplied the organs with air, while the veins governed the blood supply, and the nerves the muscle contraction
- William Harvey (1578-1657) Established the concept of blood circulation
- Chinese scholars (475-221 B.C.) “All blood in the vessels originates from the heart, “the blood and *Chi* circulate without stopping. In fifty steps they return to the starting point. Yin succeeds Yang, and vice versa, like an circle without an end”

Tentative syllabus for TKT4150 Biomechanics

- Dynamics
  - Kinematics
  - Equations of motion
  - Stress analysis
- Deformation analysis
  - Strain tensors
  - Measures of strain
- Elasticity
  - Linear (an)isotropic elasticity
  - Strain energy/large deformations
  - Elastic waves
- Basic fluid mechanics
- Blood rheology and wall mechanics
- Cardiac hemodynamics
- Circulation
  - Blood flow in arteries and veins
  - Waves
  - Distributed/lumped models
  - Integration
- Muscles
- Bone and cartilage

Chap 2. Dynamics

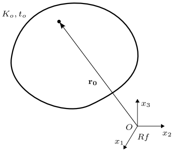
Describes the forces and interactions that produce or affect motion

- Dynamics branches
  - Rigid body dynamics
  - Solid mechanics
  - Fluid dynamics
- Constituents
  - Kinematics
  - Forces
  - Deformation

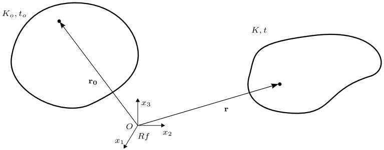
- Kinematics
  - Describes only the motions of objects
  - Not the factors that cause or affect the motion
  - Kinematics derives from Greek: *to move*

Kinematics

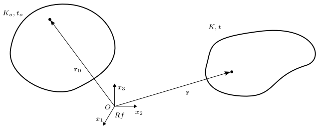
- Particle denotes a material point in a body
- Particles are localized by a reference coordinate system



- X_i denotes particles in the reference configuration K_0
- x_i is the current position of particle X_i
- $x_i = x_i(X, t)$



Lagrangian and Eulerian coordinates



- X_i Lagrangian (particle) coordinates
- x_i Eulerian (space) coordinates
- Intensive physical properties (pressure, temperature, density) are functions of either X_i and t or x_i and t
- Particle function: $f(X, t) = f(X_1, X_2, X_3, t)$
- Position function: $f(x, t) = f(x_1, x_2, x_3, t)$

Material derivative

- Velocity $\mathbf{v} = \dot{\mathbf{r}} = \frac{\partial \mathbf{r}(X,t)}{\partial t} \quad \text{with} \quad \mathbf{r} = [x_1, x_2, x_3]$
- Velocity components $v_i = \frac{\partial x_i(X,t)}{\partial t}$
- Material derivative
  The time derivative of a particle property $f(x(X,t),t)$ which originally was in location X
- Chain rule $\dot{f} = \frac{\partial f}{\partial t} + \frac{\partial f}{\partial x_1}\frac{\partial x_1}{\partial t} + \frac{\partial f}{\partial x_2}\frac{\partial x_2}{\partial t} + \frac{\partial f}{\partial x_3}\frac{\partial x_3}{\partial t}$

Einstein's summation convention

- Convention
  An index repeated once and only once in a term implies summation
- $\frac{\partial f}{\partial x_i}\frac{\partial x_i}{\partial t} \equiv \sum_{i=1}^{3} \frac{\partial f}{\partial x_i}\frac{\partial x_i}{\partial t} = \frac{\partial f}{\partial x_1}\frac{\partial x_1}{\partial t} + \frac{\partial f}{\partial x_2}\frac{\partial x_2}{\partial t} + \frac{\partial f}{\partial x_3}\frac{\partial x_3}{\partial t}$
- Material derivative

$$\dot{f} = \frac{\partial f}{\partial t} + \frac{\partial f}{\partial x_i}\frac{\partial x_i}{\partial t} = \frac{\partial f}{\partial t} + \frac{\partial f}{\partial x_i} v_i$$

Summary

- Practical information
- Introduced biomechanics
- Syllabus for this course in biomechanics
- Material derivative
- Einstein's summation convention