**Multibody System Dynamics**

**MECH 540D: 3 Credits**

Hoai Nam Huynh, Ph.D., M.Eng.
Department of Mechanical Engineering
The University of British Columbia
hoainam.huynh@ubc.ca

## Objectives

The primary focus of this course is to understand the fundamentals of computer-aided simulation of mechanical systems, i.e. multibody system dynamics.

The course will go through the conceptual definition of a mechanical system, the construction and the integration of the equations of motion by avoiding the pitfalls. Besides, students will have the opportunity to simulate mechanical systems by using a home made tool, requiring a theoretical knowledge, during the tutorials. This course does not rely on multibody commercial software in order to foster in-depth knowledge.

## Contents

1. Mathematical tools :
   - Localization in space using frames.
   - Vectors.
   - Homogeneous transformation matrices.
   - Rotation tensors.
2. Elements of a mechanical system :
   - Body.
   - Joints.
   - Force elements.
3. Kinematic analysis :
   - Degrees of freedom.
   - Configuration parameters.
   - Kinematic matrices.
4. Numerical construction of equations of motion :
   - Minimal coordinates.
   - Relative coordinates.
   - Cartesian coordinates.
5. Numerical integration :
   - Ordinary differential equations (ODE).
   - Differential algebraic equations (DAE).
   - Explicit and implicit formulas.
   - Linearization of the equations of motion.
   - Stability analysis.
   - Accuracy and stability.
6. Actuators :
   - Actuator modeling.
   - Electric motors.
   - Piezoelectric materials.
   - Hydraulic actuators.
   - Control design.

- Friction modeling.

7. Applications :
   - Mechatronic systems (robot, segway, ...).
   - Vehicles on tires.

### Learning outcomes

By the end of the course, students will be able to :

- Handle frames, rotation matrices, homogeneous transformation matrices.
- Describe joints, bodies and various force elements.
- Write the kinematics of a mechanical system using the minimal coordinates.
- Build the equations of motion of a machine.
- Integrate them numerically using an appropriate scheme.
- Control a multibody system.
- Perform an analysis of the multibody model.

### Lecture notes

Lecture notes consist of detailed slides presented during the class.
They will be sent to the students after class.

They are completed with the following book from Prof. O. Verlinden (UMONS, Belgium) : Computer-Aided Analysis of Mechanical Systems, 2016. A copy will be made available for the students.

### Tutorial sessions

Tutorial sessions are mandatory for students following this course. They will be given through Zoom application as well. Students will be asked to solve application problems in preparation to the final exam.

### Course schedule

Course and tutorial sessions will be given through Zoom application. Lectures will occur twice a week for 1.5 hours and tutorial sessions will be held once a week. The zoom link will be sent before the beginning of the course.

| Course | Activity | Day(s) | Start Time | End Time | Location |
|---|---|---|---|---|---|
| MECH 540D 201 | Lecture | Tuesday & Thursday | 3 :30 PM | 5 :00 PM | Zoom app. |
| MECH 540D 201 | Tutorial | Friday | 4 PM | 5 PM | Zoom app. |

Any question/comment related to the course can be asked to hoainam.huynh@ubc.ca.

### Additional Reference Books

- Computer Aided Kinematics and Dynamics of Mechanical Systems - Vol. I : Basic Methods - E. J. Haug, Allyn & Bacon - 1989.
- Kinematic and Dynamic Simulation of Multibody Systems - The real-time challenge - J.G. de Jalon, E. Bayo, Springer-Verlag - 1993.
- Multibody Dynamics : Vehicles, Machines and Mechanisms - H. Rahnejat - SAE - 1998.

**Prerequisites**

For mechanical engineering students, the co-requisite is one of the followings : MECH 466 or MECH 467.
Knowledge in Matlab/Simulink programming.
A general knowledge in Solid Mechanics and Machine Dynamics.

**Requirements** :

Regular lecture attendance, regular tutorial attendance, completing assignments on time and delivering them before the deadlines, and successfully taking various exams. Students are expected to come to lectures and tutorials regularly, and to be always on time.

**Grading**

- Tutorial reports → 30 %.
- Midterm exam → 25%.
- Final exam → 45% :
  - Exams will consist of open-book application questions that will need to be solved using the computer. Students will be asked to simulate a mechanical system, with the help of the tools learned during the lectures and tutorials. The source code is collected and the requested results are evaluated.
  - Attending the final exam is mandatory. Not attending the final exam leads to a mark of zero for this course even if the student already reached a mark above 50/100 before the final exam. At the final exam, students must obtain passing grades, i.e. at least 22.5/45.