ORT Braude College
Department of Electrical and Electronic Engineering

# 31890 – Dynamical System Modelling and Simulation

**Lecturer: Professor Eduard Eitelberg**
**Credits:** 3 points
**Hours:** 2 lectures per week, 2 laboratory hour every week
**Grade Composition:** 80% – written final exam (a grade of 55 is required for passing the course); 20% – oral laboratory exam
**Prerequisites**: 11006 Calculus 2M, 11121 Ordinary Differential Equations, 11232 Physics 2M, 31315 Introduction to Electrical Engineering

**Course Description:**
***The subject matter*** of this course covers two distinct but interlinked areas of knowledge or expertise: dynamical system modelling and numerical simulation of dynamical systems.

The students will learn to derive mathematical models by applying the *'law of conservation'* to various common processes with lumped parameters. The students will analyse the transient behaviour of these models in a laboratory type environment, where they will use numerical simulation methods to solve a model's non-linear state differential equations.

**Course Content:**

**I Some foundations from thermodynamics and from heat and mass transfer**

1. The First Law of Thermodynamics.
2. Properties of simple systems – $p$, $v$, $T$. Evaporation and condensation.
3. Humidity.
4. Energy transfer with and without mass: convection, conduction and radiation. Second Law limitation on energy transfer.

**II General Law of Conservation**

1. Definition of system and its boundary.
2. Quantity and its species – conservation thereof.
3. Rate of change of quantity in a system.
4. Examples of lumped systems from various domains: mechanical systems, power systems, electrical systems and circuits, economics, and others.

**III State Equations of lumped systems**

1. Definition of state.
2. State differential equations.
3. Output equations.
4. State equations – initial value problem.

**IV Linear systems**

1. Linearisation of state equations.
2. Transient behaviour of the state and system.
3. Asymptotic stability of the state.
4. Transfer functions.

**V Discrete-time models of systems – numerical integration, numerical simulation.**

1. Finite difference approximation – difference equations.
2. Stability of linear difference equations.
3. Stability of explicit and implicit Euler methods.
4. Convergence and order of the numerical method.
5. Further examples of single-step simulation methods: Trapezoidal (Tustin), Eitelberg, Runge-Kutta, …

**Laboratories (in parallel with lectures)**

1. MATLAB Arrays, array operations, graphics.
2. Relative humidity as a function of temperature.
3. MATLAB Matrix and vector operations.
4. Eigenvalue and stability calculations.
5. Introduction to Simulink, sources, sinks and other blocks.
6. Simulation of state models with initial conditions (given method and step-size).
7. Time-delay modules in Simulink.
8. Output to work-space and transient plotting.
9. Coding the explicit Euler method for a stiff example.
10. Coding the linearly implicit Euler method for a stiff example.
11. Plotting of the stability bounds of Eitelberg's $A_1$ and $A_2$ stable methods.

**Bibliography:**


1. Michael J. Moran; Howard N. Shapiro: Fundamentals of Engineering Thermodynamics. Wiley, Chichester, 5th ed., 2006.
2. Frank P. Incropera; David P. DeWitt: Fundamentals of Heat and Mass Transfer. Wiley, New York, 4th ed., 1996.
3. Ed. Eitelberg: Optimal Estimation for Engineers. NOYB Press, Durban, 1991.
4. J.D. Lambert: Computational methods in ordinary differential equations. Wiley, New York, 1973.
5. Ed. Eitelberg: Numerical simulation of stiff systems with a diagonal splitting method. Mathematics and Computers in Simulation, XXI, 1979, pp. 109-115.
6. Ed. Eitelberg: Parameter studies of a class of robust L-stable integration methods. Proceedings of the 10th IMACS World Congress, Volume 1, 1982, Montreal, Canada, pp. 22-24.
7. Ed. Eitelberg: A simple $A_2$-stable numerical method for state space models with stiff oscillations. Mathematics and Computers in Simulation, XXV, 1983, pp. 346-355.
8. Ed. Eitelberg: Control Engineering. NOYB Press, Durban, 2000.


**Learning Outcome:**
The student is able to write continuous- and discrete-time model equations for a variety of simple physical systems. The student is able to numerically calculate transient responses of these systems to initial conditions and to time-varying inputs.

**Assessment** (in English): (1) Satisfactory completion of at least 9 laboratory assignments in the allocated time is a non-negotiable condition for admission to the two following forms of assessment. (2) The laboratory work is assessed orally at convenient times before end of lectures. (3) The final assessment is on the basis of the written examination. All assessment is open-book. However, computers and programmable calculators are not allowed in the examination.

**Consultation hour:** Monday 12h30 – 13h30, in EM 403.

**Note:** This is not a contract. Written and verbal instructions may override any part of this course outline.

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