



Faculty of Eng. & Natural Sci.

ME435-202201

Scaling in Engineering Systems

Instructor(s)

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Course Content

The course introduces the scaling laws for engineering systems including multi-scale systems and consists of different scales (nano-, micro-, or macro-scales). When system modeling, design and fabrication processes are being performed, scaling and interaction of different scales become prominent. This course covers the fundamental properties of scales, design theories, modeling methods and manufacturing issues with different applications. Examples of engineering systems include micro-/macro-robotics, micro-/macro-actuators, MEMS, microfluidics, micromanipulators (AFM, microinjection technologies), robotic surgery (da Vinci robots), biosensors, MRI machines, and solar energy panels. Students will master the materials through problem sets, scientific discussions with experts from industry or medicine, and will improve their project presentation skills.

Objectives

Reason for proposing the course: To create a platform and provide conditions that is necessary to combine interested scientists and engineers working in the areas of mechatronics, biology, electronics, material science, manufacturing systems who are interested in understanding how to use scaling laws to improve engineering system's performance, multi-functionality, robustness, intelligent, while decreasing the cost. In addition, to be able to provide full responsibility to students in order to start, progress, result and report their projects for a real life problem which fits best to their interest.

Relationships ? differences in comparison to other courses already present in the catalogue (if any): This course covers the science, technology, and state-of-the-art in multi-scale systems consist of different length scales. Through this course students will learn how to implement scaling laws to engineering systems that they have in other courses and how to combine multi-scale systems consist of different length scales (nano-, micro-, or macro-scales). Through lectures and hands-on projects, participants will learn how scaling effects in nature and biology can be mimicked in engineering applications as a new technology. Bridging multiple courses.

Recommend or Required Reading

Readings

Papers and uploaded book chapters

Assessment Methods and Criteria

	Percentage(%)	Number of assessment methods
Midterm	40	1
Exam		0
Group Project	20	1
Written Report	10	1
Presentation	10	1
Homework	20	4

Course Outline

The course introduces the scaling laws for engineering systems including multi-scale systems consist of different length scales (nano-, micro-, or macro-scales). When system modeling, design and fabrication processes are being performed scaling and interaction of different length scales becomes prominent. This course covers the fundamental properties of scales, design theories, modeling methods and manufacturing issues with different application examples. Examples of engineering systems include micro-/macro-robotics, micro-/macro-actuators, MEMS, microfluidics, micromanipulators (AFM, Microinjection technologies), robotic surgery (da Vinci Robots), biosensors, MRI machines, and solar energy panels. Students master the materials through problem sets, scientific discussions with specialists from industry or medicine, and project preparation and presentations.

Weeks

Scaling in Natural Sciences

1 Scaling in Mechanical Engineering

2 Cantilevers and microscopes HW#1

3 Student presentations

4 Scaling in Electrostatics

5 Capacitors

6 Surface forces HW#2

7 Student presentations

8 Scaling in Electromagnetics

9 Electromagnetic spectrum and sensors

10 Working principle of MR HW#3

11 Student presentations

12 Scaling in Optics

13 Microscopes and telescopes HW#4

14 Student presentations

15 Exams

Learning Outcomes

Basic differential and integral calculus, demonstrate knowledge in advanced mathematical topics such as linear algebra, differential equations, complex variables, multivariable calculus, as well as computer science and physics, and use such knowledge in the design and analysis of complex systems containing hardware and software components.

Apply modeling and software techniques and their combinations in the design, simulation, realization and integration of systems such as electrical, electronic, control, fluid, mechanical and heat transfer systems using simulation and analysis programs.

Design and conduct research, do experiments, as well as analyze and interpret data.

Modeling and analysis of different engineering systems in conjunction with physical concepts were identified and effect of scaling was formulated.

Affect of Scaling in analyze, design and modeling of different engineering systems, physical phenomenon, their components or processes were investigated using using MATLAB, COMSOL, Basic Statistics in Microsoft Excel, Solidworks.

Understand different disciplines from natural and social sciences to mathematics and art, and develop interdisciplinary approaches in thinking and practice.

Think critically, follow innovations and developments in science and technology, demonstrate personal and organizational entrepreneurship and engage in life-long learning in various subjects.

Communicate effectively by oral, written, graphical and technological means and have competency in English.

Take individual and team responsibility, function effectively and respectfully as an individual and a member or a leader of a team.

Development of critical and analytical thinking and questioning skills.

Course Policies

The participants of this course will learn:

1. Practical problem-solving experience using scaling laws paired with a detailed discussion of experimental techniques to probe, understand, and design the ultimate structure of different engineering systems.
2. How to use the scaling tools to predict mechanical, electrical, thermal, optical, electromagnetic properties such as strength, deformability, elasticity, thermal capacity, etc.
3. How to use multiscale tools to combine different engineering systems.
4. Demonstrate the effect of scaling computationally-designed systems using 3D printing and other macro or micro manufacturing techniques, followed by an application either for industrial, medical, or energy field. Includes validations of scaling effects.
5. The fundamentals, simulations, processes of manufacturing and experimental applications to perform state-of-the-art techniques, such as micro surgery, MR imaging used to cover a range of length- and time-scales.

IMPORTANT: The course grade will be calculated based on averaging 6 RANDOM quizzes (60%) during the classes and homework grades (40%).

The backup quiz can be only once and it needs to be officially approved.

During the courses each student will make a presentation related to course content.