COURSE NUMBER & COURSE TITLE: ME 369 Modeling, Analysis and System Control -A		
INSTRUCTOR: Zhang Weijun/Yuan Jianjun/Zhang Dingguo	**Credits: 4**	**Language of instruction:** Chinese / English
REQUIRED COURSE OR ELECTIVE COURSE: Required		**TERMS OFFERED:** Autumn semester
COURSE STRUCTURE/SCHEDULE: 1. Lectures 2. Practical experiments		**PRE-REQUISITES:** Advanced Mathematics, College Physics, Principle of Mechanics, Analogical Electronics
ASSESSMENT TOOLS: 1. Homework, Quizzes, experiments —40% 2. Mid-term exam—30% 3. Final exam—30%		**PROFESSIONAL COMPONENT:** Classical Control System: 3 credits Modern Control System: 1credit

TEXTBOOK/READING LIST

Ogata, Modern Control Engineering, 4rd edition, Prentice Hall, 2003.
System Dynamics, 4th edition, Katsuhiko Ogata, Prentice Hall, 2002

COURSE DESCRIPTION:

The course of Modeling, Analysis and System Control is one of the important required courses for all the students in mechanical major. The course is mainly given by lectures, including comprehensive in-class discussion, practical experiments, homework, videos and quizzes. Either Chinese or English language is used in the lectures, and if the Chinese is chosen in use by the instructor, relative English proper nouns are suggested to be introduced. Which is considered to give the students a fundamental understanding and knowledge by an open-view toward the globalization. Multi-medias are utilized in the lectures no less than 60%, and both the practical experiments and computer simulation education such as MATLAB-Teaching are included.

COURSE OUTCOMES [Related ME Program Outcomes in brackets]

1. To teach students elementary tools of modeling of mechanical, electrical, fluid, and thermo fluid systems, a basic understanding of behavior of differential equations.
2. To teach basic concepts of Laplace transforms, transfer functions, and frequency response analysis, to introduce the concept of stability and the use of feedback control.
3. To introduce an appreciation for decision-making skills needed to devise models that adequately represent relevant behaviors yet remain simple.
4. Determine system performance using transfer function and state space model, Design compensators to meet control specifications.

RELATED ME PROGRAM OUTCOMES:

To understand and the mathematical modeling methods of the practical physical systems.
To understand the use of computer simulation and MATLAB.

PREPARED BY: Yuan Jianjun **REVISION DATE:** Dec. 28, 2012

ME 369 Modeling, Analysis and System Control
Course Syllabus

Subject Title: Modeling, Analysis and System Control

Subject Code: ME369

Number of Credits: 4 **Hours Assigned:** Lecture 64 hours

Practical Experiments 8 hours

Terms offered: Autumn Semester

Pre-requisite: Advanced Mathematics, College Physics, Principle of Mechanics, Analogical Electronics

Offered by: School of Mechanical Engineering

Objectives:

1. To teach students elementary tools of modeling of mechanical, electrical, fluid, and thermo fluid systems
2. To teach a basic understanding of behavior of first- and second-order linear time-invariant differential equations
3. To teach basic concepts of Laplace transforms, transfer functions, and frequency response analysis
4. To introduce the concept of stability and the use of feedback control to actively control system behavior
5. To provide examples of real-world systems to which modeling and analysis tools are applied (e.g., DC Motor) for the purpose of design
6. To introduce an appreciation for decision-making skills needed to devise models that adequately represent relevant behaviors yet remain simple
7. Determine system performance using transfer function and state space model
8. Design compensators to meet control specifications
9. Understand digital implementation of control systems
10. To teach basic concepts in numerical integration and computer simulation of mathematical models

Student Learning Outcomes:

Upon satisfactory completion of the subject, students are expected to achieve the following outcomes:

1. Learn the outline of modeling ,analysis and control of dynamic systems;
2. Learn the basic concept of Laplace Transform and inverse Laplace Transform and the solution of LTI Ordinary differential equation.
3. Modeling the mechanical, electrical, and thermo fluid elements using transfer function and state space model.
4. Draw feedback system block diagram and find closed-loop transfer function.
5. Given a system transfer function/state space model, find time-domain behavior.
6. Frequency response analysis of control system.
7. Design PI, PD, PID, lead, lag compensators to meet control goals.
8. Design of control systems in state space.
9. Learn the basic concept of digital control system.
10. Modeling, analysis of system behavior and design control system using software tools.

Course Topics:

1. **Introduction of control system (2 hours)**

   Introduce the basic concept of modeling, analysis and control of dynamic systems; a brief history of automatic control, the basic components of control system, the concepts of feed-forward and feed-back control.

2. **Laplace Transform(6 hours)**

   The definition and important properties of Laplace Transform, the inverse Laplace Transform, Find the solution of LTI ordinary differential equation.

3. **Modeling of dynamic system(4 hours)**

   Modeling of mechanical, electrical, hydraulic and mixed-domain systems (e.g. DC Motors) using transfer function

4. **Transfer function, block Diagram and signal graph.(4 hours)**

   The definition of transfer function and concepts of block diagram, signal graph, the reduction of block diagram and mason's rule.

5. **Linearization of nonlinear mathematics models. (2 hours)**

Nonlinear components and its expansion using Taylor's series, Build the linear TF or SS model of a nonlinear system.

6. Analysis of control performance in time domain. (12 hours)

The transient response of unit step, ramp and impulse input of a 1^{st} and 2^{nd} order system, the concepts of time constant, natural frequency and damping ratio, the control specification, parameters (e.g. rise time, peak time, maximum overshoot and setting time) and the relation to system model, the transient response of 2^{nd} order system with zeros, the transient response of high order system, steady state error, the concept of stability and Routh's stability criterion.

7. PID control. (2 hours)

The function of Proportional, derivative and integral control, design PD, PI and PID controller to meet control goals.

8. Frequency domain analysis of control system and design(16 hours)

Frequency response, stability margin, Nyquist diagram, Bode diagram, Nyquist stability criterion, obtaining the mathematics model from experiments, design of lead, lag compensator based on frequency response.

9. State space modeling of dynamics systems. (4 hours)

Modeling of mechanical, electrical, hydraulic and mixed-domain systems (e.g. DC Motors) using state space model.

10. State space analysis of control systems. (4 hours)

The canonical forms, eigenvalues and similarity transformation, the solution of state equations, state transition matrix, controllability and observability.

11. State space design of control systems. (4 hours)

The basic concept of pole placement approach, determination of state feedback gain matrix, full state and reduced state observer, state feedback controller design with observers.

12. Digital control (4 hours)

The system structure of digital control, Z transform and inverse Z transform, the solution of difference equation, the stability and control performance of digital system, design of digital control system.

13. Experiments (8 hours)

[1] Identification of transfer function
[2] The trajectory control of manipulators and design of PID controller.

Textbook: Ogata, Modern Control Engineering, 4^{rd} edition, Prentice Hall, 2003.

Homework: There will be 8 homework sets with problems assigned mostly from the textbook. Because of the accelerated nature of the course, the homework schedule is VERY tight. You may discuss the homework assignments with each other and with the co-teachers and instructor, but you must write your own solutions to the homework which reflect your own understanding of the material. Homework turned in by the end of class on the due date will be given full credit; assignments turned in late will receive a 25% penalty for each 24 hours.

Method of Assessment:

Homework (20%)

Midterm Exam (30%)

Final Exam (30%)

Experiment (10%)

Quiz (10%)

Reference books:

1. System Dynamics, 4th edition, Katsuhiko Ogata， Prentice Hall, 2002.

2. Feedback Control of Dynamic Systems, 5th edition， Gene F. Franklin， Prentice Hall， 2007

3. Modern Control Systems， 11th edition, Richard C. Dorf, Robert H. Bishop, Prentice Hall 2002.