Instructor

- **Class Instructor**: Dr. Jongeun Choi,
  - Website: [http://www.egr.msu.edu/~jchoi/](http://www.egr.msu.edu/~jchoi/)
  - Assistant Professor at ME department,
  - 2459 Engineering Building,
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- **Office Hours**
  - 2459 EB, MWF 10:10-11:00am, Extra hours by appointment

- **Laboratory Instructor**: Dr. C. J. Radcliffe,
  - 2445 Engineering Building
  - Email: radcliff@egr.msu.edu

Course information

- **Lecture**:
  - When: MWF: 12:40pm-1:30pm,
  - Where: 2245 Engineering Building
- **Class website**: [http://www.egr.msu.edu/classes/me451/jchoi/2010/](http://www.egr.msu.edu/classes/me451/jchoi/2010/)
- **Laboratory website**: [http://www.egr.msu.edu/classes/me451/radcliff/lab](http://www.egr.msu.edu/classes/me451/radcliff/lab)
- **Required Text**:

Main components of the course

- **Lectures** (about 40 lectures)
- **Old Math Quiz**
- **Midterm1, Midterm2**
- **Final (Final exam period)**
- **Laboratory work**
- **Grading**:
  - Homework (10%), Math Quiz (5%), Exam 1 (17.5%), Exam 2 (17.5%), Final Exam (comprehensive) (25%), Laboratory work (25%)
  - Homework will be due in one week from the day it is assigned
Tips to pass this course

- Come to the lectures as many times as you can.
- Print out and bring lecture slides to the lecture.
- Do “Exercises” given at the end of each lecture.
- Do homework every week.
- Read the textbook and the slides.
- Make use of instructor’s office hours.
- If you want to get a very good grade…
  - Read the textbook thoroughly.
  - Read optional references too.
  - Do more than given “Exercises”.
  - Use and be familiar with Matlab.

What is “Control”?

- Make some object (called system, or plant) behave as we desire.
- Imagine “control” around you!
  - Room temperature control
  - Car/bicycle driving
  - Voice volume control
  - “Control” (move) the position of the pointer
  - Cruise control or speed control
  - Process control
  - etc.

What is “Control Systems”?

- Why do we need control systems?
  - Convenient (room temperature control, laundry machine)
  - Dangerous (hot/cold places, space, bomb removal)
  - Impossible for human (nanometer scale precision positioning, work inside the small space that human cannot enter)
  - They exist in nature. (human body temperature control)
  - Lower cost, high efficiency (factory automation), etc.
  - Many examples of control systems around us

Open-Loop Control

- Open-loop Control System
  - Toaster, microwave oven, shooting a basketball

\[ Y_d \xrightarrow{\text{Controller (Actuator)}} \text{Plant} \xrightarrow{\text{input}} \text{output} \]

- Calibration is the key!
- Can be sensitive to disturbances
### Example: Toaster
- A toaster toasts bread, by setting timer.

<table>
<thead>
<tr>
<th>Setting of timer</th>
<th>Toaster</th>
<th>Toasted bread</th>
</tr>
</thead>
</table>

- **Objective**: make bread *golden browned* and crisp.
- A toaster does *not measure* the color of bread during the toasting process.
- For a fixed setting, in winter, the toast can be white and in summer, the toast can be black (Calibration!)
- A toaster would be more expensive with sensors to measure the color and actuators to adjust the timer based on the measured color.

### Example: Laundry machine
- A laundry machine washes clothes, by setting a program.

<table>
<thead>
<tr>
<th>Program setting</th>
<th>Machine</th>
<th>Washed clothes</th>
</tr>
</thead>
</table>

- A laundry machine does *not measure* how clean the clothes become.
- Control without measuring devices (sensors) are called **open-loop control**.

### Closed-Loop (Feedback) Control
- Compare actual behavior with desired behavior
- Make corrections based on the error
- The sensor and the actuator are key elements of a feedback loop
- Design control algorithm

### Ex: Automobile direction control
- Attempts to change the direction of the automobile.

<table>
<thead>
<tr>
<th>Desired direction</th>
<th>Error</th>
<th>Steering wheel angle</th>
<th>Auto</th>
<th>Direction</th>
</tr>
</thead>
</table>

- Manual closed-loop (**feedback**) control.
- Although the controlled system is “Automobile”, the **input** and the **output** of the system can be different, depending on **control objectives**!
Ex: Automobile cruise control
- Attempts to maintain the speed of the automobile.
- Cruise control can be both manual and automatic.
- Note the similarity of the diagram above to the diagram in the previous slide!

Basic elements in feedback control systems

Control system design objective
To design a controller s.t. the output follows the reference in a “satisfactory” manner even in the face of disturbances.

Systematic controller design process
1. Modeling
2. Analysis
3. Design
4. Implementation

Goals of this course
To learn basics of feedback control systems
- Modeling as a transfer function and a block diagram
  - Laplace transform (Mathematics!)
  - Mechanical, electrical, electromechanical systems
- Analysis
  - Step response, frequency response
  - Stability: Routh-Hurwitz criterion, (Nyquist criterion)
- Design
  - Root locus technique, frequency response technique, PID control, lead/lag compensator
- Theory, (simulation with Matlab), practice in laboratories
Course roadmap

**Modeling**
- Laplace transform
- Transfer function
- Models for systems
  - mechanical
  - electrical
  - electromechanical
- Linearization

**Analysis**
- Time response
  - Transient
  - Steady state
- Frequency response
  - Bode plot
- Stability
  - Routh-Hurwitz
  - (Nyquist)

**Design**
- Design specs
- Root locus
- Frequency domain
- PID & Lead-lag
- Design examples

(Matlab simulations & laboratories)

Summary & Exercises

- **Introduction**
  - Examples of control systems
  - Open loop and closed loop (feedback) control
  - Automatic control is a lot of fun!

- **Next**
  - Laplace transform

- **Exercises**
  - Buy the course textbook at the Bookstore.
  - Read Chapter 1 and Apendix A, B of the textbook.