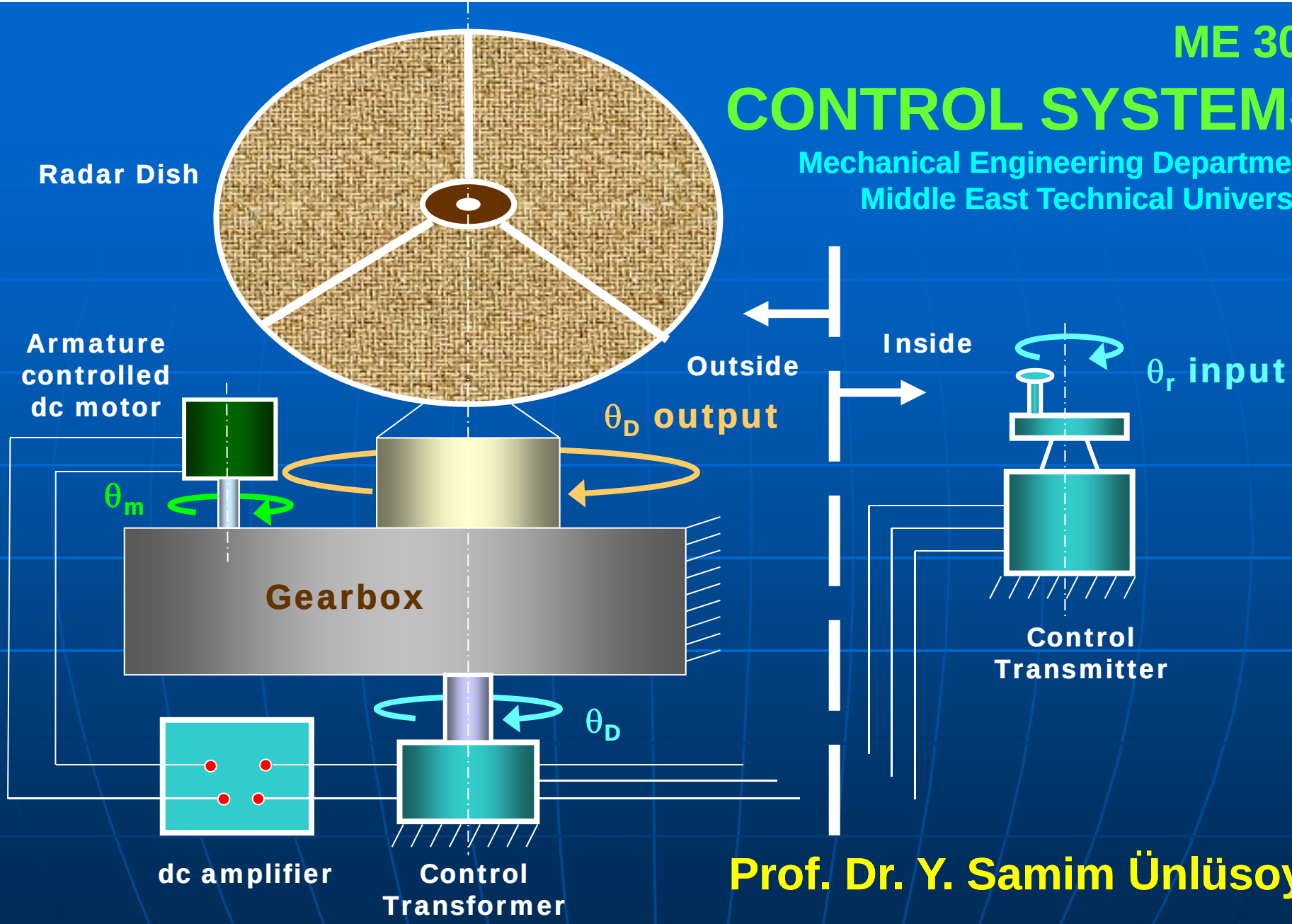
ME 304
CONTROL SYSTEMS

Mechanical Engineering Department,
Middle East Technical University



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CH I

COURSE OUTLINE

I. INTRODUCTION & BASIC CONCEPTS

II. MODELING DYNAMIC SYSTEMS

III. CONTROL SYSTEM COMPONENTS

IV. STABILITY

V. TRANSIENT RESPONSE

VI. STEADY STATE RESPONSE

VII. DISTURBANCE REJECTION

VIII. BASIC CONTROL ACTIONS & CONTROLLERS

IX. FREQUENCY RESPONSE ANALYSIS

X. SENSITIVITY ANALYSIS

XI. ROOT LOCUS ANALYSIS

CONTROL SYSTEMS
OBJECTIVES

To get familiar with

- **various control systems and**

to introduce

- **fundamental concepts and terminology of Control Systems,**
- **classification of Control Systems.**

WHAT IS A CONTROL SYSTEM ?

A control system is a collection of components assembled to produce a desired response for a given input.

EXAMPLES of CONTROL SYSTEMS

Automotive :

- Directional Control (Steering),
- Speed & Acceleration Control ,
- ABS – ESP,
- Cruise Control,
- Climate Control,
- Engine Control,
- etc.

EXAMPLES of CONTROL SYSTEMS

Home Appliances :

- Home heating
- Automatic washing machine,
- Refrigerator,
- Microwave oven,
- Toaster,
- etc.

EXAMPLES of CONTROL SYSTEMS

Aviation / Aerospace :

- Autopilot Applications,
- Space Vehicles,
- Missile Guidance Systems,
- Target Tracking (radar),
- etc.

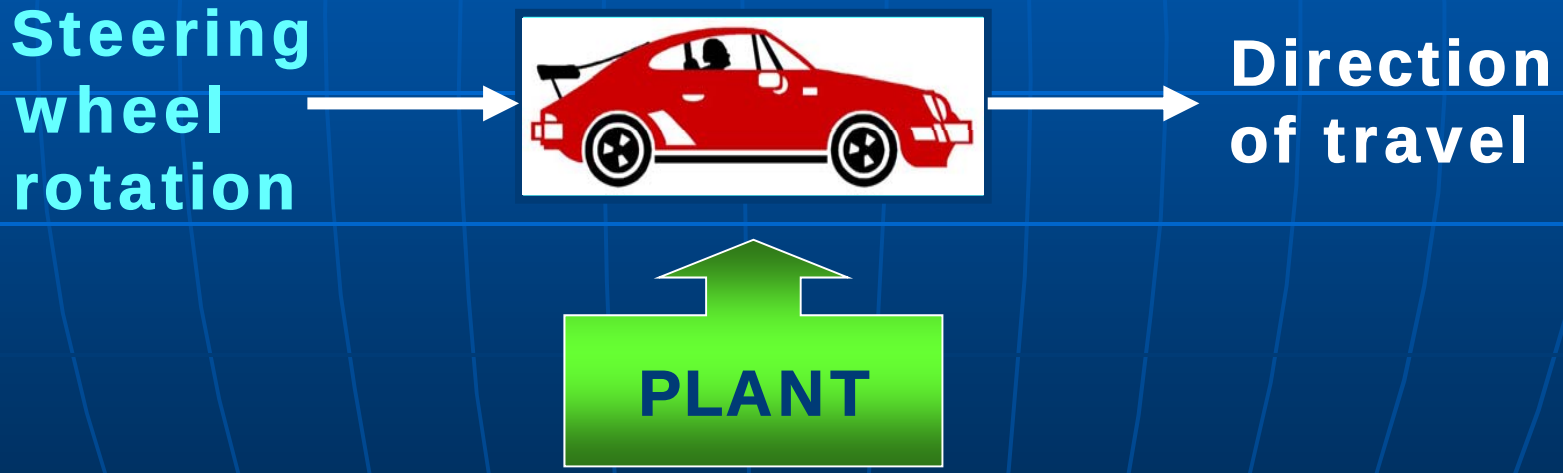
EXAMPLES of CONTROL SYSTEMS

Manufacturing Industry :

- Automation,
- Robotics,
- CNC Machining Centers,
- etc.

BASIC DEFINITIONS

Plant **: a physical object, system or process that is to be controlled.**



BASIC DEFINITIONS

***Process*: is an operation to be controlled.**

Examples:

- **chemical process,**
- **economic process,**
- **biological process.**

BASIC DEFINITIONS

Input **: an effect (generated outside the plant) that causes the plant to behave in a certain way.**

BASIC DEFINITIONS

***Output* (controlled variable) : the quantity or condition that is of interest and thus is controlled.**

BASIC DEFINITIONS

Reference (command) input :

a signal supplied to the control system which represents the desired value (or variation) of the controlled output .

BASIC DEFINITIONS

Disturbance input **: is an unwanted input that tends to adversely affect the value of the output of a system.**

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BASIC DEFINITIONS

Controller **: a device (or human being) which adjusts the control signals according to a set of predetermined rules.**

Control signal is the output of the controller that will be used to bring the output of the system as close to the desired value as possible.

BASIC DEFINITIONS

Control Law **(strategy) :** **set of predetermined rules used (by the controller) to adjust the control signals.**

BASIC DEFINITION

Thus control is the process of :

- adjusting the control signals such that,
- regardless of the disturbances,
- the controlled output of the plant is forced to behave as close to the desired way as possible.

CLASSIFICATION

Control Sytems can be classified into two basic types :

1) **Open loop** (OL) control systems,

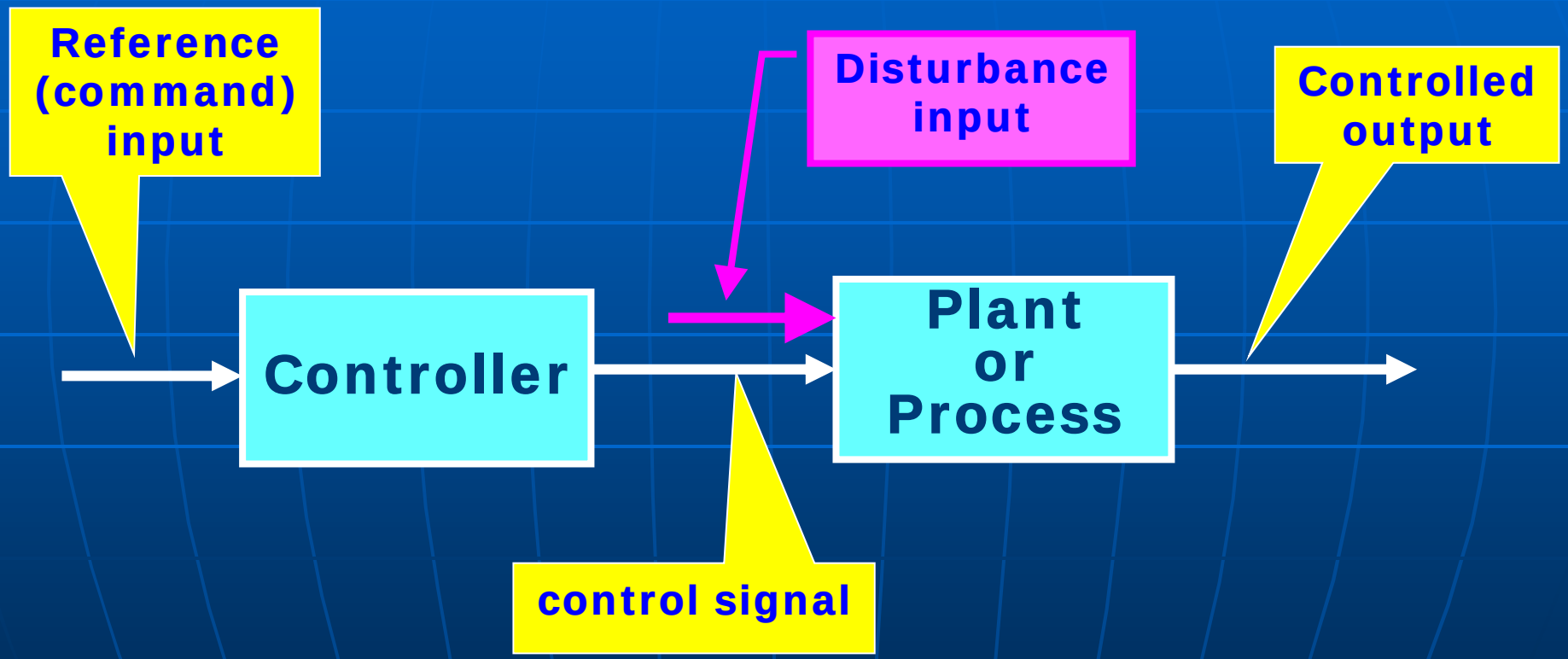
2) **Closed Loop** (CL) or **Feedback** (FB) control systems.

OPEN LOOP CONTROL

Control systems in which the output has no effect on the control action are called *Open Loop* control systems.

In an open loop control system the output is neither measured nor fed back for comparison with the reference input.

OPEN LOOP CONTROL

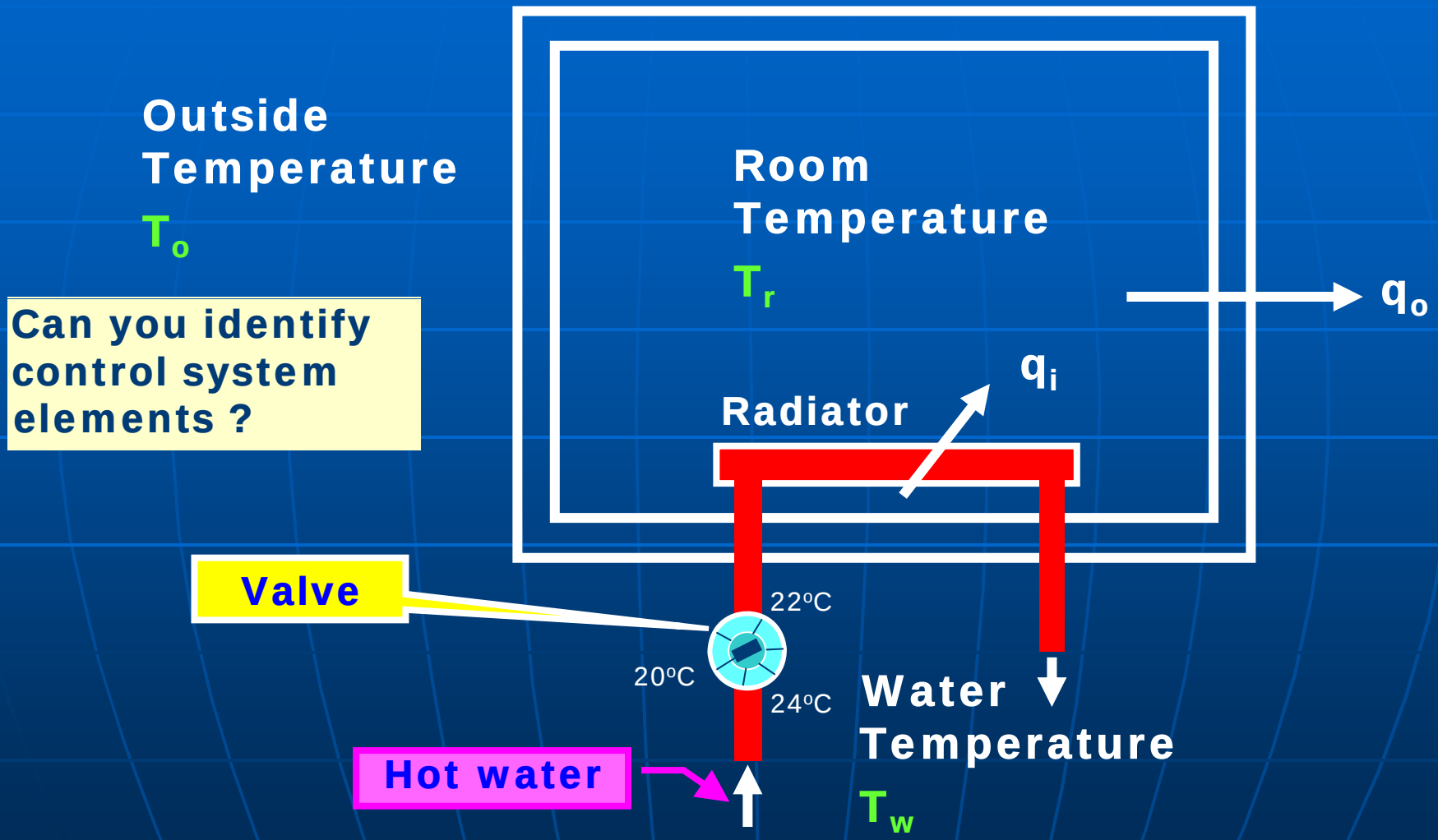


EX – 1 / Room Temperature Control

Hot water is used to keep a room at a specified temperature.

- It is circulated through a radiator and heat flows into the room.
- Heat will flow out through the walls.
- Room temperature is set by adjusting the flow rate of hot water through the radiator.

Ex -1 / Room Temperature Control



EX – 1 / Room Temperature Control

In this example, the flow rate of the hot water is usually calibrated on the dial of the valve on a typical day.

Obviously, on a particularly cold day, the dial setting and the actual room temperature will not agree.

EX – 2 / Photocopy Machine Drum Heating

When switched on, a photocopy machine will not start until the drum is heated to a predetermined temperature.

One way of heating the drum may be passing a current through a coil inside the drum for a fixed period of time, say 2 minutes.

EX – 2 / Photocopy Machine Drum Heating

Depending upon

- how long ago it was switched off,
- environmental temperature, or
- the mains voltage

the drum temperature may have different values after 2 minutes of heating.

OPEN LOOP CONTROL

As a general rule of thumb :

“Any control system working on a time basis is open loop.”

Consider a simple toaster. Is it an open loop system ?

CLOSED LOOP CONTROL

In a ***Closed Loop or Feedback*** control system, the ***controlled output*** is measured and compared with the ***reference input.***

The difference between the two, called **error**, is fed into the **controller** which produces a **control signal** to reduce this error.

CLOSED LOOP CONTROL

Thus a **closed loop (feedback)** control system contains additional elements.

- Sensors or transducers,
- Comparator (error detector),
- Actuator.

CLOSED LOOP CONTROL

Sensors

The controlled output is measured by sensors

> "devices that measure a variable and convert it into a signal – ususally electrical – which can be read by an observer or by an instrument "

so that it can be fed back and compared with the desired input.

CLOSED LOOP CONTROL

Comparator (error detector)

The difference between the

- desired (reference) input, and
- the controlled output

is measured by a **comparator (error detector)** and is fed into the controller which produces a control signal to reduce this error.

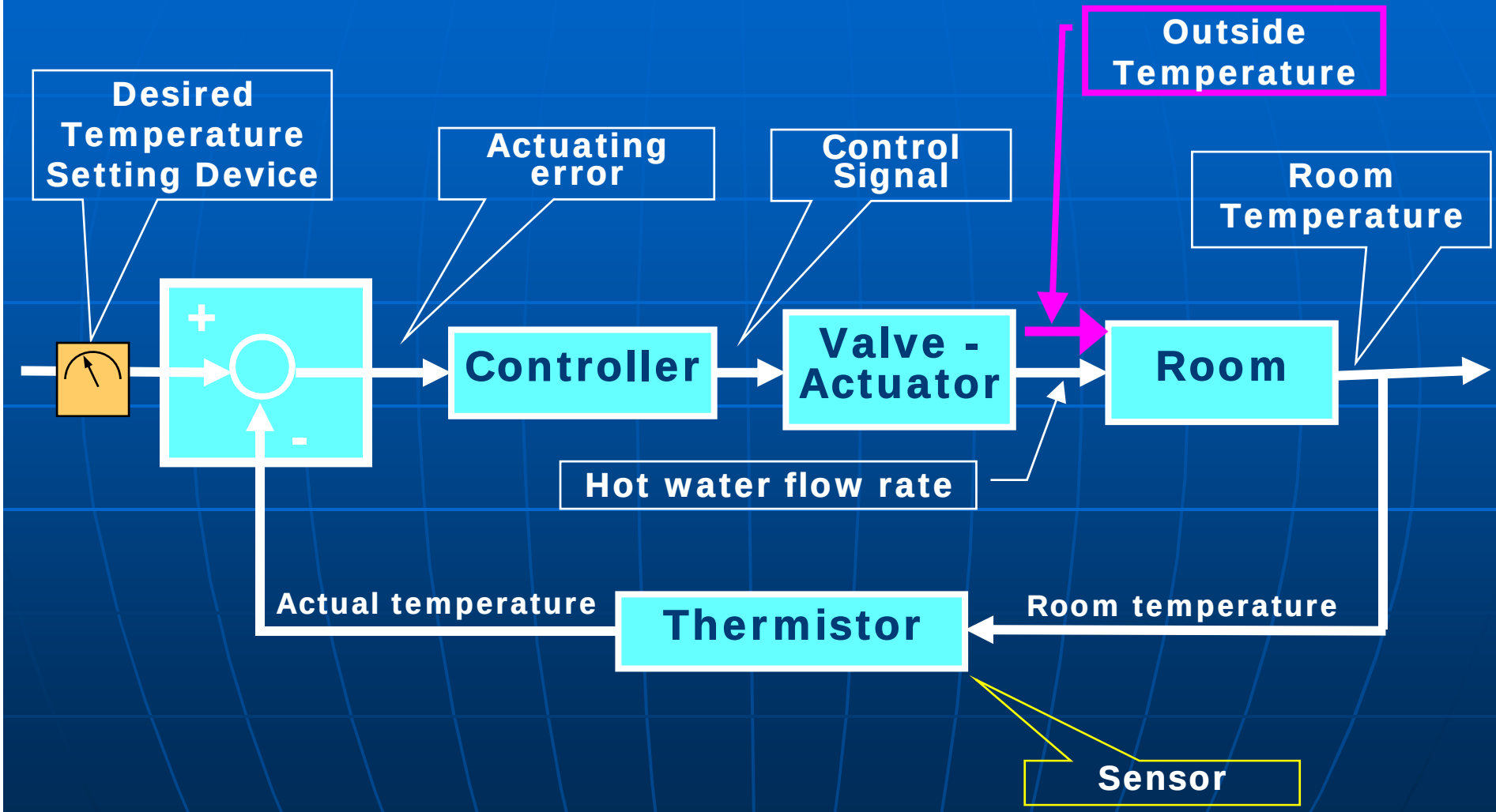
CLOSED LOOP CONTROL

Actuator

The output of the controller is usually amplified to a sufficiently high power level to drive an actuator, which is usually a power device such as electric motor, hydraulic motor etc., to change the controlled output.

The actuator is usually combined with the plant in block diagrams.

EX – 3 / Room Temperature Control



COMPARISON OF OL & CL SYSTEMS

Open Loop Systems

- Simple,
- Low cost,
- Stability is not a major problem,
- Cannot function properly in the presence of disturbances and parameter variations.

COMPARISON OF OL & CL SYSTEMS

Closed Loop (Feedback) Systems

- More elements,
- Higher cost,
- Stability is a major problem,
- Relatively insensitive to disturbances and variations of parameter values.

OTHER CLASSIFICATIONS

Another classification of control Systems - according to the objective of control

1) Regulator

2) Servomechanism

OTHER CLASSIFICATIONS

Regulator : Objective is to keep the controlled output at a constant value at all times in the presence of disturbances.

The command input for a regulator is either zero or constant.

OTHER CLASSIFICATIONS

Servomechanism : Objective is to keep the controlled output following a time varying command input.

In its original use, a servomechanism is a control system with mechanical position, velocity or acceleration as the controlled output.

FURTHER CLASSIFICATIONS

Analog – Digital

Manual – Automatic

Active - Passive

Continuous time – Discrete time

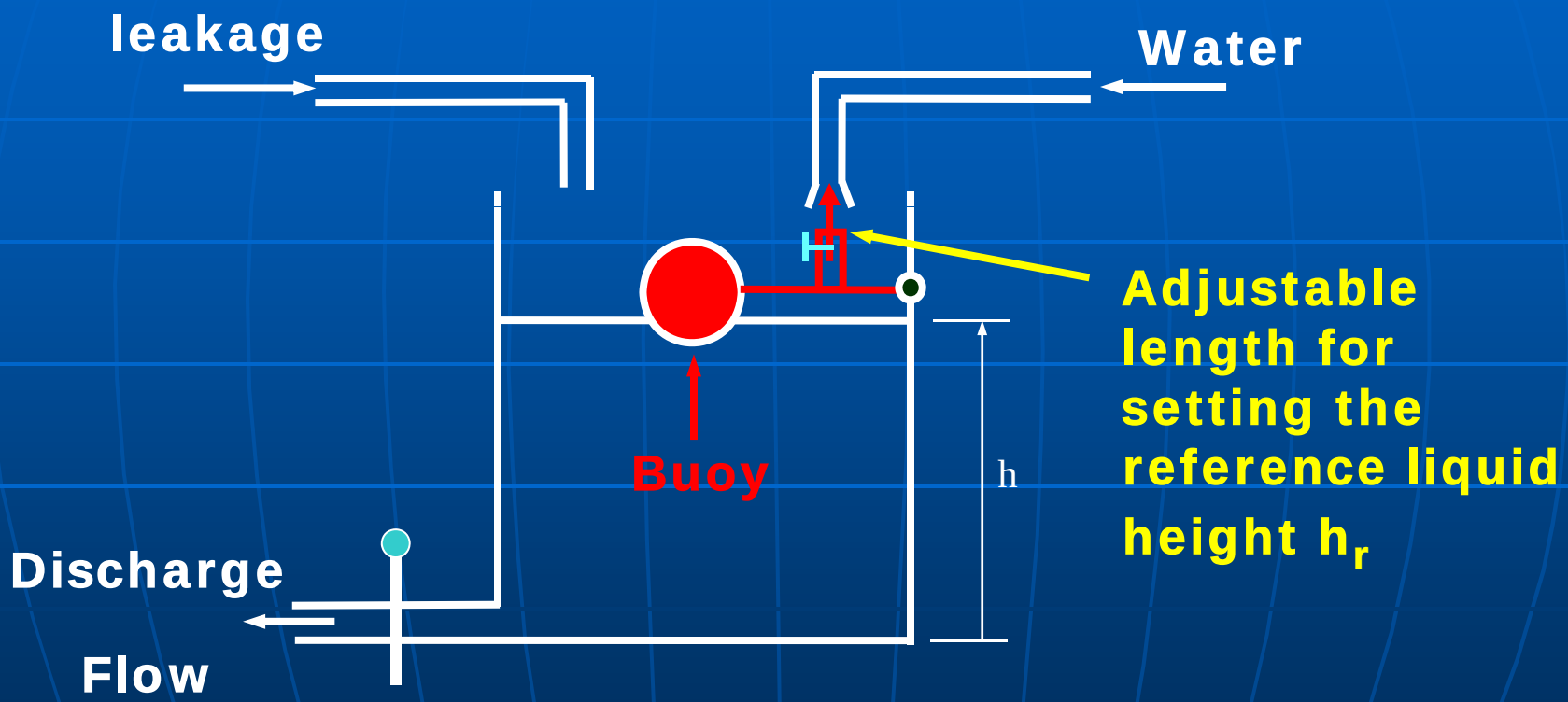
Single input/Single Output (SISO) –
Multi input/Multi Output (MIMO)

FURTHER CLASSIFICATIONS

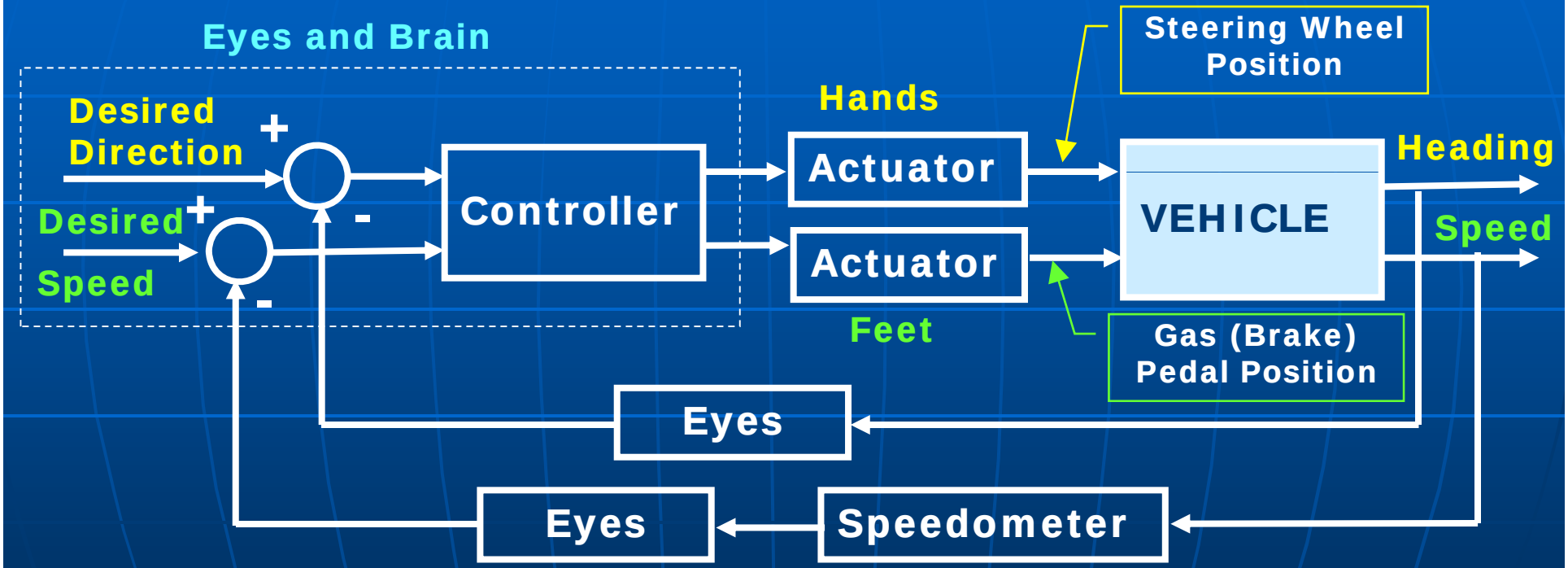
In this course, the subject is classical control, which deals with **Single Input/Single Output (SISO)** systems only.

Multi input/Multi Output (MIMO) systems will be the subject of the graduate course ME 511 Modern Control.

EXAMPLE – Water Level Control



EXAMPLE – Driver/Car System



EXAMPLES – Classify !

- The autopilot system of an aircraft or ship.
- Guidance system of a (heat seeking) missile.
- Guidance system of a ballistic missile (inertial guidance system).
- A driver-car system.

READING

Nise, CH-1

(Dorf & Bishop, CH-1)

(Ogata, CH-1)