SE513: Systems Identification

Lecture 1

Introduction to Systems Identification

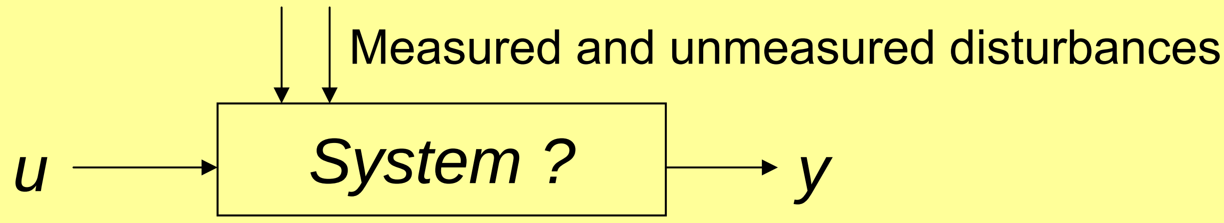
Dr. Samir Al-Amer

Lecture Outlines

- What is Identification
- Modeling vs. Identification
- Types of models
- Flow chart for systems identification
- Problems in identification

Systems Identification

- Identification is a process in which experimental data is used to obtain a mathematical model describing the system



- Identification is a process that uses u(t) and y(t) to determine the dynamics of the system

Why do we need models?

- Models can be used to improve our understanding of the process.
- Models are needed in designing better controllers
- A Model can be a part of some controllers like feed forward controllers
- A model can be very valuable in optimizing the operating conditions to get the best performance of control systems

The Four Problems of Identification

Representation	Measurement
Estimation	Validation

Representation

What types of models are used to represent the system?

Types of Models:

- Mental, intuitive, verbal
- Graphs and tables: step response, Bode plot
- Mathematical models
  - static/dynamic, linear/nonlinear, lumped/distributed, continuous/discrete, time-domain/frequency domain

Representation
issues

Some of the issues

- How to select the model structure
- Flexibility of the model
- Complexity of the model

Measurement

- Which physical quantities should be measured?
- How should we measure them?
- Some of the issues:
  - Some variables of interest are difficult or impossible to measure
  - Presence of noise in the measured data

Estimation

- How do we estimate the model parameters from the measured data?

  How do we estimate the nonparametric model from the measured data?

Validation

- Can the model explain the measured data?
- Are the confidence limits on the model acceptable?

The Four Problems of Identification

Representation	Measurement
Estimation	Validation

How do we obtain mathematical models?

Modeling

(Theoretical)

- Construct a simplified version using idealized elements
- Write element laws
- Write interaction laws
- Combine element laws and interaction laws to obtain the model

Identification

(Experimental)

- Conduct an experiment
- Collect data
- Fit data to a model
- Verify the model

Natural Laws in Modeling

In processing systems,

- Conservation of energy
- Conservation of mass
- Conservation of individual components
- Conservation of momentum

are useful in Obtaining mathematical models

Conservation Principle

over any time period,

the rate of accumulation of S within the system

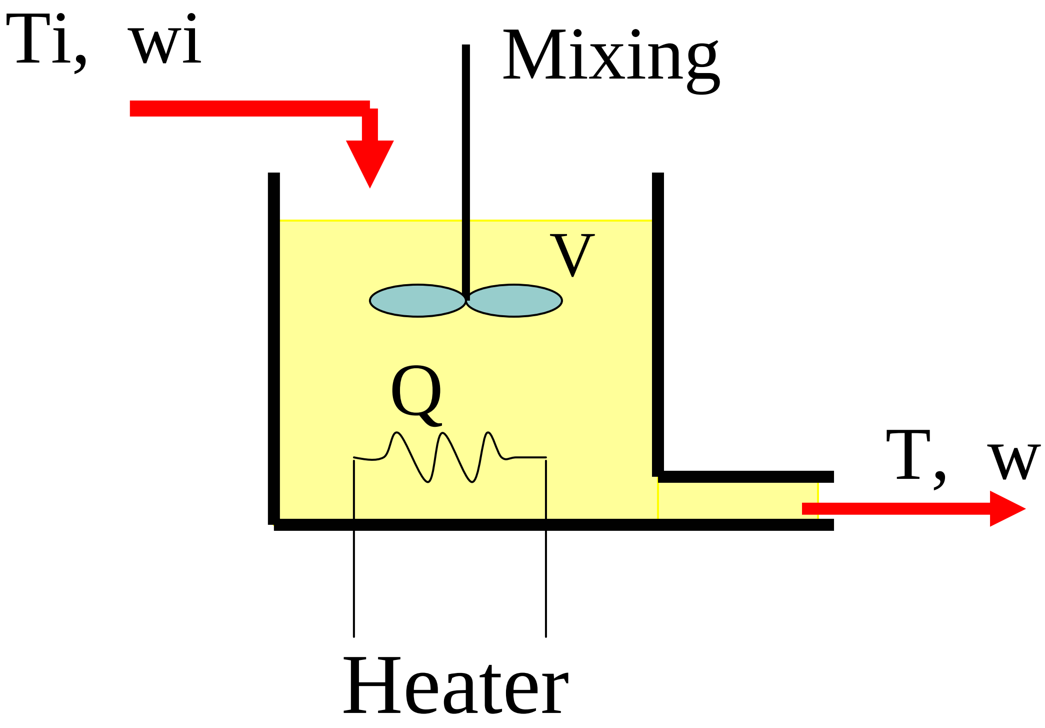
= flow rate of S in the system

− flow rate of S out of the system

\+ rate of the amount generated within the system

− rate of the amount consumed within the system

Heated Stirred Tank



V: volume of liquid

T: temperature inside tank

temperature at outlet

Ti : temperature at inlet

wi : inlet flow rate

w: outlet flow rate

Heated Stirred Tank

Conservation of energy

$$\left\{\begin{matrix} rate\,of \\ energy \\ accumulation \end{matrix}\right\} = \left\{\begin{matrix} rate\,of \\ energy\ of \\ inlet\,material \end{matrix}\right\} - \left\{\begin{matrix} rate\,of \\ energy\ of \\ outlet\,material \end{matrix}\right\} + \left\{\begin{matrix} rate\,of\ energy \\ provided \\ by\,heater \end{matrix}\right\}$$

$$\left\{V\rho C\frac{dT}{dt}\right\} = \left\{w_i C(T_i - T_{ref})\right\} - \left\{wC(T - T_{ref})\right\} + \left\{Q\right\}$$

$$V\rho C\frac{dT}{dt} = wC(T_i - T) + Q$$

V : *volume* C : *specific heat* w : *outlet flow rate* Q : *heat flow rate*

T_i : *inlet temp.* T : *outlet temp* T_{ref} : Reference temp

Heated Stirred Tank

Conservation of mass and Energy

Mass Conservation

$$\begin{Bmatrix} rate\ of\ mass \\ accumulation \end{Bmatrix} = \begin{Bmatrix} rate\ of\ mass \\ of\ inlet\ material \end{Bmatrix} - \begin{Bmatrix} rate\ of\ mass \\ of\ outlet\ material \end{Bmatrix}$$

$$\frac{d\left(V\rho\right)}{dt} = w_i - w$$

Energy Balance

$$C\frac{d\left(V\,\rho(T - T_{ref})\right)}{dt} = w_i\,C(T_i - T_{ref}) - w\,C(T - T_{ref}) + Q$$

Heated Stirred Tank Model

Mass Conservation

$$\frac{d(V\rho)}{dt} = w_i - w$$

Energy Balance

$$C\frac{d\left(V\rho(T - T_{ref})\right)}{dt} = w_i C(T_i - T_{ref}) - wC(T - T_{ref}) + Q$$

Combining

$$\boxed{C(T - T_{ref})(w_i - w) + V\rho C\frac{dT}{dt} = w_i C(T_i - T_{ref}) - wC(T - T_{ref}) + Q}$$

Heated Stirred Tank Model

$$Alternative\ Model$$

$$\frac{dV}{dt} = \frac{1}{\rho}(w_i - w)$$

$$\frac{dT}{dt} = \frac{w_i}{V\rho}(T_i - T) + \frac{Q}{V\rho C}$$

further simplifications are possible : Example V is constant,

Electrically Heated Stirred Tank Model

$$Assumptions:$$

$w_i = w$ (inlet flow rate = outlet flow rate)

$(volume = \text{constant})$

(Heater has significant heat capacitance)

Electrical energy heats the coils

then the coil heats the liquid.

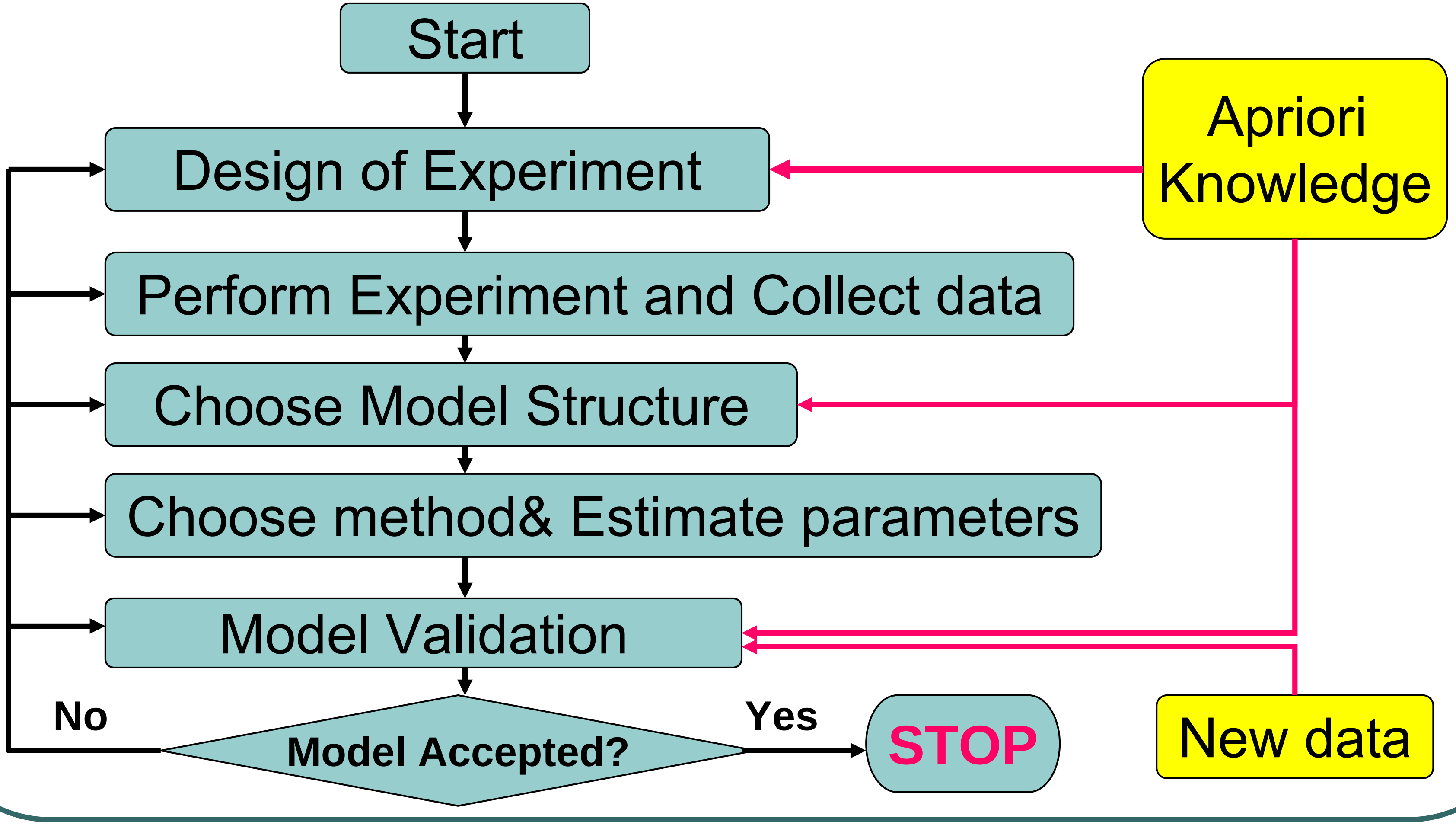
Modeling verses Identification

- **Modeling:**
  - The have some physical insight
  - In many cases modeling from basic laws may be too complex to be practical
  - In some cases the model derived from the basic laws may contain unknown parameters
- **Identification:**
  - Limited validity models (depends operating point, input,…)
  - Little physical insight (some parameters have no physical meaning)
  - They are easy to construct and use

System Identification

- Perform an experiment
- Collect data
- Assume a model
- Use data to estimate unknown parameters
- Validate model

Flow Chart for System Identification



Problems in Identification

- Model Selection
- Presence of noise in the measured data
- Some variables of interest are difficult or impossible to measure
- If the system is time-varying system, problems may occur if a time-invariant model is used.

Course Objectives

- To be able to design an identification experiment
- To be able to perform identification experiment and collect data
- To be able to solve parameter estimation problems
- To be able to perform model validation
- To be exposed to current research on identification
- To be able to use existing software / write own programs to solve identification problems

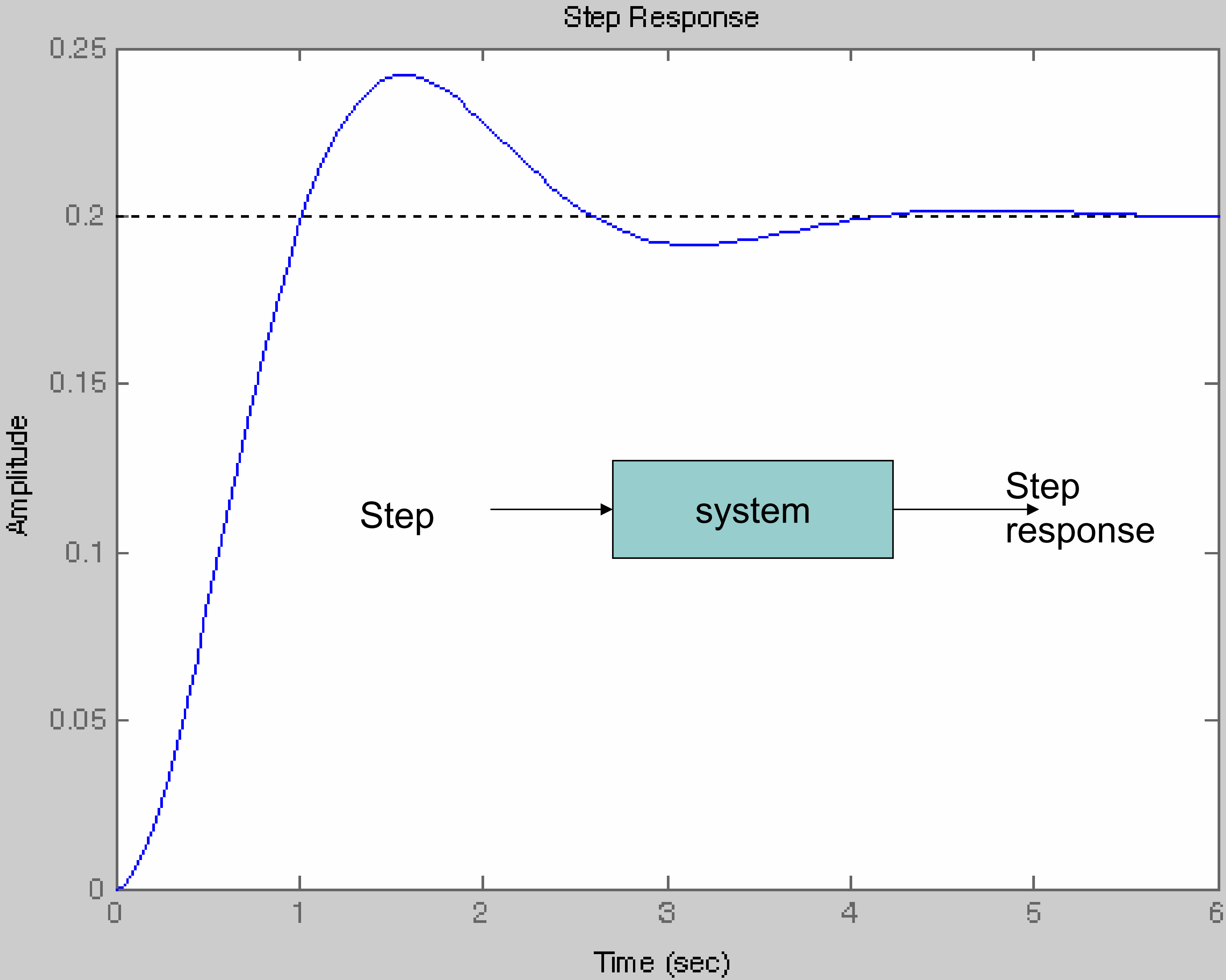
Reading Material

- Chapter 1 (Soderstrom & Stoica)

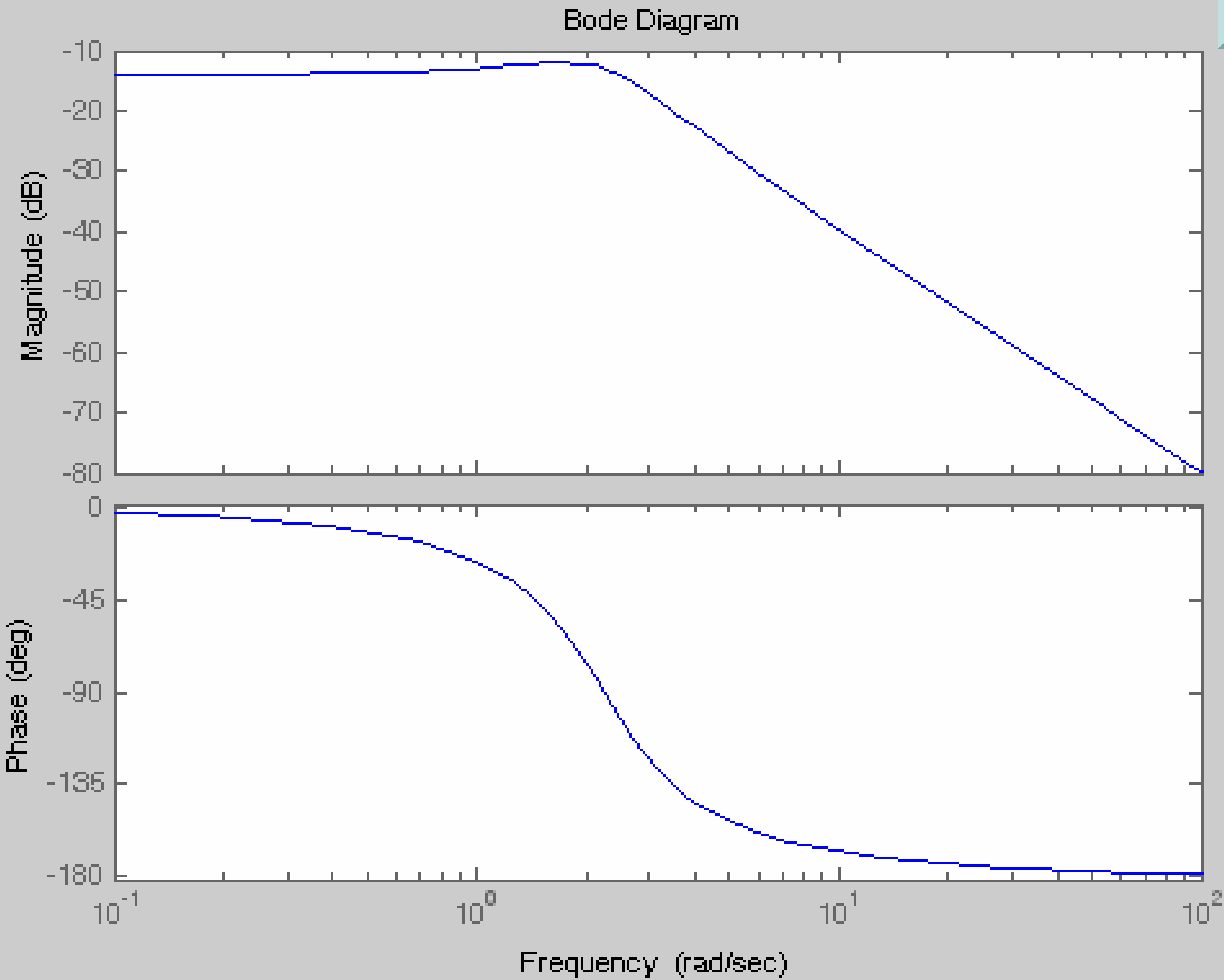
Write

- One idea that you completely understand from the material of this lecture.

- One Question that you want to ask



Step Response
Amplitude
0.25
0.2
0.15
0.1
0.05
0
Time (sec)
0
1
2
3
4
5
6
Step
system
Step
response


Bode Diagram
Magnitude (dB)
-10
-20
-30
-40
-50
-60
-70
-80
Phase (deg)
0
-45
-90
-135
-180
10^{-1}
10^{0}
10^{1}
10^{2}
Frequency (rad/sec)