For linear, time invariant systems, the state equations can be written

where

- _____ column vector of \( n \) state variables,
- _____ column vector of \( m \) inputs,
- _____ matrix of system parameters,
- _____ matrix of system parameters

Spring - Mass - Damper

Differential Equation form:

Transfer Function form:

State Variable form:

Assume \( x=0 \) at static equilibrium
Important Steps in Modeling

1. Clearly understand the purposes of the model
   - □ ____________________________
   - with the model?

2. Determine what is the system, what is the boundary, what is the environment.
   - □ Make ____________________________
   - to determine what aspects of the system must be captured in the model

Important Steps in Modeling

3. Determine the energy/power transfer characteristics of the system
   - □ ____________________________ elements
     - □ mass, spring, capacitor, inductor, water tank, etc.
   - □ ____________________________ elements
     - □ damper, resistor, valve, etc.
   - □ ____________________________ elements
     - □ gear, lever, op-amp, etc.

Important Steps in Modeling

4. With lumped-parameter systems there are only two types of variables:
   - □ ____________________________ (force, electrical current, fluid flow)
   - □ ____________________________ (velocity, voltage, pressure/head)

5. Write fundamental laws for each element

Important Steps in Modeling

6. Write equations which describe the interconnections of elements
   - □ ____________________________
   - □ ____________________________
   - □ ____________________________

7. Manipulate equations to suitable form
   - □ high order differential equations
   - □ ____________________________
   - □ ____________________________
Most Important Modeling Step

9. Never confuse the mathematical model with the real world system that is being studied
   □ math model __________________________!
   □ always good to have __________________ results for comparison
   □ if model results do not match the experiment, then __________________________

Approach in 577

The vast majority of our models will be
   □ lumped parameter
   □ deterministic
   □ __________________ time
   □ __________________
   □ __________________

Electrical & Mechanical Systems

Electrical variables:
   □
   □

Electrical elements:
   □
   □
   □

Mechanical variables:
   □
   □

Mechanical elements:
   □
   □
   □

Interconnection Laws

Electrical Systems:
   Kirchoff’s Current Law, at any node,
   Kirchoff’s Voltage Law, for any loop,

Mechanical Systems:
   Using D’Alembert’s Principle, at any “node”,
   Finding absolute velocity,
Electrical - Hydraulic Analogy

Electrical variables:
- voltage, $e$
- current, $i$

Electrical elements:
- capacitance, $C$
- inductance, $L$
- resistance, $R$

Hydraulic variables:

Hydraulic elements:

Electrical - Hydraulic Analogy

Electrical element:
- ideal voltage source

Hydraulic element:
- ideal head (pressure) source

Electrical - Hydraulic Analogy

Electrical element:
- ideal current source

Hydraulic element:
- ideal flow source