Dynamic Systems

- Electrical
- Mechanical
- Hydraulic
- Thermal

Examples:
- Moving car
- Electric circuits
- Telescope positioning system
Computer Aided Modeling and Design of Dynamic Systems

Basic Concepts

Step 1. Develop an engineering model
Step 2. Write differential equations
Step 3. Determine a solution
Step 4. Write a program

Physical System Schematic
Differential Equations Block Diagram or Bond Graph
Output Data tables & Graphs
Simulation Language

1. Develop an engineering model

Where is the mass at all times? [ mass (m) ]

Inertia elements
Kinetic energy

Compliance elements
Potential energy

Resistive elements
Dissipate energy

Ground

\[-k(y-y_g)- b(y-y_g) - mg = m \ddot{y}\]
2. Write differential equations

\[ \Sigma F_y = m \ddot{y} = m \frac{d^2y}{dt^2} \]

\[ \Sigma F_y = \frac{d}{dt} \left( m \frac{dy}{dt} \right) \]

\[-k(y-y_g) - b(\dot{y}-\dot{y}_g) - mg = m \ddot{y} \]

External forces

(mass)

Inertia

Kinetic energy

(damper)

Resistive

dissipate

energy

(spring)

Compliance

Potential energy

3. Determine the solution

Options

- Analytical
- Block diagram
- Bond graph model
- Write a program
- Use simulation tools
- Frequency domain (Laplace Transforms)

Block Diagram

A block diagram represents the dynamics of the system and describes program statements in single instructions.
4. Write a Program

Options
- Your own
- Simulation Language Input

For Simulation Language
(no logical sort)

\[
\begin{align*}
MYDD &= -m \ddot{y} - k(y - y_0) \\
YD &= \frac{1}{M} \text{INTEG}(MYDD, MYDDIN) \\
\text{DIFF} &= YD - Y0D \\
YMY0 &= \text{INTEG}(\text{DIFF}, \text{DIFFIN}) \\
Y &= YMY0 + Y0
\end{align*}
\]

EQUIVALENT REPRESENTATIONS

Physical representation

Bond Graph

Block Diagram
FUNDAMENTALS OF BOND GRAPH MODELING

BASIC PRINCIPLES AND DIFFERENTIAL EQUATIONS

Simple mathematically equivalent second order systems

\[ \frac{dQ}{dt} R + \frac{1}{C} Q + L \frac{d^2 Q}{dt^2} = V(t) \]

\[ L \ddot{Q} + R \dot{Q} + \frac{1}{C} Q = V(t) \]

\[ iR + \frac{1}{C} \int idt + L \frac{di}{dt} = V(t) \]

\[ m\ddot{x} + b\dot{x} + kx = F(t) \]
**BOND GRAPH MODELS**

Simple mathematically equivalent second order systems

\[ L\ddot{Q} + R\dot{Q} + \frac{1}{C}Q = V(t) \]

\[ m\ddot{x} + b\dot{x} + kx = F(t) \]