## Steps in Dynamic Modeling

1. Identify objective for the simulation
2. Draw a schematic diagram, labeling process variables
3. List all assumptions
4. Determine spatial dependence
   * yes = Partial Differential Equation (PDE)
   * no = Ordinary Differential Equation (ODE)
5. Write dynamic balances (mass, species, energy)
6. Other relations (thermo, reactions, geometry, etc.)
7. Degrees of freedom, does number of equations = number of unknowns?
8. Classify inputs as
   * Fixed values
   * Disturbances
   * Manipulated variables
9. Classify outputs as
   * States
   * Controlled variables
10. Simplify balance equations based on assumptions
11. Simulate steady state conditions (if possible)
12. Simulate the output with an input step

Sources: http://apmonitor.com/pdc/index.php/Main/DynamicModeling

Sources:

<http://apmonitor.com/pdc/index.php/Main/PhysicsBasedModels>

Closed system energy balance: https://youtu.be/UAinLG2lUWs

## Mass balance

Refer to <https://youtu.be/CqjI-oJBpoU>

## Species Balance

Refer to https://youtu.be/CqjI-oJBpoU?t=95

When there are no reactions:

If the volume is changing with respect to time, apply chain rule:

## Energy balance (simplified)

Where:

: Heat input

: Work done on the fluid

: Internal energy

: Specific enthalpy (units per kg or mol)

: Heat capacity