Deductive Problem Solving Strategy

A Method to Solve Open-Ended Problems

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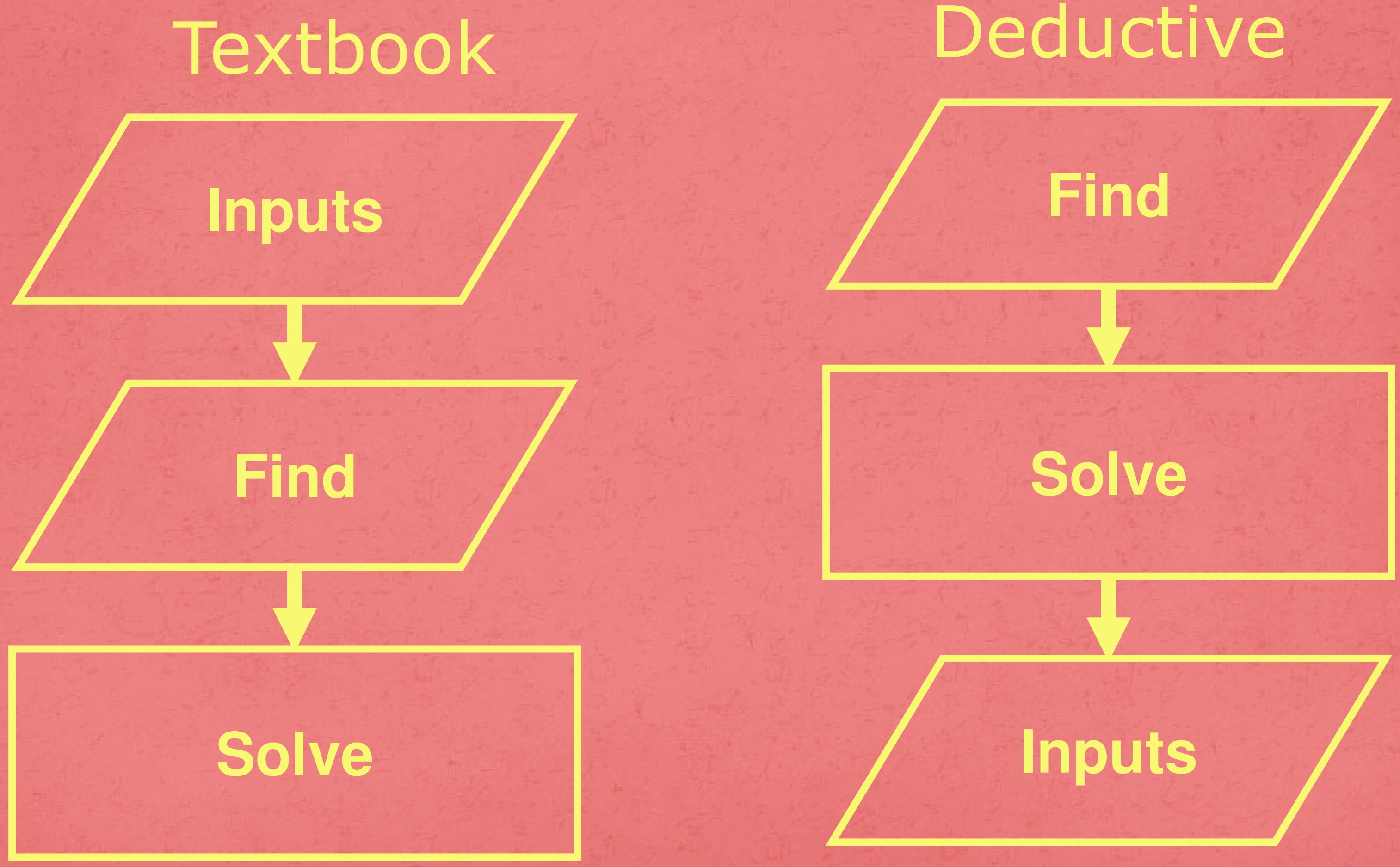
Introduction

- Textbook problems
  - Analytical skills
  - Inductive and deductive
- Open-ended problems
  - Missing inputs
  - Less order
  - Represents workplace
  - Enhances learning
- Deductive Strategy
  - General to specific
  - Structure to disorder

Comparison



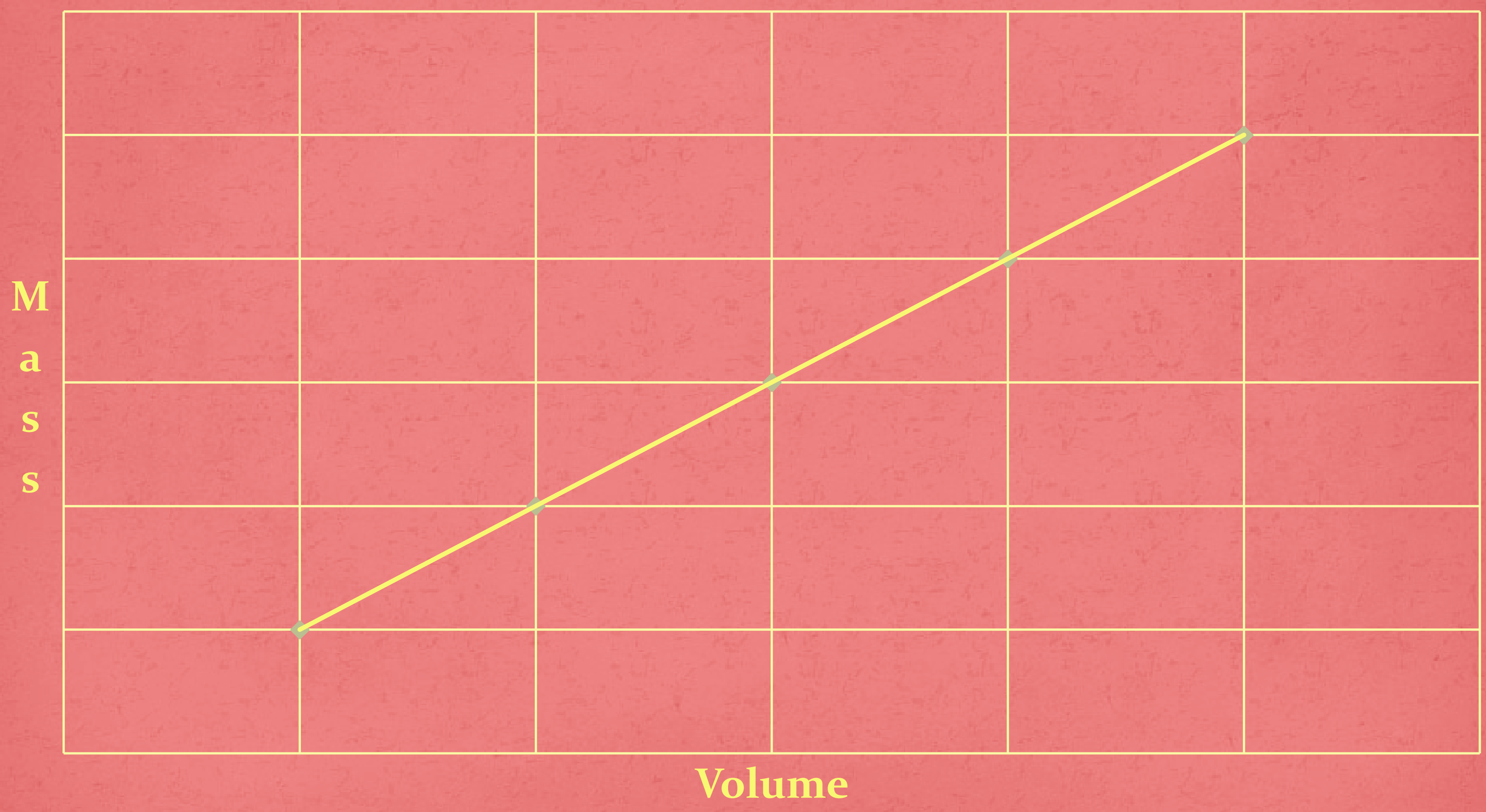
Find

- In general
  - Dependent variable
  - Objective
  - Goal
- This presentation
  - New tool for first semester thermodynamic students
  - Three examples using the following:
    - Ideal gas law
    - Newton's second law of motion
    - Definitions of work, power and acceleration

System Schematic

- Simple representation of system
- Identify system boundaries
- Identify relevant characteristics
  - Dimensions
  - Forces
  - Reference frame

Property Plot



Deduce Inputs

- Sources of Equations (3 of 5)
  - Laws of Science and Math
    - Geometry
    - Newton's Second Law
  - Definitions
    - Density
    - Power
    - Acceleration
  - Property Relationships (Ideal Gas Law)

Solution

$$\rho = \frac{m}{Vol}$$

"Definition of Density"

$$P = \rho \times R \times T$$

"Ideal Gas Law"

$$Vol = W \times H \times D$$

"Volume of a Rectangular Prism"

3 Equations and 3 Unknowns with 6 specified variables

Check Units

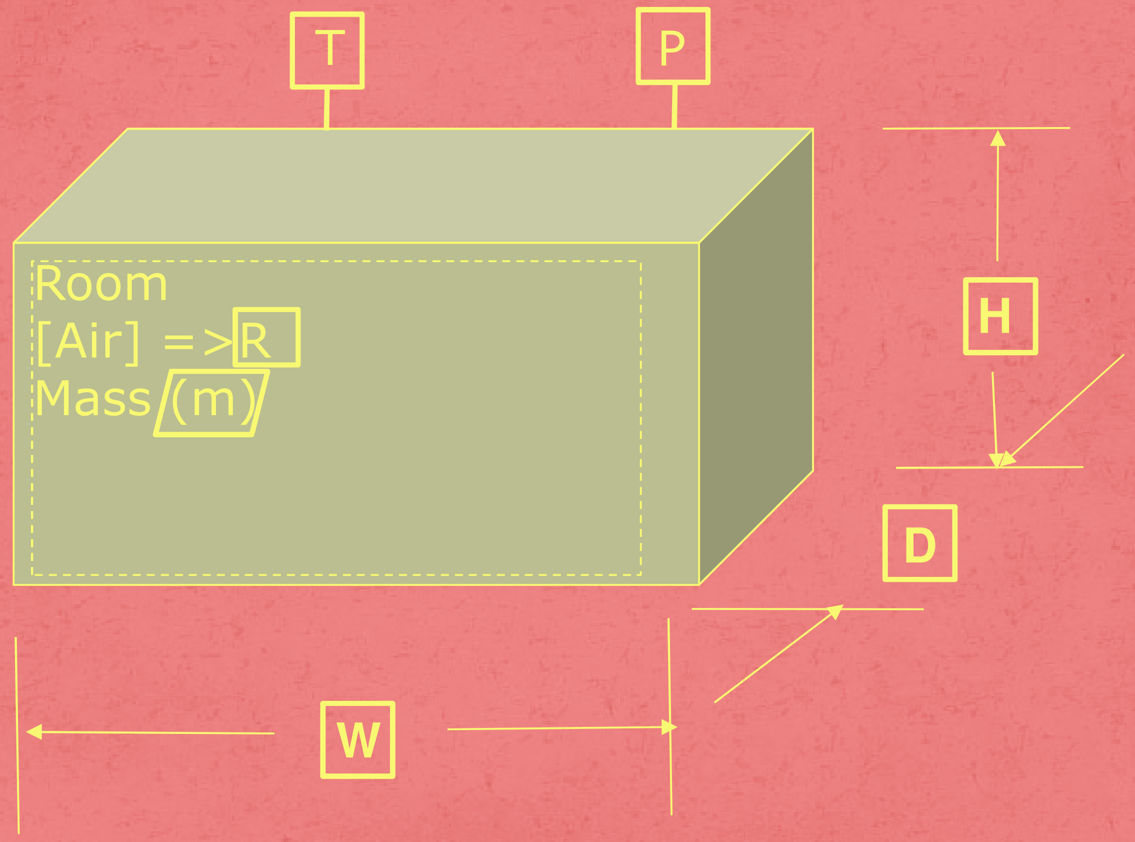
$$\rho = \frac{m}{Vol} \qquad \frac{kg}{m^3} = \frac{kg}{m^3}$$

$$P = \rho \times R \times T$$

$$kPa = \frac{kg}{m^3} \times \frac{kJ}{kg - K} \times \frac{K}{1} \times \frac{kN - m}{kJ} \times \frac{kPa - m^2}{kN}$$

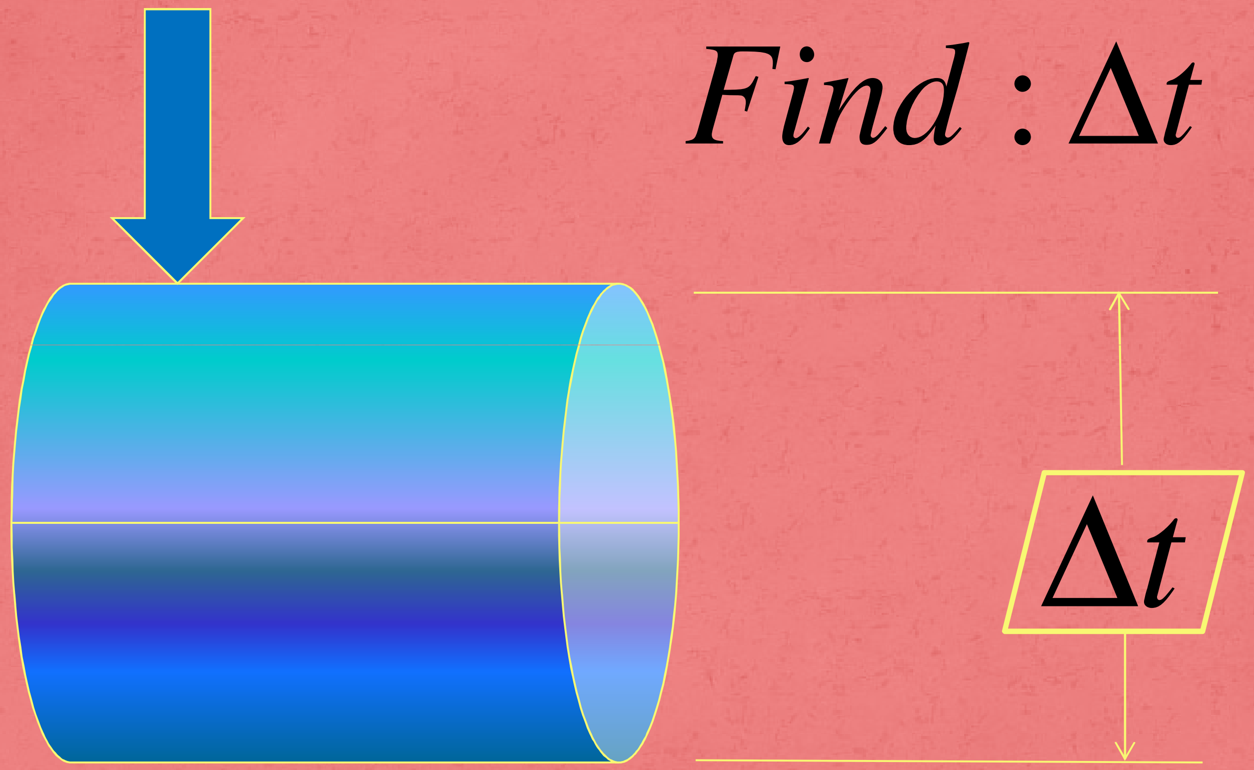
$$Vol = W \times H \times D \qquad m^3 = m \times m \times m$$

Update Schematic

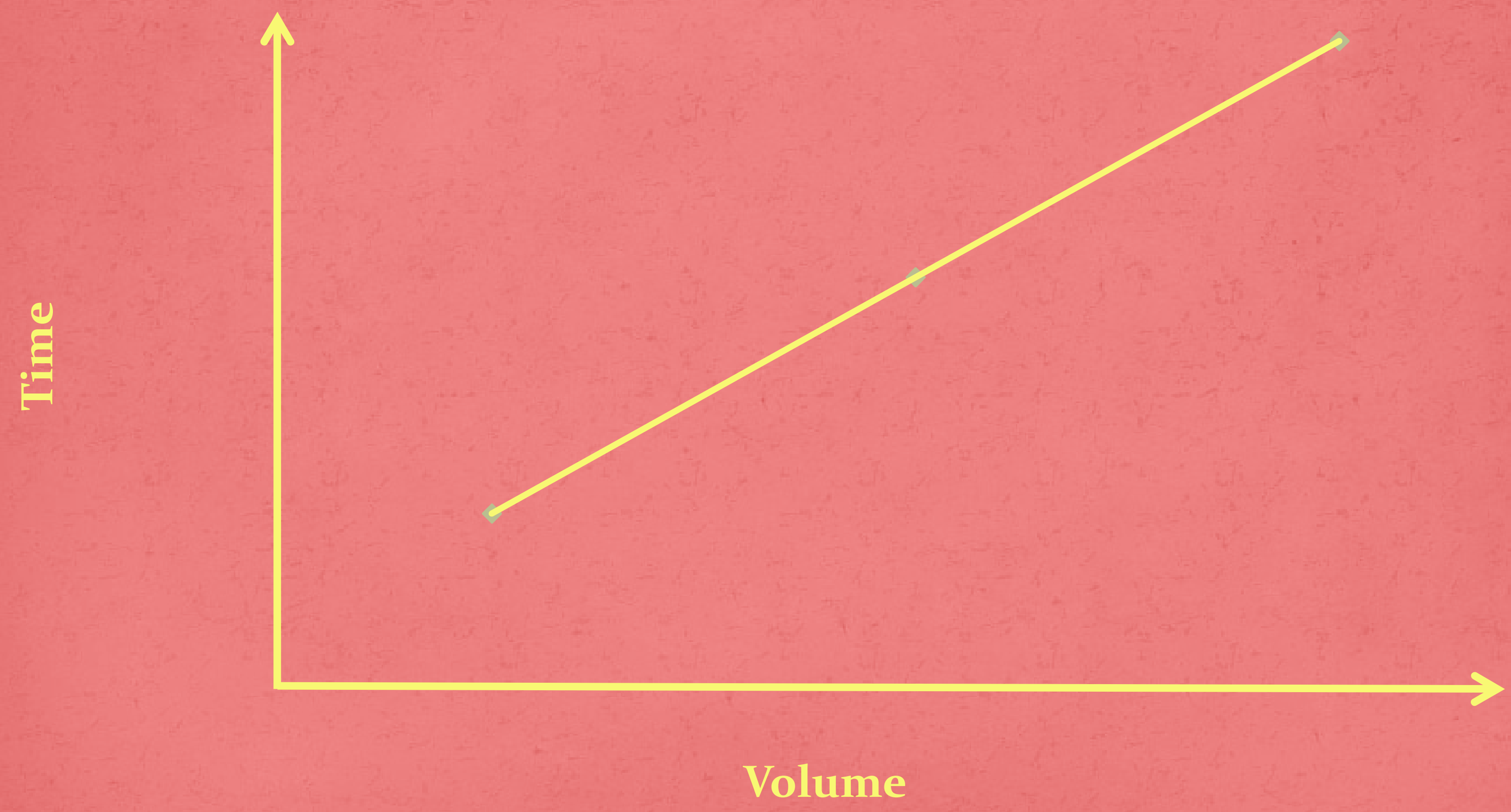


Time to Fill a Gas Tank

$$Find : \Delta t$$



Property Plot



Equations

$$\dot{V} = \frac{Vol}{\Delta t}$$

"Definition of Volumetric Flow Rate"

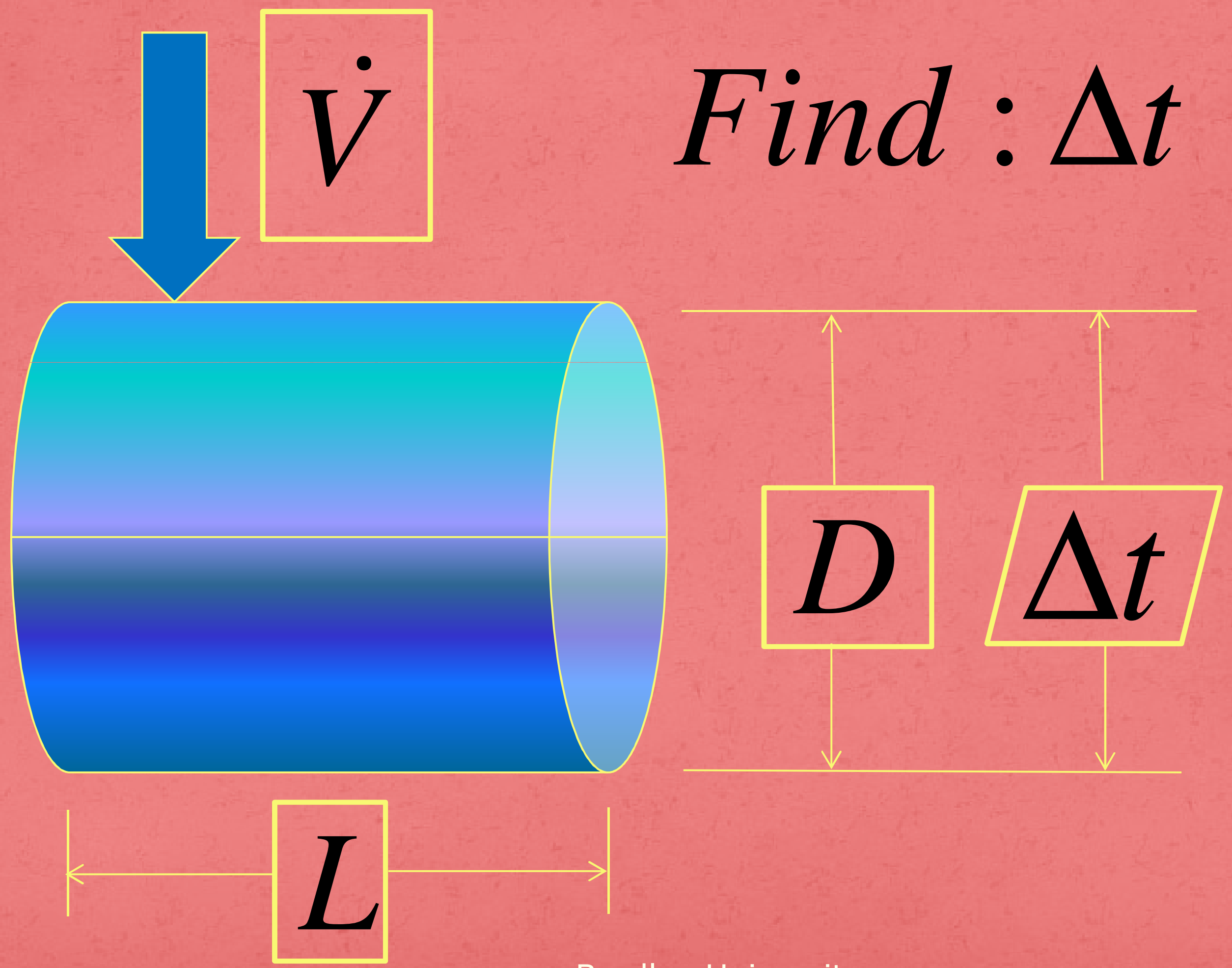
$$Vol = A \times L$$

"Geometry: Volume of Cyl."

$$A = \frac{\pi D^2}{4}$$

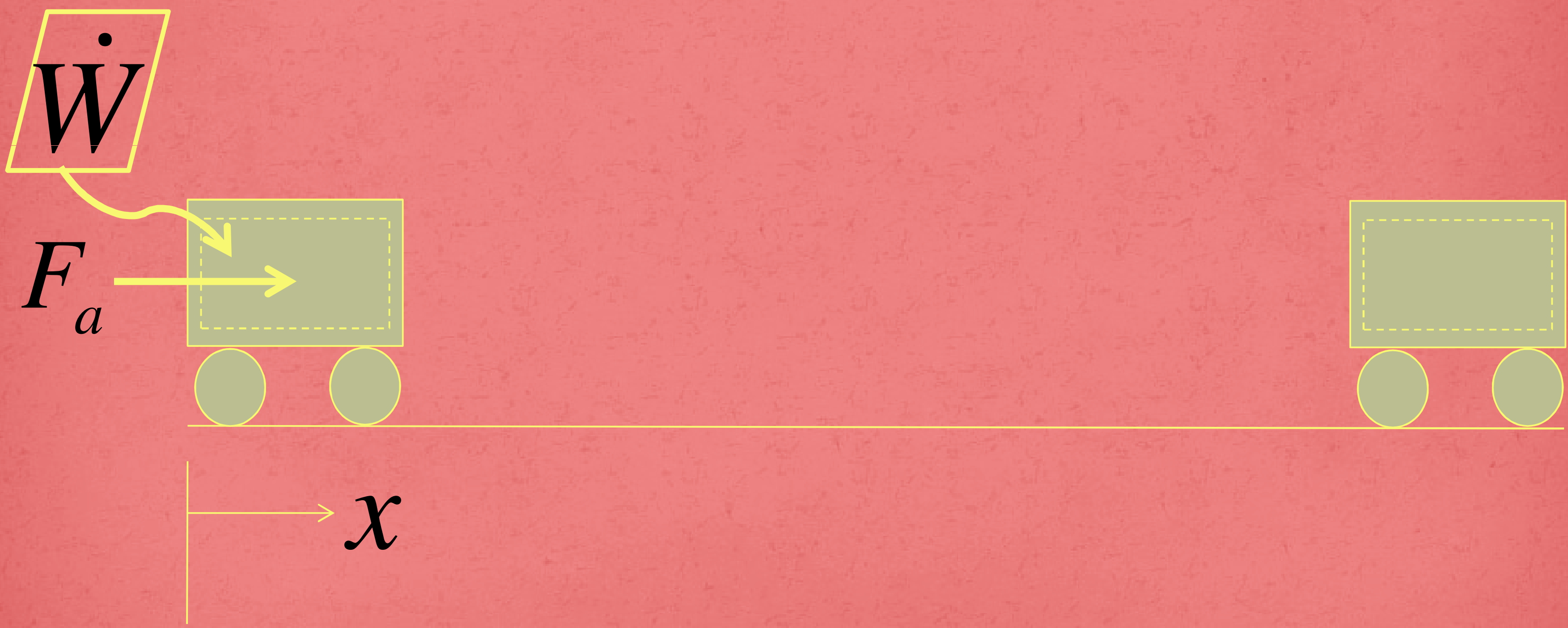
"Geometry: Area of Circle"

Update Schematic

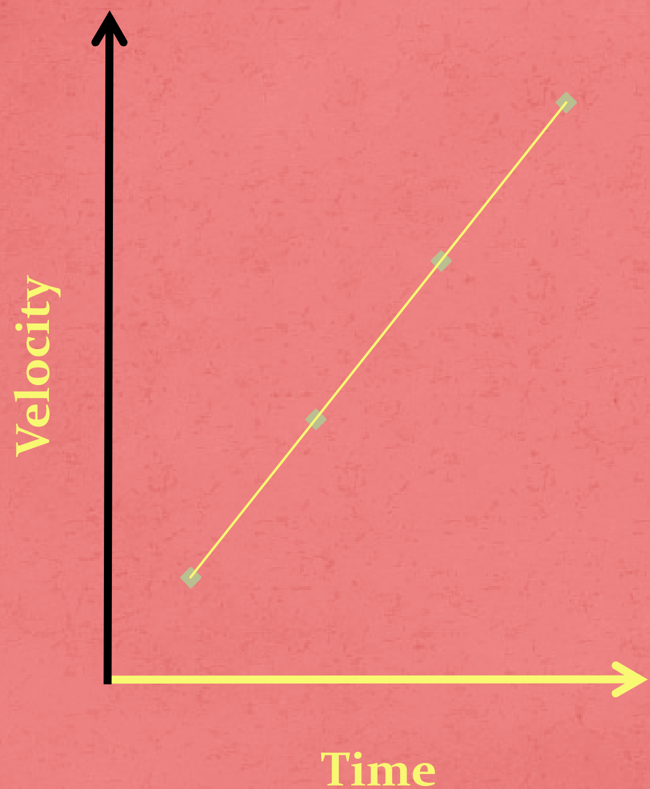


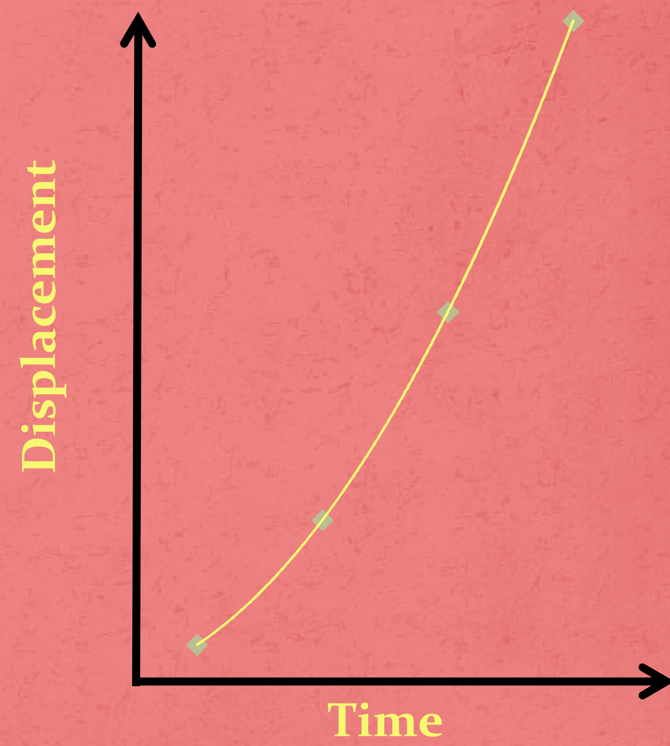
Power to Accelerate

$$Find : \dot{W}$$



Property Plots





Equations for Power

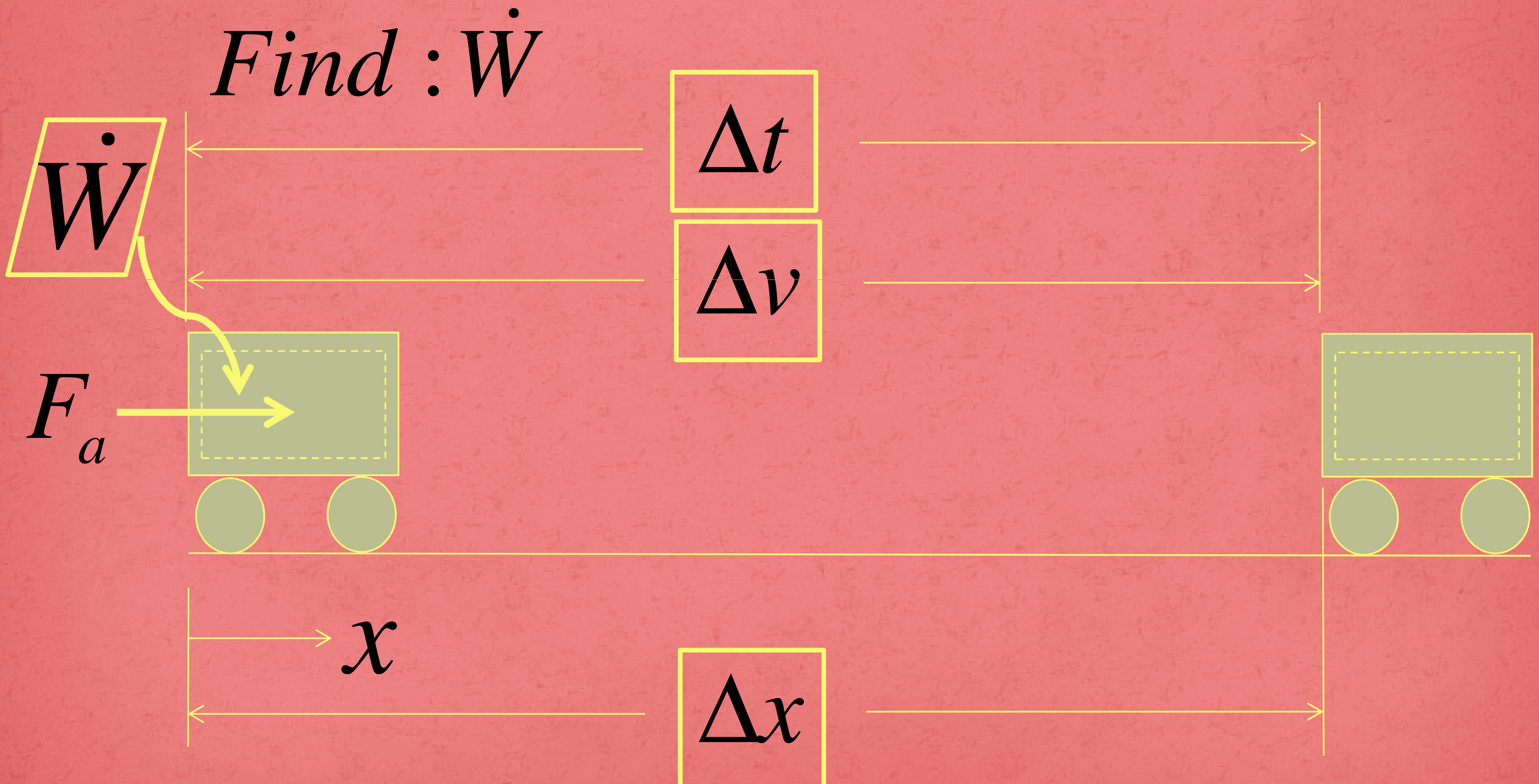
$$\dot{W} = \frac{W}{\Delta t}$$ "Definition of Power"

$$W = F_a \times \Delta x$$ "Definition of Work"

$$F_a = \frac{m \times a}{g_c}$$ "Newton's Second Law"

$$a = \frac{\Delta v}{\Delta t}$$ "Definition of Acceleration"

Update Schematic



Summary of Deductive Strategy

- Determine Objective
- Define Problem
  - Schematic
  - Property Plot
- Solve
  - Equations: unknowns to specified
  - Three categories
- Check

Conclusions

- Open-ended problems
  - Enhance learning
  - Prepare for work force
  - High level of disorder
- Deductive problem solving
  - Systematic approach to minimize disorder
  - Objective->Equations->Measurements
  - Adapt existing problem solving strategy

Deductive Problem Solving Strategy

A Method to Solve Open Ended Problems

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Summary of the Deductive Problem-solving Strategy

This strategy starts with the objective of the problem and then works its way to the inputs needed to solve the problem. The key question to ask is which relationship will provide the bridge between what is needed (the dependent variable) and what can be specified or measured (the independent variables). The deductive approach will assist you when you face problems that are not well defined such as the ones you will face in industry. If you discipline yourself to follow all these steps, even for easy problems, you will have a tool to help you when you face a problem where you have no idea where to begin.

1) **Draw a system schematic.** The schematic is essential to the definition of the problem. **In the schematic, identify the system boundaries, all energy interactions (i.e., heat and work) which cross the boundaries, identify any relevant reference frames (e.g., position) and the positive direction and any other significant variable.**
   a) **Use descriptive variable names** (e.g., P_i rather than x_1 for initial pressure)
   b) **Provide references or sources for all equations** (e.g., conservation of energy).
   c) **Summarize any assumptions used when applying the equations. Justify the relevance of the assumptions to the problem.** (e.g., Ideal gas because the compressibility factor (Z) is near 1)
2) **Construct process diagrams (e.g., P vs. v, P vs. h, T vs. length, etc.).**
   a) **Mark all state points between each component**
   b) **For heat exchangers, superimpose the inlet temperature of the other fluid**
3) **Find: Determine the dependent variable(s). Start with the objective or goal of the problem.** For optimization problems identify the objective function (a dependent function that has a maximum or minimum as the independent variable(s) are varied over their range(s)). One useful objective function for design problems is the total life-cycle cost or present worth of a system. Another objective for comparisons between alternatives is percent difference.
4) **Solution:**
   a) **Determine a relationship (or equation) which contains the dependent variable.** The relationship needs to move the solutions towards something that can be measured or specified. Variables which can often be measured directly with instruments include: length, time, flow rate, temperature, force and pressure. Variables which can be specified often include the isentropic efficiency or heat exchanger effectiveness or geometry.
      i) **Choose from one of the following five basic types of relationships**. Tip: Choose the simplest form of a relationship. For example the simplest form of the definition of isentropic efficiency for a compressor is the ratio of ideal power input to actual power input. Some authors combine the conservation of energy with the definition to express the isentropic efficiency in terms of enthalpies. The enthalpy form of the equation is less straightforward and therefore should not be used.
      ii) **The first relationship is a law of science or math**. For thermal science problems the following laws may be relevant to the problem. Conservation of mass, momentum and energy. For heat transfer the following laws may be relevant: Fourier's Law for conduction, Newton's Law of Cooling for convection and Stefan-Boltzmann Law for radiation. For convection, empirical relationships are used to

determine the heat transfer coefficient. For radiation, view factor relationships may be helpful. (e.g., reciprocity, summation, superposition, and symmetry.)

iii) **The second relationship is a definition.** Definitions of efficiency, coefficient of performance, isentropic efficiency and heat exchanger effectiveness are useful for energy systems.

iv) **The third relationship comes from thermodynamics property relationships.** Often these will be used when a property which cannot be measured directly is needed. Examples of these properties which are difficult to measure include: specific internal energy, specific enthalpy or specific entropy. The property relationship connects the unknown property to ones which can be measured or are known from process information (e.g. isentropic). Here it is useful to refer to the property plot to determine which independent, intensive properties are the best.

v) **The fourth is a regression analysis.** These are most commonly used to relate initial cost data to the design variable(s).

vi) **The fifth and last type of relationship is knowledge about the process.** For example: constant volume, pressure or entropy processes.

b) **Evaluate each of the variables in the equation.**
   i) **Draw a box around all the variables in the equation that can either be specified or measured.**
   ii) **Circle all new unknowns that have not already been counted.**
   iii) **Place a parallelogram around the variable for which the equation is being used to find its value.**

c) **Moving left to right, for the first circled variable, determine a relationship (equation), from the previous five categories, which can be used to solve for it.**

d) **Indent one level and enter the equation. Note: every circled variable from the same equation will have the same level of indentation.**

e) **Repeat steps c) through e) until the first circled variable of the most recent equation can be determined from specified information.**

f) **Move systematically, from left to right, through the circled variables in the most recent equation and repeat step d) through f) for the next circled variable.**

g) **Continue until each of the circled variables in the most recent equation can be determined from specified information**.

h) **Return to the nearest equation containing a circled variable that does not yet have an equation and repeat steps d) through h),**

i) **Continue adding equations until you have an independent equation for each unknown variable.** At this point the solution is complete.

5) **Create Summaries**
   a) **Summarize all the variables, along with their values and associated units, which need to be specified or measured in a table. Identify the source of the data. (e.g. handbook, measurement, etc.)**
   b) **Create a nomenclature section to define all variables and their units**.

6) **Perform reality checks**
   a) **Check equations for dimensional homogeneity**
   b) **For computer solutions, perform sample calculations at one set of conditions**