The University of Texas at Austin

Mechanical Engineering Department

MODELING OF PHYSICAL SYSTEMS

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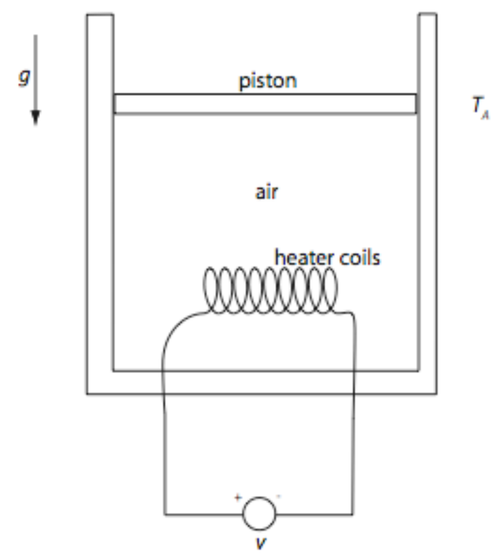
Assigned 4/22/2022	**Assignment 6**	Due 5/6/2022

Read Chapter 10 and 11

1. Consider the electro-thermo-mechanical system shown below. A piston is forced to move by the expansion of air in the cylinder. Neglect any friction between the piston and the cylinder walls. Assume conduction through the walls and piston with an outside wall temperature maintained at T_A by a thermal bath. The piston has a mass m and a radius r. The initial height of the piston is given as h_0. The piston and cylinder are made of steel and wall thickness t. The heater coil has electrical resistance R and has input voltage $v(t)$.

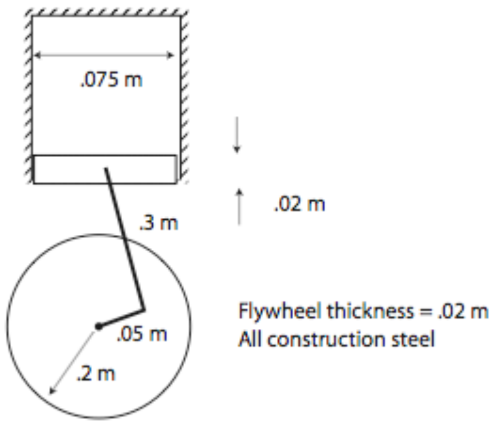


   a. Develop a bond graph model of this system.

   b. Develop state equations for this system.

   c. Develop output equations for chamber temperature and piston height.

2. Consider a simplified model of a diesel engine that burns hydrogen as a fuel.



The compression ratio = $\text{Volume}_{max}/\text{Volume}_{min} = 20$. The simplified reaction is $H_2 + O_2 \Leftrightarrow 2\ OH$. The standard reference values are:

$T_0 = 298\ °K$

$P_0 = 101.325\ \text{kPa}$

$R = 8.3144\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$v_0 = \frac{RT_0}{P_0}$

$s_{0_{H_2}} = 130.58 \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$s_{0_{O_2}} = 205.03\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$s_{0OH} = 188.7\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$\mu_{0H_2} = -38913\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$\mu_{0O_2} = -61099\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$\mu_{0OH} = -298233\ \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

Specific heats are:

$c_{p_{H_2}} = 28.64 \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$c_{p_{HO_2}} = 29.12 \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$c_{p_{OH}} = 33.56 \frac{\text{kJ}}{\text{kmol} - °\text{K}}$

$c_v = c_p - R$

The rate law is

$v_f = k_f C_{H_2} C_{O_2}$ where $C_i = \frac{N_i}{V}$

$k_f = 1.7\ \times 10^3 e^{-200045/RT}$

Initial conditions are

$V(0) = V_{max}$

$N(0) = \dfrac{P_0 V_{max}}{RT_0}$

$N_{OH}(0) = 1\ \times 10^{-6} N(0)$

$N_{O_2}(0) = \frac{1}{2}(N(0)\text{-}\ N_{OH}(0))$

$N_{H_2}(0) = \frac{1}{2}(N(0)\text{-}\ N_{OH}(0))$

h(0) = 150% of angular momentum of the flywheel to adiabatically compress an ideal gas to full compression.

Develop a bond graph model, write state equations, and perform a digital simulation for one combustion cycle (from V_{max} to V_{min} back to V_{max}).