Homework #4

MEMS 0051 - Introduction to Thermodynamics

Assigned February 2nd, 2018
Due: February 9th, 2018

Problem #1

a) You push a lawnmower with a total force of 50 [N] at a constant velocity of 0.1 [m/s] for a total of 10 seconds. The lawnmower has a mass of 20 [kg].
   i.) How much power ($\dot{W}$) are you transferring to the lawnmower [W]?
   ii.) How much work (W) do you transfer to the lawnmower during those 10 seconds [J]?
   iii.) How much specific work (w) do you transfer to the lawnmower [J/kg]?

b) Now assume that heat is leaving the lawnmower at a rate of 2 [W] throughout the 10 seconds.
   i.) How much total heat (Q) leaves the lawnmower during those 10 seconds [J]?
   ii.) How much specific heat (q) leaves the lawnmower during those 10 seconds [kJ/kg]?

c) Now consider the lawnmower as a thermodynamic system with a control surface drawn all around it. Make sure you use the 1st Law sign conventions for heat and work.
   i.) Is work positive or negative for the lawnmower system? Explain.
   ii.) Is heat positive or negative for the lawnmower system? Explain.

Problem #2

a) A piston cylinder is initially filled with air occupying 0.5 [m^3]at a pressure of 100 [kPa]. The piston then compresses the air to a new volume of 0.2 [m^3]. The compression process is governed by the polytropic equation: $P_1\forall_1^n = P_2\forall_2^n$. Determine how much work is done by the gas for the following polytropic indices:
   i.) $n=\infty$
   ii.) $n=0$
   iii.) $n=1$
   iv.) $n=1.4$

b) Now assume that we don't know the polytropic index, but we do know that the final pressure is 200 kPa. Solve for the polytropic index, n

Problem #3

a) Determine the change in internal energy, (U_2-U_1), for each of the following ideal gas cases. (Hint: refer to Table A.5 to look up $C_\forall$ for each of these gases.)
   i.) 1 [kg] of argon going from 300 K to 400 K
   ii.) 2.5 [kg] of carbon dioxide going from 500 K to 300 K
   iii.) 2 [kg] of nitrogen going from 400 K to 300 K

Problem #4

a) A piston-cylinder device contains air at 100 [kPa], 25 °C and 0.2 [m^3]. The air then undergoes an isobaric, polytropic expansion to a volume of 0.4 [m^3]. (R=0.287 [kJ/kg-K] for air).
   i.) What is the mass of air contained in the piston-cylinder?
   ii.) What is the final temperature after expansion?
   iii.) How much work is done by the gas during this expansion?
   iv.) What is the change in internal energy, (U_2-U_1), during this expansion?
   v.) How much heat is transferred into the gas during this expansion?

Problem #5

a) Water contained in a piston-cylinder assembly has an initial temperature of 150 °C, a quality of 50% and an initial volume of 0.05 m^3. The pressure of the process is given as $P(\forall)=100 + C\forall^{0.5}$ [kPa], where C is a constant. Heat is transferred to the piston-cylinder until the final pressure reaches 600 kPa.

i.) Determine the heat input. (Hint, you need to determine C.)