ROSE-HULMAN Institute of Technology
Department of Mechanical Engineering

Section: ☐ 01 (6th hour) ______________________ **Name**

☐ 02 (7th hour)

______________________ **CM**

Exam 3

Nov 2, 2012

Problem 1	______/ 40
Problem 2	______/ 30
Problem 3	______/ 30
Total	______/ 100

Show all work for full credit.

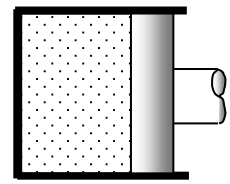
Open book, computer use for computational purposes, one 8 ½ x 11" handwritten equation sheet.

If you use tabular data from your text, do **not** interpolate values. Use the nearest value in the table(s).

Problem 1 (40 pts)

A **Dr. Thom Simple Cycle** (DTS cycle) is a closed-system/periodic cycle consisting of only three steps as follows:

(1)→(2) Constant volume heat addition
(2)→(3) Reversible, adiabatic expansion
(3)→(1) Constant pressure heat rejection

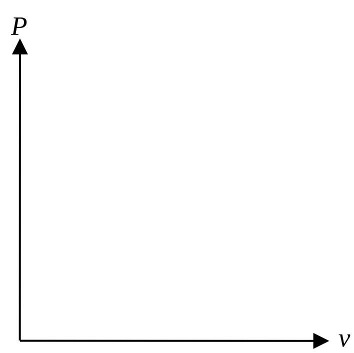


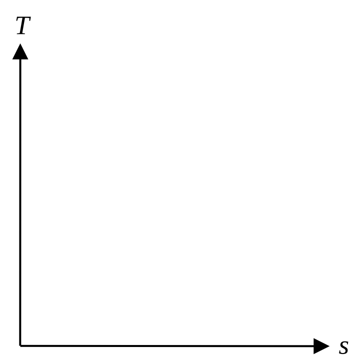
A particular DTS cycle is to be modeled using the **air standard** assumptions. The air at the beginning of the heat addition is P_1 = 90 kPa and T_1 = 310 K. After the heat addition the pressure is P_2 = 531.4 kPa The heat rejected in process (3)→(1) is $q_{out,31}$ = 456.6 kJ/kg.

This information is summarized in the table below. (You do not need to fill in all values in the table.)

State	*T* [K]	*P* [kPa]	*u* [kJ/kg]	*h* [kJ/kg]	s^0 [kJ/kg·K]	P_r	v_r
1	310	90	221.25	310.24	1.73498	1.5546	572.3
2		531.4					
3							
			$q_{out,31}$ = 456.6 kJ/kg				

(a) Sketch the *P-v* and *T-s* diagrams for a DTS cycle.



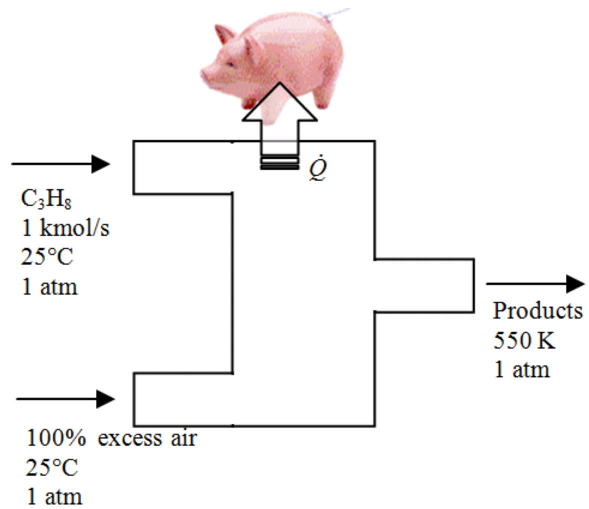


(b) Find the heat transfer and work per unit mass for each step in the given cycle (in kJ/kg). **Assume an air-standard cycle** (R = 0.287 kJ/kg-K.)
(c) Find the cycle efficiency.
(d) If the cycle is to produce a net work output of 400 kJ, what mass of air is required?

Problem 2 (30 pts)

Hank Hill has fired up his propane (C_3H_8) grill for a Texas style BBQ. (He did not invite Dr. Thom, however, as he refused to cook veggie burgers on *his* propane grill.) Hank's grill is modeled as a steady state, steady flow reaction chamber as shown in the figure. Assuming that the fuel is supplied with 100% *excess* air,

(a) find the balanced chemical reaction equation and
(b) the rate of heat transfer (in kW) supplied to the BBQ.



Problem 3 (30 Points)

(a)

i. (3 pts) True / False Compression ratio is given by $r = v_{max}/v_{min}$

ii. (3 pts) True / False Compression ratio is given by $r = P_{max}/P_{min}$

(b) (6 pts) Define **adiabatic flame temperature**.

(c) (10 pts) 1 k-mol of methane (CH_4) is combusted with theoretical air. The products of combustion are at a pressure of 100 kPa. The balanced reaction is given below.

$$CH_4 + 2[O_2 + 3.76N_2] \rightarrow CO_2 + 2H_2O + 7.52N_2$$

If the products are at $T = 40°C$, how many k-mols of water are in the liquid phase? (Assume $40°C < T_{dew}$)

Answer only one of the next two questions.

(d) (8 pts) Prove that for a closed system undergoing a constant pressure process the heat transfer is given by

$$Q_{12} = m(h_2 - h_1)$$

(e) (8 pts) Prove that for an isentropic process of an ideal gas with constant specific heats the pressure and temperature are related by

$$(P_2/P_1) = (T_2/T_1)^{k/(k-1)}$$

(Hints: $R = c_p - c_v$, $k = c_p/c_v$)