ROSE-HULMAN Institute of Technology
Sophomore Engineering Curriculum

ES201 –Conservation & Accounting Principles | Winter 2014-2015

Section [1 pt]: □ 01 (1st period)
□ 02 (2nd period)

Name [1 pt] ______________________

CM [1 pt] ______________________

Exam 3

Feb 12, 2015

Problem 1	______/ 32
Problem 2	______/ 33
Problem 3	______/ 32
Total	______/ 100

Rules:

- Closed book/notes exam. (Unit conversion page provided)
- Help sheet allowed. (8-1/2 x 11" sheet of paper, one side, handwritten)
- Laptops may be used for computational purposes only; no pre-prepared worksheets or files may be used.

Instructions:

- Show all work for complete credit.
- Start all problems at the **analysis** stage, but clearly label any information you use for your solution.
- Problems involving conservation principles **must clearly identify the system in a separate drawing and show a clear, logical progression from the basic principle.**
- Don't expect us to read your mind as to how or why you did something in the solution. Clearly indicate how you arrived at your answer.
- **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all I would have to do is plug in the numbers into a well-documented solution.)

Problem 1 (32 pts)

(a) [15 pts (3 pts each)]

True **False** Heat transfer must result in an increase of system temperature.

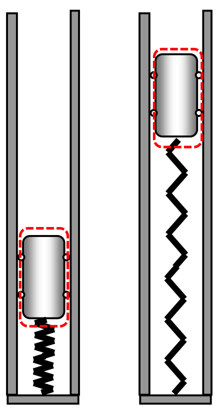
True **False** Heat transfer is the transport of energy due to a spatially-occurring temperature difference (a temperature difference in space).

True **False** A system's gravitational potential energy can be negative.

True **False** A moving surface force (contact force) on a system boundary must always do work.

True **False** If there is energy transfer at a non-flow boundary and it is not heat transfer, it must be work.

(b) [6 pts (3 pts each)] A slider is pushed up through a **frictionless** cylinder by a spring as shown in the figure. For a system consisting of only the slider,



(1) (2)

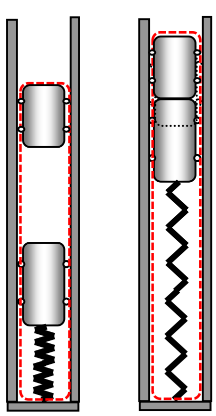
i. what is the work?

o $W_{in} < 0$
o $W_{in} = 0$
o $W_{in} > 0$

ii. What is the change in internal energy?

o $U_2 - U_1 < 0$
o $U_2 - U_1 = 0$
o $U_2 - U_1 > 0$

(c) [6 pts (3 pts each)] A slider is pushed up through a **frictionless** cylinder by a spring as shown in the figure, colliding with a second slider. For a system consisting of the spring and *both* sliders before and after the collision,



(1) (2)

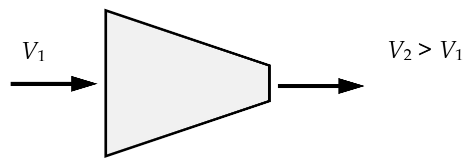
i. what is the work?

o $W_{in} < 0$
o $W_{in} = 0$
o $W_{in} > 0$

ii. What is the change in internal energy?

o $U_2 - U_1 < 0$
o $U_2 - U_1 = 0$
o $U_2 - U_1 > 0$

(d) [5 pts] Air is accelerated through an adiabatic nozzle operating at steady state. If air can be modeled as an ideal gas with constant specific heats, how does the temperature at the exit compare to that of the inlet?



- o $T_2 < T_1$
- o $T_2 = T_1$
- o $T_2 > T_1$
- o Insufficient information to be determined

Problem 2 (33 pts)

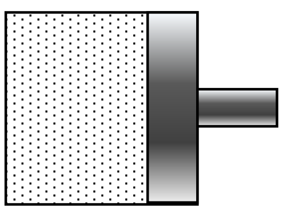
A piston-cylinder contains a mass m = 0.3 kg of air (c_v = 0.713 kJ/kg-K, c_p = 1.001 kJ/kg-K, R = 0.287 kJ/kg-K) initially at T_1 = 25°C, P_1 = 150 kPa and $\mathcal{V}_1$ = 0.17 m^3. The air is compressed during a process for which $P = A + B/\mathcal{V}$, where A and B are constants. (See figure.) The volume after the compression is $\mathcal{V}_2$ = 0.11 m^3. Air can be treated as an ideal gas with constant specific heats.

(a) Find the work into or out of the air, in kJ.
(b) Find the final pressure and temperature.

For part (c) assume that the answers above are $W_{in,1\rightarrow2}$ = 15 kJ, P_2 = 320 kPa, and T_2 = 405 K. (They aren't.)

(c) Find the heat transfer into or out of the air, in kJ.

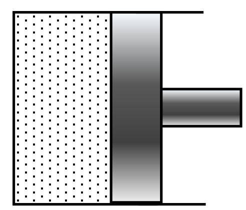
(1)



m = 0.3 kg
P_1 = 150 kPa
T_1 = 25°C
$\mathcal{V}_1$ = 0.17 m^3

From (1) to (2) $P = A + B/\mathcal{V}$
where
A = -125 kPa
B = 46.8 kPa·m^3

(2)



m = 0.3 kg
P_2 = ?
T_2 = ?
$\mathcal{V}_2$ = 0.11 m^3

Problem 3 (32 pts)

A pump powered by an AC motor is to be used to pump water (c = 4.18 kJ/kg-K, ρ = 997 kg/m³) through a constant diameter pipe to a storage tank on the roof of a small building. An AC motor powers the pump, supplying it with 0.30 kW of shaft power. The required flow rate of water is $\dot{\forall}$ = 0.002 m³/s. Other operating conditions are given in the figure.

(a) Under these conditions, what is the height of the building to which the pump can deliver the required flow rate?

(b) The motor has a surface area of 0.09 m², a temperature of 40°C, and exchanges heat with the surrounding air with temperature of 22°C and convection heat transfer coefficient of 25 W/m²-°C. Assuming an input voltage of 120 V and a power factor of one (a purely resistive load) what is the electrical current to the motor?