ES201 - Examination III Fall 2005-2006 $5^{th}/6^{th}$ hours

NAME____SECTION_______________

BOX NUMBER__________

Problem 1 (21) ________________

Problem 2 (39) ________________

Problem 3 (40) ________________

Total (100) ________________

INSTRUCTIONS

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

1) 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 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 your 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.)
2) Useful Rule of Thumb (Heuristic): (100 point exam)/(50 min) = 2 points/minute. That means a 10 point problem is not worth more than 5 minutes of your time (at least the first time around).
3) Please remain seated until the end of class or everyone finishes. (Raise your hand and I'll pick up your exam if you have other work you need or want to do.)

USEFUL INFORMATION	SI	USCS	Molar Mass	
Ideal Gas Constant: R_u	= 8.314 kJ/(kmol-K)	= 1545 (ft-lbf)/(lbmol-°R)	Air	28.97
		= 1.986 Btu/(lbmol-°R)	O_2	32.00
Standard Acceleration of Gravity: g	= 9.810 m/s^2	= 32.174 ft/s^2	N_2	28.01
Density of liquid water	= 1000 kg/m^3	= 62.4 lbm/ft^3	H_2	2.016
		= 1.94 slug/ft^3	CO_2	44.01

Problem 1

a. Consider the black box shown below. Fluid flows into the box on one side, is changed by some unknown process inside the box, and flows out the other side. We don't know if heat transfer or work is done on the fluid while it is in the box.

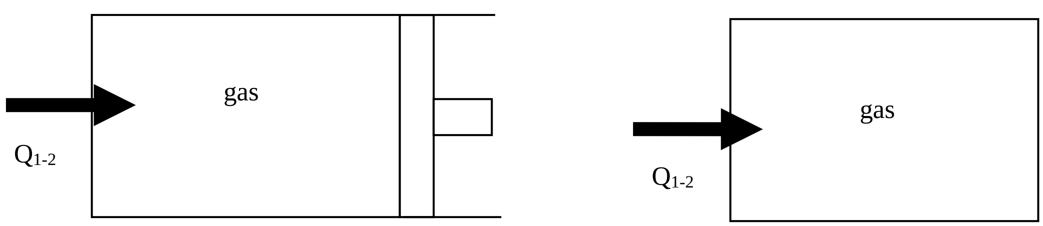
i) (4pts) Suppose the fluid is an ideal gas with specific heats c_v=300 J/kgK, R=700 J/kg K, and c_p=1000 J/kg K. What is Δu for the gas from the inlet to the outlet?

ii) (4 pts) Suppose the fluid is an incompressible liquid with specific heat c=300 J/kgK and inlet density ρ_1=1000 kg/m^3. What is Δh for the liquid from the inlet to the outlet?

b. (5pts) Suppose that we have a cube of ice sitting outside on the ground on a warm (but cloudy) day. The length of one edge of the cube is L=0.5 m. The ice is at 0 ºC and the air is at 30 ºC. If we assume that the main heat transfer mechanism is convection, and that the convection coefficient is h=10 W/m^{2}K, what is the rate of heat transfer from the air to the ice? (You may neglect heat transfer from the cube to the ground.)

c. (4pts) A kitchen range has a broiler rated at 3240 Watts. If it uses 240 Volt AC power and if the power factor for the broiler is 1, how many amps does the range draw when the broiler is on?

d. (4pts) Consider two insulated containers of an ideal gas, as shown below. The container on the left is closed by a piston. When the container is heated, the piston moves up. The container on the right is completely rigid, and is also heated. Both containers have the same mass of gas in them, and at the start both gases are at the same temperature, pressure, and volume. Both containers receive the same heat input.



Which statement about the final temperatures in the two gas containers is true? (Circle one)

i) $T_{left} < T_{right}$

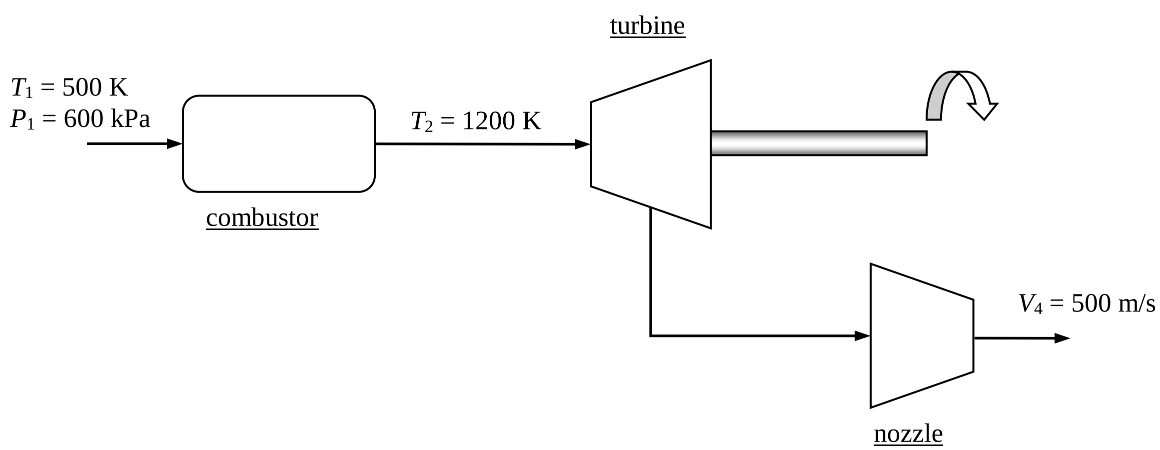
ii) $T_{left} > T_{right}$

iii) $T_{left} = T_{right}$

Problem 2 (39 pts)

In this problem, you will be analyzing the latter half of a jet engine operation which consists of a combustor, a turbine and a nozzle. Compressed air at 600 kPa and 500 K enters the combustor at a mass flow rate of 10 kg/sec. The combustion process can be modeled by a simple heat addition. The inlet temperature to the turbine is 1200 K, limited for metallurgical reasons. The hot gas is partially expanded through the turbine which generates a shaft power output of 2 MW. The gas is further expanded and accelerated through the nozzle to a high speed of 500 m/s at the nozzle exit. You may assume both the turbine and nozzle to be adiabatic and neglect changes in potential energy in your analysis. You may also consider the kinetic energy of the gas to be negligible except at the nozzle exit. Air can be modeled as an ideal gas with specific heats c_v = 0.718 kJ/kg-K, c_p = 1.005 kJ/kg-K.

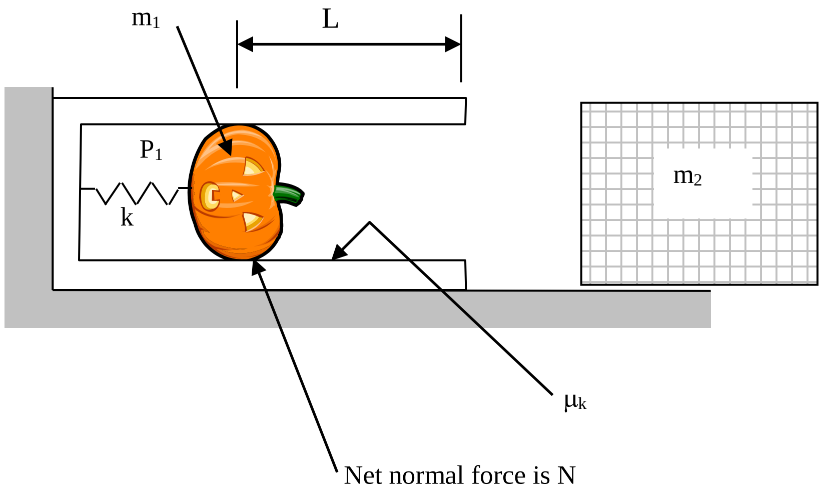
a) What is the heat transfer rate in the combustor in kW?
b) What is the temperature at the turbine exit in K?
c) What is the temperature at the nozzle exit in K?



Problem 3 (40 pts)

A pumpkin, m_1, is launched from a spring-assisted compressed air cannon as shown. Assume that the initial volume behind the pumpkin is $\not{V}_1$, that when the pumpkin exits the volume is $\not{V}_2$,and that the cannon is well insulated. Assume that $P\not{V}^{1.4}$= a constant for this process. When the pumpkin reaches the end of the cannon (i.e. when it has traveled a distance L), the spring will be unstretched and the pumpkin will fly out the end of the tube. You may also assume that the net normal force between the pumpkin and the cannon is a constant and is equal to N. The pumpkin is launched into and impacts a block of mass m_2. The pumpkin does not rebound from the block and the two move to the right together.

Determine the **algebraic** equations necessary to find the velocity of the pumpkin/block just after the impact. You may assume that P_1, $\not{V}_1$, $\not{V}_2$, m_1, m_2, μ_k, k, N, and L are known. Do not solve these equations. Your solution should consist of a list of equations and unknowns.



Length

1 ft = 12 in = 0.3048 m = 1/3 yd

1 m = 100 cm = 1000 mm = 39.37 in = 3.2808 ft

1 mile = 5280 ft = 1609.3 m

Mass

1 kg = 1000 g = 2.2046 lbm

1 lbm = 16 oz = 0.45359 kg

1 slug = 32.174 lbm

Temperature Values

(T/K) = (T/ ºR) / 1.8

(T/K) = (T/ ºC) + 273.15

(T/ºC) = [(T/ ºF) – 32]/1.8

(T/ºR) = 1.8(T/K)

(T/ºR) = (T/ ºF) + 459.67

(T/ ºF) = 1.8(T/ ºC) + 32

Temperature Differences

$(\Delta T/^{o}R) = 1.8(\Delta T / K)$

$(\Delta T/^{o}R) = (\Delta T/^{o}F)$

$(\Delta T / K) = (\Delta T/^{o}C)$

Volume

1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.315 ft^3 = 264.17 gal

1 ft^3 = 1728 in^3 = 7.4805 gal = 0.028317 m^3

1 gal = 0.13368 ft^3 = 0.0037854 m^3

Volumetric Flow Rate

1 m^3/s = 35.315 ft^3/s = 264.17 gal/s

1 ft^3/s = 1.6990 m^3/min = 7.4805 gal/s = 448.83 gal/min

Force

1 N = 1 kg·m/s^2 = 0.22481 lbf

1 lbf = 1 slug·ft/s^2 = 32.174 lbm·ft/s^2 = 4.4482 N

Pressure

1 atm = 101.325 kPa = 1.01325 bar = 14.696 lbf/in^2

1 bar = 100 kPa = 10^5 Pa

1 Pa = 1 N/m^2 = 10^{-3} kPa

1 lbf/in^2 = 6.8947 kPa = 6894.7 N/m^2

[lbf/in^2 often abbreviated as "psi"]

Energy

1 J = 1 N·m

1 kJ = 1000 J = 737.56 ft·lbf = 0.94782 Btu

1 Btu = 1.0551 kJ = 778.17 ft·lbf

1 ft·lbf = 1.3558 J

Energy Transfer Rate

1 kW = 1 kJ/s = 737.56 ft·lbf/s = 1.3410 hp = 0.94782 Btu/s

1 Btu/s = 1.0551 kW = 1.4149 hp = 778.17 ft·lbf/s

1 hp = 550 ft·lbf/s = 0.74571 kW = 0.70679 Btu/s

Specific Energy

1 kJ/kg = 1000 m^2/s^2

1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2