ES201 – Examination III   Winter 2002-2003   Richards

NAME____BOX NUMBER_______________

Problem 1 (30) ________________

Problem 2 (40) ________________

Problem 3 (30) ________________

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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 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.)
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

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

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

$(\Delta T/{}^oR) = (\Delta T/{}^oF)$

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

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

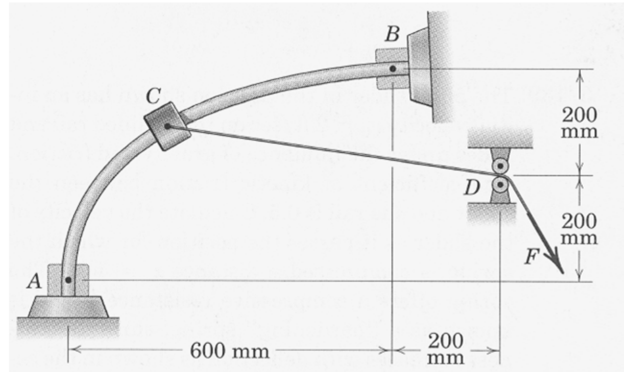
1 Btu/lbm = 25037 ft^2/s^2

1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1 (30 points)

The collar *C* slides on the curved rod in the vertical plane under the action of a constant force *F* in the cord guided by the small pulleys at *D*. The collar has a mass of 0.70 kg and slides without friction.

If the collar is released from rest at *A*, determine the value of the constant force *F* that will result in the collar striking the stop at *B* with a velocity of 4 m/s.



Problem 2 (40 points)

The system shown at right is the back end of a jet aircraft engine. Operating information about the system is shown in the table and figure. Air flows steadily through the system. Assume changes in gravitational potential energy are negligible and air can be modeled as an ideal gas with room temperature specific heats.

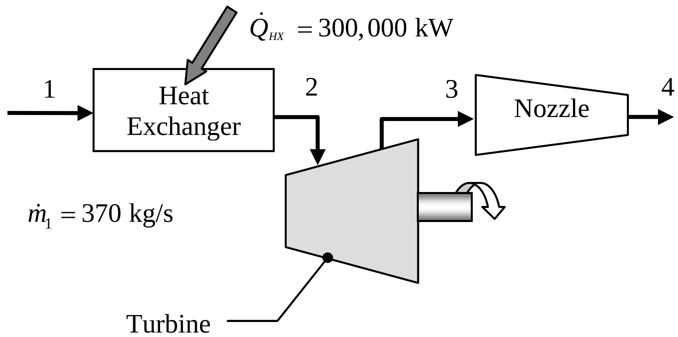
(a) Determine the velocity of the air leaving the nozzle, in m/s.

(b) Determine the cross-sectional area A_c at the nozzle outlet, in m^2

(c) Determine the shaft power out of the turbine, in kW.

State	T (^{o}C)	P(kPa)	V (m/s)	A_c (m^2)
1	600	800	$V_1 \approx V_2$	----
2	???	800	$V_2 \approx V_3$	----
3	1300	600	$V_3 << V_4$	----
4	950	100	???	???

Turbine: steady-state and adiabatic
Nozzle: steady-state and adiabatic
Heat exchanger: steady-state



Problem 3 (30 points)

A well-insulated copper tank of mass 13 kg contains 4 kg of liquid water. Initially, the temperature of the copper is 27°C and the temperature of the water is 50°C. As the tank and its contents come to equilibrium, an electrical resistor of negligible mass transfers 100 kJ of energy to the contents of the tank. Assume copper and liquid water can be modeled as incompressible substances.

(a) Determine the final temperature of the tank and water.

(b) If current through the resistor is 0.5 amps and the applied voltage is 110 volts, determine (i) the electrical power supplied to the resistor and (ii) how long the resistor was "on" to deliver 100 kJ of electrical energy.