ES201 – Examination III Fall 2002-2003 Richards/Berry

NAME____BOX NUMBER______________

Problem 1 (30) ________________

Problem 2 (35) ________________

Problem 3 (35) ________________

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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 (35 points)

Air is contained inside of a piston-cylinder device that also contains an electric resistance heating element (see the figure). The cylinder walls and piston are heavily insulated giving an adiabatic boundary. The air expands from State 1 to State 2 in a constant pressure (isobaric) process.

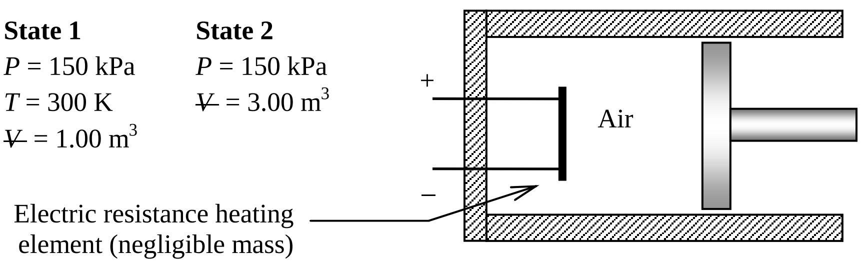
During the expansion process electrical energy is supplied to the resistance heating element. For purposes of this analysis, you may assume that the heating element has negligible mass. Assume that air can be modeled as an **ideal gas** with room temperature specific heats. Also assume changes in kinetic and gravitational potential energy are negligible.

(a) Determine the temperature of the gas in State 2.

(b) Determine the *direction* and *magnitude* of the transfer of energy by electric work for the process, in kJ.

State 1
P = 150 kPa
T = 300 K
V = 1.00 m^3

State 2
P = 150 kPa
V = 3.00 m^3

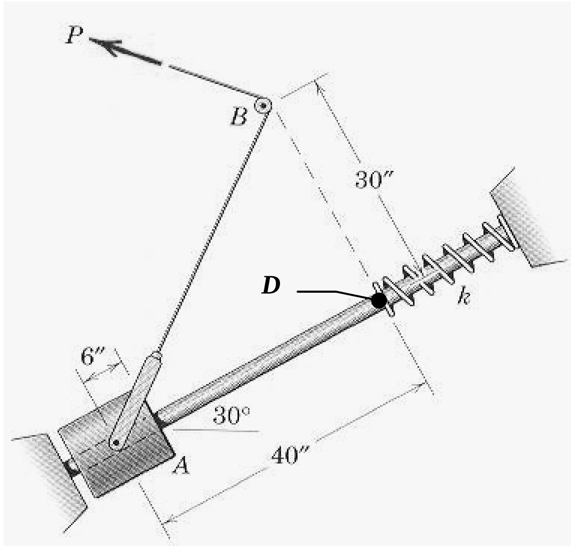


Problem 2 (30 points)

The Collar *A* is released from rest at the position shown in the figure and slides up the fixed rod under the action of a constant force *P* applied to the cable. The rod is inclined at 30^{o} from the horizontal as shown in the figure, and the position of the small pulley *B* is fixed. When the collar has traveled 40 inches along the rod to position *D*, the spring is compressed 6 inches, the cable makes a 90^{o} angle with the rod (see dashed line), and the collar is still moving with an unknown velocity.

The mass of the collar is 30 lbm and the constant force P = 50 lbf. The spring has a stiffness k = 200 lbf/ft. Assume that friction between the collar and rod is negligible.

Determine the speed of the collar, in ft/s, when the collar reaches Point *D*, i.e. the cable is coincident with the dashed line in the figure.



Problem 3 (35 points)

A hydroelectric turbine-generator produces an electric power output of 20 MW (megawatts). Water enters the turbine penstock at Point 1 and exits the turbine at Point 2 as shown in the figure. The known information at the inlet and exit are shown in the figure. The turbine-generator operates adiabatically at steady-state conditions. *Do not neglect kinetic or gravitational potential energy unless you can substantiate your assumption.*

Assume water can be modeled as an **incompressible substance** with room temperature specific heats.

(a) Determine the mass flow rate of the water through the turbine-generator, in kg/s.

(b) If a shaft *inside* the turbine-generator system transmits 22 MW of power at a rotational speed of 100 rpm, determine the torque in the shaft.