ES 201 - Examination 3 Fall 2007-2008

Name ______________________________________ Box Number _______________

Section _______________

Problem 1 (32 points) ________________

Problem 2 (34 points) ________________

Problem 3 (34 points) ________________

____

Total (100 points) ________________

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 IN A SEPARATE DRAWING and show a clear, logical progression from the basic principle(s).**
   - **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 and how you used the given information in the process.
   - **Always crunch numbers last on an exam**. The final numerical answer is worth the least amount of points. (Especially if all we 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 [kg/kmol; lbm/lbmol]	
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

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

$(T/K) = (T/{}^{o}C) + 273.15$

$(T/{}^{o}C) = [(T/{}^{o}F) - 32]/1.8$

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

$(T/{}^{o}R) = (T/{}^{o}F) + 459.67$

$(T/{}^{o}F) = 1.8(T/{}^{o}C) + 32$

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

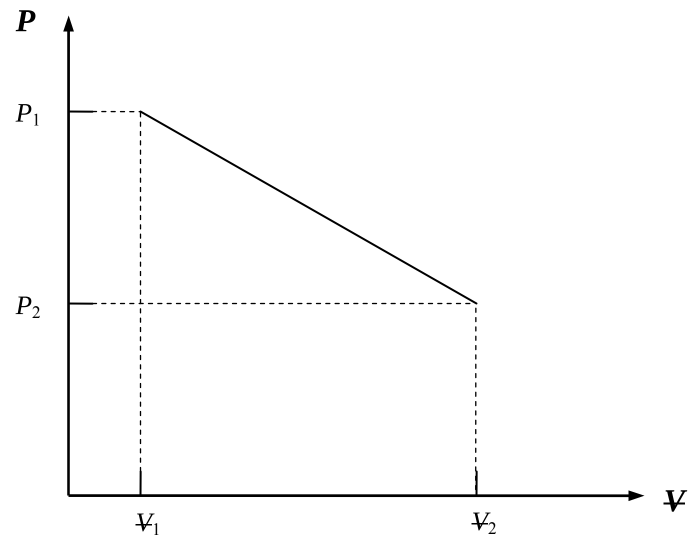
1 kJ/kg = 1000 m^2/s^2

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

1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1 (32 points)

1. (a) (6 points) The pressure-volume relationship for a puffer fish is shown on the diagram below. How much work is done on the gas in going from State 1 to State 2? Express your answer in terms of P_1, P_2, V_1, and V_2.



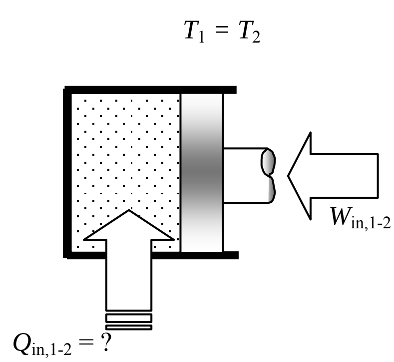
(b) (6 points) An ideal gas contained in a piston cylinder undergoes an **isothermal** process, so that at the end of the process $T_1 = T_2$. Energy in the form of work is added to the system in the amount of $W_{in,1\text{-}2}$, say 30 kJ. The heat transfer $Q_{in,1\text{-}2}$ into the system is

i) zero

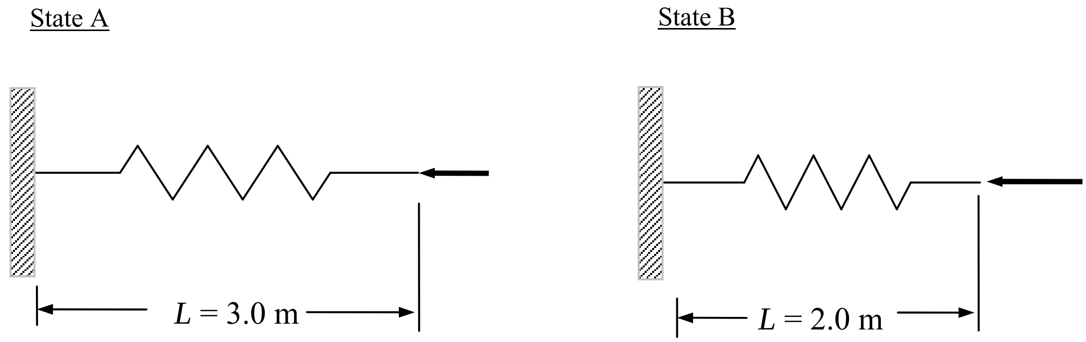
ii) positive

iii) negative

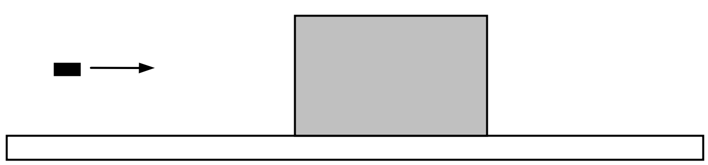
iv) cannot be determined



(c) (6 points) Consider the spring shown below. The unstretched length of the spring is 4.0 m, and the spring constant is 30 N/m. What is the energy required to move the spring from State A to State B?



(d) (6 points) Initially, a stationary wooden block rests on a frictional surface (State A). Suddenly, a fast moving bullet penetrates into the block and is trapped inside (State B). The block (with the bullet inside) slides along the surface until it comes to stop (State C). Circle ***all*** the correct statements below:



i) linear momentum is conserved from State A to State B

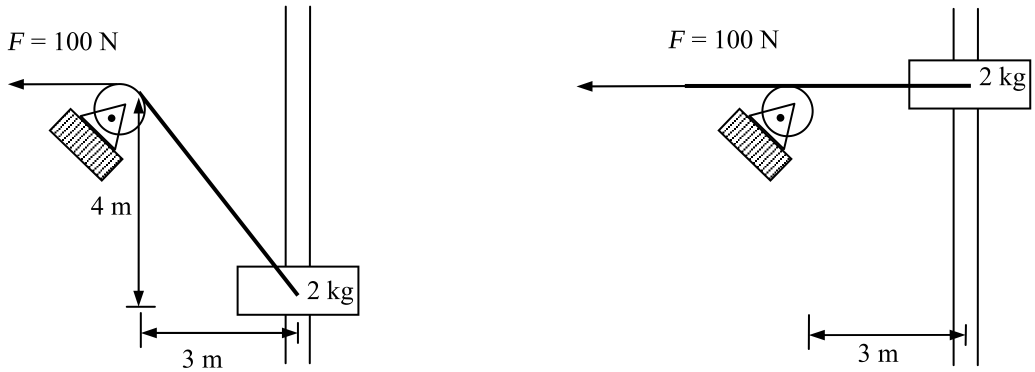
ii) the mechanical energy (work-energy) principle is valid from State A to State B

iii) linear momentum is conserved from State B to State C

iv) the mechanical energy (work-energy) principle is valid from State B to State C

(e) (8 points) A block is pulled up a frictionless pole by a constant external force of 100 N. If the block is stationary in State A, what is the velocity of the block in State B? You may assume that the pulley is frictionless and massless, and that the acceleration due to gravity is 9.8 m/s^2. **Be sure to indicate your system.**

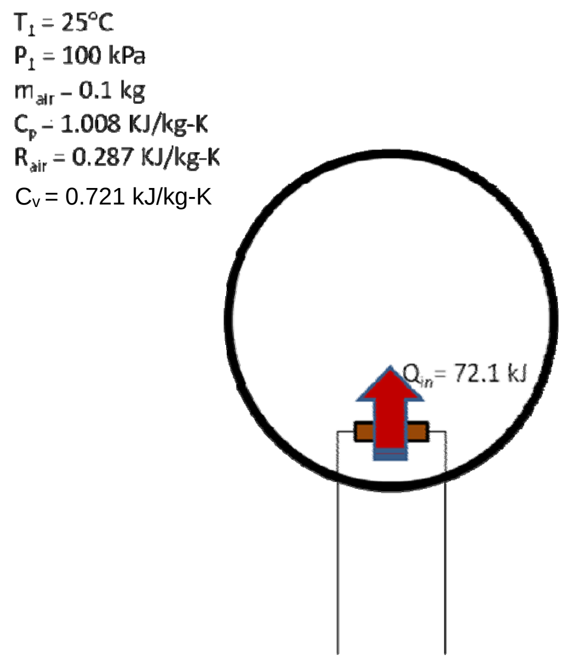
State A　　　　　　　　State B



Problem 2 (34 points)

0.1 kg of air, initially at $T_1 = 25\ ^oC$ and $p_1 = 100$ kPa, is placed inside of a rigid, adiabatic, spherical container. A heating element is used to add 72.1 kJ of thermal energy to the air. Assuming the air to act as an ideal gas with constant properties (given in diagram), determine the following:

(a) the volume of the air inside the container,
(b) the final temperature of the air after the heat addition,
(c) the final pressure of the air after the heat addition.



Problem 3 (34 points)

A model submarine that works on the same principle as seen in *The Hunt for Red October* (a magneto-hydrodynamic drive) is to be tested in a large water tunnel. The sub rests on stationary stand as water at a steady velocity of V_{in} flows into the drive. The outlet temperature of the water is to be limited to ΔT above the inlet temperature. The inlet and outlet areas of the flow channel are shown in the figure.

Modeling the process as adiabatic and assuming water is an incompressible substance with density, ρ, and specific heat, c, find the required power input into the drive.