NAME____BOX NUMBER________________

Problem 1 (30) __________

Problem 2 (35) __________

Problem 3 (35) __________

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 or accounting principles MUST clearly identify the system and show a clear, logical progression from the basic principle(s) to the problem-specific solution.**
   - **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 point/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-^{o}R)	Air	28.97
		= 1.986 Btu/(lbmol-^{o}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

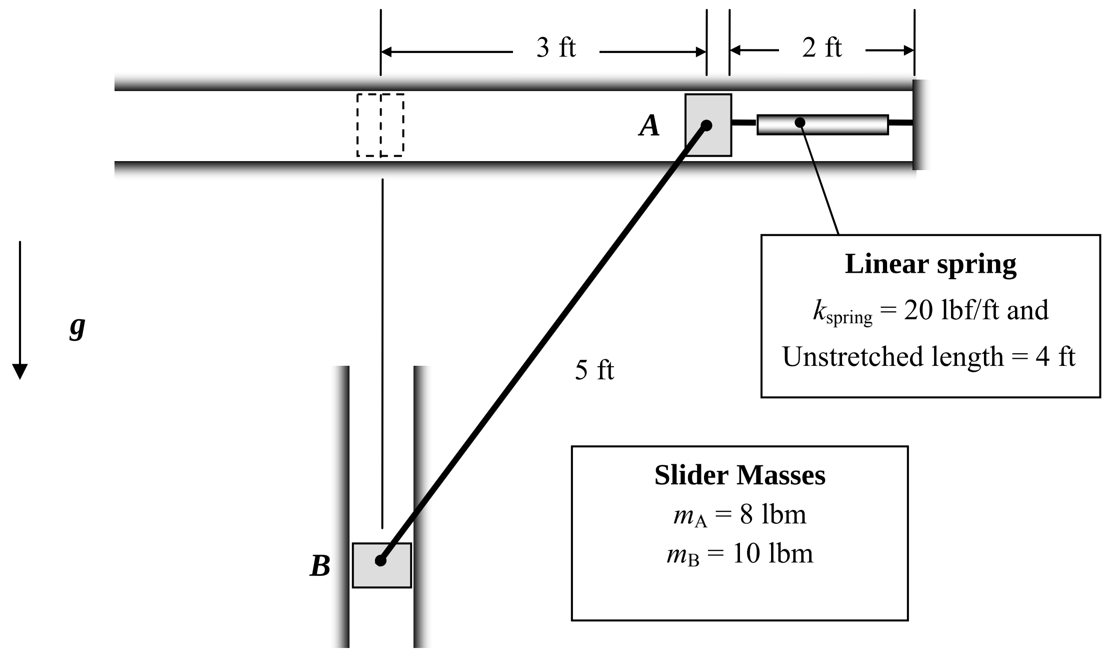
1 ft·lbf /lbm = 32.174 ft^2/s^2

Problem 1 (30 points)

Two slider masses, *A* and *B*, are connected by a massless, rigid link *AB*, and slider *A* is attached to a linear spring as shown in the figure. The slider masses move freely in their guides. The rigid link that connects the sliders is attached by frictionless pin joints and rotates freely.

Initially, slider *A* is held stationary against a spring compressing it 2 ft as shown in the figure. When released, sliders *A* and *B* and the rigid link *AB* are free to move.

Determine the velocity of slider *A* as it crosses the centerline of the vertical slot, in ft/s (See dashed outline of slider *A* in figure.)



Problem 2 (35 points)

Liquid water enters a steady-state, adiabatic pump at 28^{o}C and 100 kPa with a mass flow rate of 100 kg/s and leaves the pump at 28^{o}C and 2 MPa. The inlet area of the pump is 0.04 m^2 and the outlet area of the pump is 0.02 m^3. Changes in elevation are negligible.

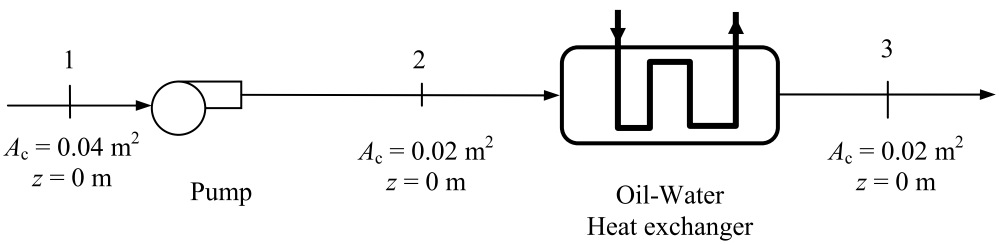
Leaving the pump, the high-pressure water is heated to 200^{o}C by hot oil in an oil-water heat exchanger. The water stream undergoes a negligible pressure drop as it flows through the heat exchanger and remains a liquid throughout the heating process. Inlet and outlet flow areas appear on the figure and changes in elevation are negligible. .

Assume liquid water behaves like an incompressible substance with room-temperature specific heats using the following information: $\rho = 1000$ kg/m^3; $c = 4.18$ kJ/(kg-K) .

Determine:

(a) the power required to operate the pump, in kW.

(b) the heat transfer rate of energy into the water in the heat exchanger, in kW.



Problem 3 (35 points)

The piston cylinder device, shown in the figure, models one cylinder of a large stationary power plant. The system contains air.

During an expansion process where pressure and volume are related by the expression $P{\cdot}V^2$ = Constant, the gas does 18.0 kN·m of work. Additional state information appears with the figure below:

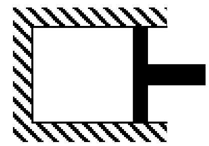
Assume that air behaves like as an ideal gas with contant, room-temperature specific heats using the following information:

R = 0.2870 kJ/(kg K); M_{air} = 28.97 kg/kmol; c_p = 1.005 kJ/(kg K); c_v = 0.718 kJ/(kg K)

State 1: T_1 = 2000 K; V_1 = ?? P_1 = ??; m_1 = 0.04181 kg

Process 1–2: Expansion process with $P{\cdot}V^2$ = Constant
18.0 kN·m work done by gas

State 2: T_2 = ??; $V_2 = 0.05\ m^3$; P_2 = 120 kPa



Determine:

(a) the *magnitude* and *direction* of the heat transfer for the process, in kJ.

(b) the initial volume of the gas, V_1 in m^3.