NAME____		SECTION_______________

BOX NUMBER__________

Problem 1	(XX)	________________

Problem 2	(XX)	________________

Problem 3	(XX)	________________

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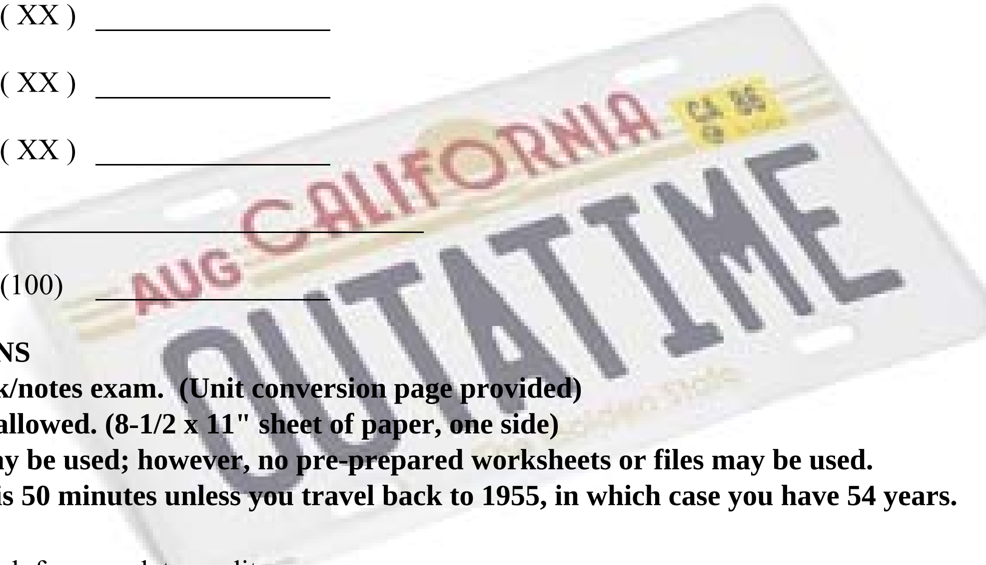
Total	(100)	________________



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.**
- **Time limit is 50 minutes unless you travel back to 1955, in which case you have 54 years.**

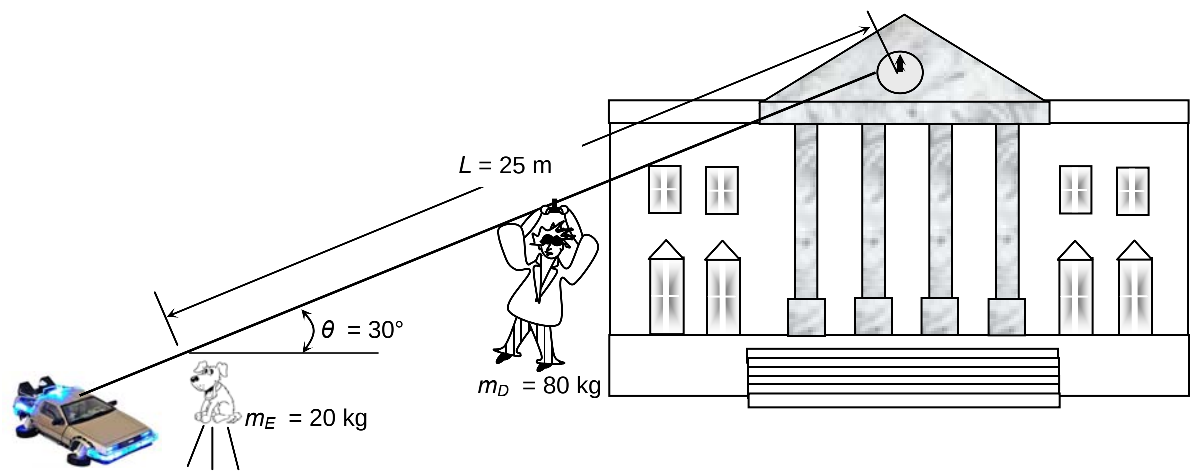
1) Show all work for complete credit.
   - Start all problems at the ANALYSIS stage, but clearly label any information you use for your solution.
   - **Problems involving conservation principles MUST CLEARLY IDENTIFY THE SYSTEM IN A SEPARATE DRAWING and show a clear, logical progression from the basic principle.**
   - 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-^oR)	Air	28.97
		= 1.986 Btu/(lbmol-^oR)	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 (35 pts)

Doc Brown slides down a zip line from the Hill Valley Court house en route to the Delorean Time Machine. Just meters away from the DeLorean, his dog Einstein suddenly jumps up and collides with him, consequently getting caught in his lab coat. Dimensions of the zip line and the masses of Einstein and Doc Brown are given in the figure

a) If Doc Brown starts from rest at the top of the court house and slides along the line 25 meters before running into Einstein, find his speed just prior to colliding with Einstein. Assume the sliding is resisted by a constant friction force of f_{Brake} = 150 N.
b) Find the speed of Doc Brown and Einstein just after they collide. Assume that Einstein's has negligible initial velocity. Assume that collision happens over a very small time.



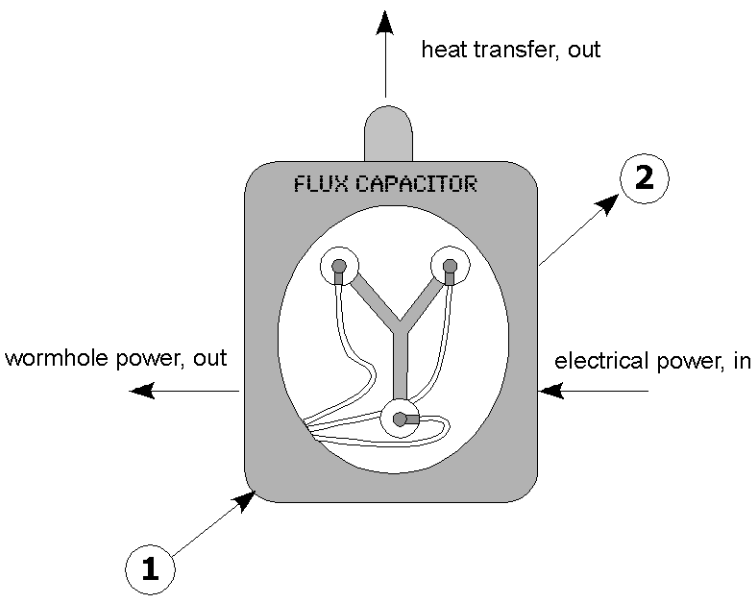
Problem 2 (30 pts)

The flux capacitor in the DeLorean-made-into-a-time-machine requires a total of 1.21 gigaJoules† to run through the 'time travel process' (that is, take the time machine from one time period to another). The 'time travel process' takes a total of 60 seconds to complete and draws constant electrical power. To prevent overheating, a coolant liquid flows through the flux capacitor from point 1 to point 2.

a) Assuming and that the flux capacitor runs steadily through the 'time travel process', and that the power required to create the time-travel wormholes is 20 MW, determine the heat transfer rate from the flux capacitor, given the other parameters as indicated.

b) To avoid overheating the inside of the DeLorean Time Machine, the heat generated by the flux capacitor is dissipated by a heat exchanger on the back of the car. Assuming that the heat transfer rate out of the flux capacitor in part (a) is 40 kW (it isn't, really) and that the surface temperature of the heat exchanger is 70 °C and the surrounding temperature is 10°C, with an heat transfer coefficient of 70 W/m^2-K, what would the required surface area of the heat exchanger (in m^2)?

Note: For the specialized coolant liquid, $c = 12\,{}^{\text{kJ}}\!/\!{}_{\text{kg-K}}$ and $\rho = 1500\,{}^{\text{kg}}\!/\!{}_{\text{m}^3}$



At point 1:

$\dot{m}_1 = 200$ kg/sec

$T_1 = 18°C$

$P_1 = 250$ kPa

$V_1 = 5\,{}^{\text{m}}\!/\!{}_{\text{s}}$

At point 2:

$\dot{m}_2 =$

$T_2 = 45°C$

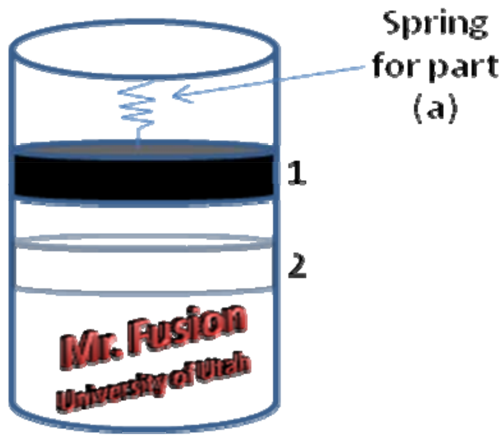
$P_2 = 100$ kPa

$V_2 = 15\,{}^{\text{m}}\!/\!{}_{\text{s}}$

It's worth noting that in his excitement describing the amount of energy needed to run through the 'time travel process', Dr. Emmett Brown accidentally referred to a power (1.21 gigaWatts) and not an amount of energy. We've corrected his misstep in this problem.

Problem 3 (35 pts)

Before going forward to the future, Doc needs to fuel up the time machine with the new "Mr. Fusion" device. It works by creating fusion energy from compressing a gas consisting of a mixture of banana peels, skunky beer, and rotten tomatoes, which behaves as an ideal gas (properties R, c_p, and c_v).



a) In order to activate Mr. Fusion, Doc must compress a spring that will transfer energy to the gas mixture. The spring (with spring constant k) is initially compressed by length x_0 Doc further compresses it to length x_1. Solve for the work, W, that must be done by Doc to compress the spring.

b) The peel/beer/tomato gas is then compressed from state 1 to state 2 with $PV^{1.4}=C$, where C is a constant. Given P_1, V_1, and V_2, find: P_2 and the work done during the compression, W, in terms of the given values (assume that the spring does not interact with this process).

c) If the initial temperature of the gas is T_1, find T_2 and the heat released from the gas in terms of the given values.

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