February 25, 1997
Exam #1

Name:______________________________
KSU ID Number:______________________________

KANSAS STATE UNIVERSITY
Department of Mechanical Engineering
ME-523 Thermodynamics II

INSTRUCTIONS

This is ***closed book, closed notes*** exam. All work must be neat and complete to receive full credit. Show any necessary coordinate systems, control volumes, governing (basic) equation(s), assumptions, and answer ***with units*** labeled clearly. State all numerical answers to three significant figure precision. You will receive ***substantial*** partial credit for correct problem setup.

Begin each problem in the space provided on the examination sheets. If additional space is needed, use the back of the examination sheet, and then, if you need more, the extra paper provided. Use a separate sheet of paper for the continuation of each problem. Write your name on each sheet of paper you plan to turn in at the end of the exam.

Turn in the problem solutions by placing them in the proper stack. Place any continuation sheets behind the examination sheet for each problem. Discard anything you do not want graded.

Exam Performance

Problem 1(40)	
Problem 2(30)	
Problem 3(30)	
Total(100)	

February 25, 1997 Name:______________________________

Exam #1 KSU ID Number:______________________________

Problem 1: (40 points)

A gas turbine receives heated air at 2 MPa, 1400 K at a rate of 6 kg/s. Twenty percent of the air flow is extracted at a midway point through the turbine where the conditions are 1000 K, 450 kPa. The rest of the air leaves the gas turbine at 100 kPa, 800 K. The ambient conditions are 300 K, 100 kPa, and the specific heat of air is 1 kJ/kg-K. The universal gas constant for air is 0.287 kJ/kg-K.

Find: Calculate the actual power, entropy generation, stream availability at each inlet and exit point, the reversible power, and the irreversibility for this process. Except for the availabilities, all your answers should be total quantities (i.e., not per kg or kmole!).

Solution:

February 25, 1997 Name:______________________________
Exam #1 KSU ID Number:______________________________

Problem 2: (30 points)

A 10 kg cube of material is heated by a 1500 K sun lamp at the rate of 20 kW. A tube carrying oil flows through the center of the cube at a rate of 0.1 kg/s. The oil enters the cube at 20°C and leaves the cube at 30°C. Any other heat transfer is with the environment, which is at 300 K, 100 kPa. The specific heat of the material is 0.5 kJ/kg-K and the specific heat of the incompressible oil is 2 kJ/kg-K. This is a steady state process.

Find: Calculate the entropy generation rate and the reversible power for this process.

Solution:

February 25, 1997 Name:______________________________

Exam #1 KSU ID Number:______________________________

Problem 3: (30 points)

A 1 m^3 tank is filled with CO_2 from a high pressure line that is at a constant 1 MPa, 400 K. The tank is initially evacuated, and is filled until the pressure reaches 300 kPa. During the filling process, 300 kJ of heat is transferred from the environment, which is at 300 K, 100 kPa, to the CO_2 in the tank. Use the CO_2 table provided. The molecular weight of CO_2 is 44 kg/kmole.

Find: Calculate the reversible work associated with this process (kJ).

Solution:

Table of CO_2 properties.

T (K)	$\bar{h}$ (kJ/kmole)	$\bar{u}$ (kJ/kmole)	$\bar{s}^0$ (kJ/kmole-K)
300	9431	6939	213.915
400	13372	10046	225.225
500	17678	13521	234.814
520	18576	14253	236.575
540	19485	14996	238.292
560	20407	15751	239.962
580	21337	16515	241.602
600	22280	17291	243.199
620	23231	18076	244.758
630	23709	18471	245.524
640	24190	18869	246.282
650	24674	19270	247.032

Thermo 2 Equation Sheet

$$\frac{dm_{cv}}{dt} = \sum_{in} \dot{m} - \sum_{out} \dot{m} \qquad m_{cv,2} - m_{cv,1} = \sum_{in} m - \sum_{out} m \qquad \dot{m} = \rho VA$$

$$\sum_{i=0}^{n} \dot{Q}_i - \dot{W}_a + \sum_{in} \dot{m}\left(h + \frac{V^2}{2} + gz\right) - \sum_{exit} \dot{m}\left(h + \frac{V^2}{2} + gz\right) = \frac{dE_{cv}}{dt}$$

$$\sum_{i=0}^{n} Q_i - W_a + \sum_{in} m\left(h + \frac{V^2}{2} + gz\right) - \sum_{exit} m\left(h + \frac{V^2}{2} + gz\right) = E_{cv,2} - E_{cv,1}$$

$$\frac{dS_{cv}}{dt} = \dot{\sigma}_{cv} + \sum_{i=o}^{n} \frac{\dot{Q}_i}{T_i} + \sum_{in} \dot{m}s - \sum_{exit} \dot{m}s$$

$$S_{cv,2} - S_{cv,1} = \sigma_{cv} + \sum_{i=o}^{n} \frac{Q_i}{T_i} + \sum_{in} ms - \sum_{exit} ms$$

$$\dot{W}_{rev} = \sum_{in} \dot{m}\left[(h-h_0) - T_0(s-s_0) + \frac{V^2}{2} + g(z-z_0)\right] - \sum_{exit} \dot{m}\left[(h-h_0) - T_0(s-s_0) + \frac{V^2}{2} + g(z-z_0)\right] + \sum_{i=1}^{n} \dot{Q}_i\left(1 - \frac{T_0}{T_i}\right)$$

$$W_{rev} = m_{cv,2}\left[(u-u_0) + p_0(v-v_0) - T_0(s-s_0)\right]_{cv,2} - m_{cv,1}\left[(u-u_0) + p_0(v-v_0) - T_0(s-s_0)\right]_{cv,1} +$$

$$\sum_{in} m\left[(u-u_0) - T_0(s-s_0)\right] - \sum_{exit} m\left[(u-u_0) - T_0(s-s_0)\right] + \sum_{i=1}^{n} Q_i\left(1 - \frac{T_0}{T_i}\right)$$

$$Tds = du + pdv = dh - vdp \qquad h = u + pv$$

$$\Delta s = s_2^0 - s_1^0 - R\ln\left(\frac{p_2}{p_1}\right) \qquad \Delta s = c_p \ln\left(\frac{T_2}{T_1}\right) - R\ln\left(\frac{p_2}{p_1}\right) = c_v \ln\left(\frac{T_2}{T_1}\right) + R\ln\left(\frac{v_2}{v_1}\right)$$

$$\phi = (u-u_0) + p_0(v-v_0) - T_0(s-s_0) \qquad \psi = (h-h_0) - T_0(s-s_0) + \frac{V^2}{2} + g(z-z_0)$$

$$PV = mRT \qquad M = \frac{mass}{moles}$$

$$c_p = \frac{dh}{dT} \qquad c_v = \frac{du}{dT} \qquad c_p - c_v = R \qquad R_u = 8.314 \text{ kJ / kg - K}$$

$$I = W_{rev} - W_{a,u} = T_0\sigma \qquad W_{a,u} = W_a + W_0 \qquad W_0 = p_0(V_1 - V_2)$$