Student Code Number: _____

Ph.D. Qualifying Exam

Thermodynamics

C.W. Somerton and N.T. Wright

Directions: Work all six problems. Problems are equally weighted. Each student is allowed one book and five sheets of notes.

Problem 1

In a jet propulsion cycle, air enters the turbine of isentropic efficiency 0.743 at 1800 K and 800 kPa. The turbine must produce an actual work output of 415.7 kJ/kg. An ideal nozzle follows the turbine and exhausts to a pressure of 82.4 kPa. Determine

a.) the air velocity at the exit of the nozzle (80%)
b.) the irreversibility of the turbine (20%)

Problem 2

Consider a compressor that is being used to fill a gas cylinder of volume 0.11 m^3 with nitrogen, N_2. Nitrogen enters the compressor at 100 kPa and 290 K, and its pressure is increased to 467.8 kPa. The gas cylinder initially contains nitrogen at 100 kPa and 290 K.

(a) Determine the work in kJ required to fill the tank to a pressure of 400 kPa. (60%)

(b) If the final temperature in the tank is 350 K, what is the heat transfer in kJ from the tank during the filling process? (40%)

Problem 3

Blood enters the left ventricle (LV) of the heart from the lungs during diastole. The pressure of the blood from the lungs is 6 mmHg (760 mmHg = 1 atm). During systole, the blood exits the heart at 120 mmHg. The volume of blood in the LV is 80 ml at the start of diastole and 160 ml at the start of systole.

1. Calculate the work done by the LV during 24 hours, if the heat beats 65 times each minute. (75%)
2. Assume that the work done by the heart (left and right ventricles) is 10% greater than that of the LV alone. More over, assume that the heart itself uses 225 ml/min of blood, consuming 65 % of the oxygen in that blood. The blood contains 19.4 ml of oxygen for each 100 ml of blood. Human tissue requires 4.83 kcal for each liter of oxygen consumed (1 cal = 4.186 J). Neglecting heat losses, calculate the first law efficiency of the heart. (25%)

Problem 4

Steam at 14.7 psia and 250°F enters a non-ideal compressor and exits at 160 psia and 400°F. The ambient temperature is 70°F. The work input is claimed to be 120 Btu/lb_m. Determine whether this claim can be correct.

Problem 5

It is desired to provide air for space heating at 25°C and 50% relative humidity. Air is available at 15°C and 30% relative humidity. To achieve the desired air conditioning it is proposed to heat the air with heating coils followed by a water spray at 15°C (evaporative cooler) to obtain the desired exit relative humidity. Determine:

a) the heating requirements (1/3)
b) the air conditions after the heater (1/3)
c) the mass of liquid water required in the evaporative cooler (1/3)

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Problem 6

Bituminous coal has a higher heating value of 32,520 kJ/kg with the following composition by mass %

Combustibles (participate in the chemical reaction)

C: 78.8% H: 5.2% O: 5.8%

Non-Combustibles (do not participate in the chemical reaction)

N: 1.6% H_2O: 2.8% S: 0.7% Ash: 5.1%

The coal is burned with 75% excess air at 350K and 100 kPa. If the combustion products leave at 750 K and 100 kPa, determine

(a) the heat transfer (kJ/kg) (75%)
(b) dew point of the products (25%)