1. (a) What is internal energy? Describe it on a molecular scale. (4%)
   (b) Roughly compare the variations of constant specific heats c_p with respect to temperature for the three gases: Ar, N_2 and NO_2. Also discuss the reasons for their differences. (6%)

2. A closed vessel contains 1 kg of saturated liquid water at 100°C (state 1). The vessel is heated and expands internally reversibly at a constant pressure until the liquid water becomes saturated vapor (state 2) completely.
   (a) Calculate the net heat Q_{12} needed for this process based on the first law of thermodynamics. (8%)
   (b) While the entropy of the saturated liquid water is s_f= 1.3069 kJ/kg K, what is the value of the saturated vapor entropy s_g? (5%)
   (c) What will the net heat Q_{12} and the net work W_{12} become if the process is irreversible? Discuss based on the first law and the second law of thermodynamics. Also discuss the possible reasons for the irreversibilities during this process. (7%)

   Relevant properties are given in the following Table.

TABLE SATURATED WATER—TEMPERATURE TABLE: SI UNITS

		Specific volume, m³/kg			Internal energy, kJ/kg			Enthalpy, kJ/kg		
Temp., °C, T	Press., kPa, P	Sat. liquid, v_f	Evap., v_{fg}	Sat. vapor, v_g	Sat. liquid, u_f	Evap., u_{fg}	Sat. vapor, u_g	Sat. liquid, h_f	Evap., h_{fg}	Sat. vapor, h_g
100	101.32	0.0010434	1.673	1.674	418.96	2087.2	2506.1	419.06	2256.7	2675.7

3. Vapor power cycles
   (a) What four processes make up the simple ideal Rankine cycle? (5%)
   (b) What is an ideal **Reheat** Rankine cycle? Also draw a *T-s* diagram for the ideal reheat Rankine cycle. (5%)

4. Refrigerant-134a enters the compressor of a refrigerator as superheated vapor at 0.14 MPa and -10°C at a rate of 0.05 kg/s and leaves at 0.8 MPa and 50°C. The refrigerant is cooled in the condenser to 26°C and 0.72 MPa and is throttled to 0.15 MPa. Disregarding any heat transfer and pressure drops in the connecting lines between the components,
   (a) draw a *T-s* diagram for the cycle; (5%)
   (b) determine the rate of heat removal from the refrigerated space and the power input to the compressor; (5%)
   (c) determine the adiabatic efficiency of the compressor; (5%)
   (d) and determine the coefficient of performance of the refrigerator. (5%)
   Given the following:
   h_1 = 243.40 kJ/kg at the compressor inlet,
   h_2 = 284.39 kJ/kg at the condenser inlet,
   h_3 = 85.75 kJ/kg at the expansion inlet,
   h_4 = 85.75 kJ/kg at the evaporator inlet.

5. A wide moving belt passes through a container of a viscous liquid. The belt moves vertically upward with a constant velocity, V_0. Because of viscous forces the belt picks up a film of liquid of thickness h. Gravity tends to make the fluid drain down the belt. Determine an expression for the average velocity of the fluid film as it is dragged up the belt. Assume that the flow is laminar, steady and uniform. (20%)

6. (a) Please define the boundary layer thickness (δ), the displacement thickness (δ^*) and the momentum thickness (Θ). (6%)
   (b) For the laminar flow of an incompressible fluid past a flat plate without pressure gradient, please derive the momentum integral equation [$\tau_w = f(\rho, U, \Theta)$]. (7%)
   (c) Consider the laminar flow of an incompressible fluid past a flat plate at $y = 0$. The boundary layer velocity profile is approximated as $u = Uy/\delta$ for $0 \le y \le \delta$ and $u = U$ for $y > \delta$. Determine the expression for shear stress [$\tau_w = f(\rho, \mu, U, x)$] using the momentum integral equation. (7%)