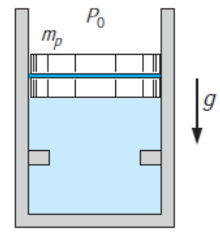
Engineering Thermodynamics **Problem Sheet 2** **First Law for closed systems**

1. 1.5 kg of air can be expanded between two states as it does 31 kJ of work and receives 16 kJ of heat. A second kind of expansion can be found between the same initial and final states, which require a heat input of only 10 kJ. What is the change of specific internal energy in the first expansion? Also, what is the work done during the second expansion?

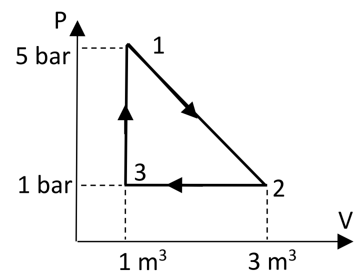
2. A piston-cylinder has 0.5 kg air at 2000 kPa and 1000 K. The Piston has stops so that the minimum volume cannot fall below 0.03 m^3. The air is now cooled to 400 K by heat transfer to the ambient. Find the final volume and pressure of the air. Does it hit the stop? Also find the work done, heat transferred and the change in internal energy in the process. [Ans: W= -83.5 kJ]



3. A vertical piston-cylinder has a linear spring mounted so that at zero cylinder volume, the balancing pressure inside the cylinder is zero. The cylinder is charged with 0.25 kg of air at 500 kPa and 300 K. Heat is now added so that the volume doubles. Show the process on the p-V diagram. Also find (i) the final pressure and temperature, and (ii) the work done and heat transfer. [1 Mpa, 1200 K; W= 32.3, kJ, 193.6 kJ]

4. A quantity of air occupying a volume of 1 m^3 at 4 bar and 150°C is allowed to expand isentropically to 1 bar. Its enthalpy is then raised by 70 kJ by heating at constant pressure. What is the total work done during this process? Assume C_p = 1.005 kJ/kgK for air. If the process is to be replaced by a reversible polytropic expansion which results in the same final state being reached, what index of expansion is required? Neatly draw the processes in p-v plot. Assume γ=1.4 for air.

5. 4 kg of an ideal gas of molecular weight 100 executes an internally reversible cycle as described in the figure. Find, (i) for each process the heat addition, work done and the change in internal energy, (ii) The maximum cycle temperature (iii) the net work done, (iii) Efficiency/ COP of the cycle, and (v) ΔH during process 1 -2. Assume γ=1.5



6. A system consists of 2 kg of carbon dioxide gas initially at state 1, where p_1 = 1 bar, T_1 = 300 K. The system undergoes a power cycle consisting of the following processes: (i) Process 1–2: constant volume to p_2, $p_2 > p_1$, (ii) Process 2–3: expansion with $pv^{1.28}$ = constant, (iii) Process 3–1: constant-pressure compression. Assuming the ideal gas model and neglecting kinetic and potential energy effects, (a) sketch the cycle on a p–v diagram. (b) Plot the thermal efficiency versus p_2/p_1 ranging from 1.05 to 4.

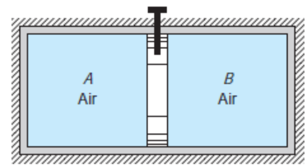
7. 4.4 kg of CO_2 gas is expanded quasi-statically in a piston cylinder device at constant pressure of 1.0 MPa until its volume increases from 0.4 m^3 to 0.8 m^3. Then the piston is pinned (fixed) and the gas is cooled until its pressure drops to half of the initial value. Finally, the gas is compressed quasi-statically following a polytropic process back to the initial state. Find the (i) exponent of the polytrope, and (ii) the work done by the gas during the cycle. Also, identify the process(es) during which heat rejection will take place, and calculate the heat rejection(s). Assume C_p/C_v = 1.26 for CO_2.

8. One kilogram of air, initially at 5 bar, 350 K, and 3 kg of carbon dioxide (CO_2), initially at 2 bar, 450 K, are confined to opposite sides of a rigid, well-insulated container. The partition is free to move and allows conduction from one gas to the other without energy storage in the partition itself. The air and carbon

dioxide each behave as ideal gases. Determine the final equilibrium temperature, in K, and the final pressure, in bar, assuming constant specific heats.

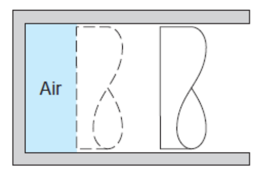
9. A tank has a volume of 1 m^3 with oxygen at 15 °C, 300 kPa. Another tank contains 4 kg oxygen at 60 °C, 500 kPa. The two tanks are connected by a pipe and valve that is opened, allowing the whole system to come to a single equilibrium state with the ambient at 20 °C. Find the final pressure and the heat transfer.

10. An insulated cylinder is divided into two parts of 1 m^3 each by an initially locked piston, as shown in Fig. Side A has air at 200 kPa, 300 K, and side B has air at 1.0 MPa, 1000 K. The piston is now unlocked so that it is free to move, and it conducts heat so that the air comes to a uniform temperature $T_A = T_B$. Find the mass in both A and B and the final T and P. [Ans: 2.32 kg, 3.48 kg; 736 K, 613 kPa]



11. A rigid insulated tank is separated into two rooms by a stiff plate. Room A, of 0.5 m^3, contains air at 250 kPa and 300 K and room B, of 1 m^3, has air at 500 kPa and 1000 K. The plate is removed and the air comes to a uniform state. Find the final pressure and temperature.

12. A piston/cylinder assembly in a car contains 0.2 L of air at 90 kPa and 20◦C, as shown in Figure. The air is compressed in a quasi-equilibrium polytropic process with polytropic exponent n = 1.25 to a final volume six times smaller. Determine the final pressure and temperature, and the heat transfer for the process. Also calculate the specific heat for the polytropic process.



13. An insulated cylinder is divided into two parts. One side of the cylinder contains N_2 gas and the other side contains He gas at different states as shown in the figure. The two chambers are separated by a conducting Copper wall that is held in its position by a pin. Find the final temperature and pressure of each chamber if (a) the copper wall is held in position by the pin, and if (b) the pin is removed. [T_f= 56°C]