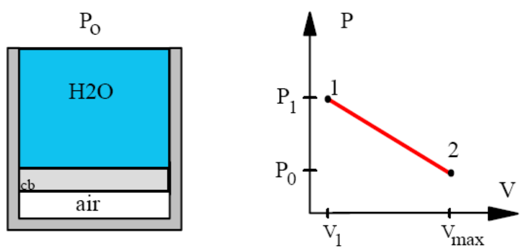
Assignment on Chapter 3

(Note: Answers are given in the square brackets)

1. 2.5 kJ of work must be delivered isobarically on a rod from a piston/cylinder containing air at at 500 kPa. What is value of diameter cylinder needed to restrict the rod motion to maximum 0.5 m? **[0.113 m]**
2. A gas initially at 1 MPa, 500°C is contained in a piston-cylinder arrangement of initial volume of 0.1 m^3. The gas expanded isothermally to a final pressure of 100 kPa. Determine the work. **[230.3 kJ]**
3. A cylinder has 0.1kg of air with a 5 kg piston on top. A valve at the bottom of cylinder is opened to let out the air out and the piston (dia = 2.5cm) drops by 0.25m. What is the work involved in the process? **[– 0.0245kJ]**
4. A chiller cools liquid water (Sp. Ht = 4.2 J/gmK) for air-conditioning purposes. Assume 2.5 kg/s water at 20^oC and 100 kPa is cooled to 5^oC in a chiller. How much heat transfer (kW) is needed? **[156.75 kW]**
5. Helium gas expands from 125 kPa, 350 K and 0.25 m^3 to 100 kPa in a polytropic process with γ = 1.667. How much work does it give out? **[4.09 kJ]**
6. For the following conditions of water determine the state: (i) T=60C; V=5000cm^3/gm (ii) T=60C; V=10000cm^3/gm (iii) T=80C; V=0.5cm^3/gm (iv) T=90C; P= 200kPa (v) P = 100 kPa, T = 150C (vi) U = 2000kJ /kg, T=40C (vii) U = 2500kJ /kg, T=70C (viii) U = 3000kJ /kg, V=240cm^3/gm (ix) H = 3500kJ /kg, V=240cm^3/gm (x) H = 3300kJ /kg, P=1300kPa. *(Use P-V diagrams to arrive at the answer).*
7. A piston-cylinder assembly contains 0.1 kg wet steam of quality 0.75 (X) at 100 kPa. If 150 kJ energy is added as heat while the pressure of the steam is held constant determine the final state of steam and work done by the steam. **[State of steam: Superheated; W = 25.567 kJ]**
8. In a particular engine cylinder one mole of an ideal gas (γ=1.4) is compressed from 25^oC and 0.1 MPa till its volume is reduced to 1/12 of the original value. The process of compression can be approximated to follow the relation $PV^{1.25}$ = constant. Determine the work and heat interactions. Also calculate the final temperature and pressure of the gas. **[T_2 = 554.7 K, Q = -3.201 kJ]**
9. An adiabatic compressor operating under steady-state conditions receives air (ideal gas) at 0.1 MPa and 300 K and discharges at 1 MPa. If the flow rate of air through the compressor is 2 mol/s, determine the power consumption of the compressor. **[16.25 kW]**
10. A rigid and insulated tank of 2 m^3 capacity is divided into two equal compartments by a partition. One compartment contains an ideal gas at 600 K and 1 MPa while the second compartment contains the same gas at 300 K and 0.1 MPa. Determine the final temperature and pressure of the gas in the tank if the partition gets punctured. Assume γ=1.4 for the gas. **[T_f = 550 K, P_f = 0.55 MPa]**
11. A 10 m high cylinder, cross-sectional area 0.1 m^2, has a mass less piston at the bottom with water at 20°C on top of it, shown in figure below. Air at 300 K, volume 0.3 m^3, under the piston is heated so that the piston moves up, spilling all the water out. Find the total heat transfer to the air needed. **[220.7 kJ]**



12. A piston/cylinder contains 0.001 m^3 air at 300 K, 150 kPa. The air is now compressed in a process in which $PV^{12.5}$ = C to a final pressure of 600 kPa. Find the work performed by the air and the heat transfer. **[W = -0.192 kJ, Q = -0.072 kJ]**
13. A nozzle receives 0.1 kg/s steam at 1 MPa, 400^oC with negligible velocity. The exit is at 500 kPa, 350^oC and the flow is adiabatic. Find the nozzle exit velocity and the exit area. **[u_e = 438.7 m/s, A = 1.3 cm^2]**
14. A diffuser has air entering at 100 kPa, 300 K, with a velocity of 200 m/s. The inlet cross-sectional area of the diffuser is 100 mm^2. At the exit, the area is 860 mm^2, and the exit velocity is 20 m/s. Determine the exit pressure and temperature of the air. **[P_e = 123.92 kPa, T_e = 319.74 K]**

15. An exhaust fan in a building should be able to move 2.5 kg/s air at 98 kPa, 20^oC through a 0.4 m diameter vent hole. How high a velocity must it generate and how much power is required to do that? **[V = 17.1 m/s, W = 0.366 kW]**

16. Helium in a steel tank is at 250 kPa, 300 K with a volume of 0.1 m^3. It is used to fill a balloon. When the tank pressure drops to 150 kPa the flow of helium stops by itself. If all the helium still is at 300 K how big a balloon can one get? Assume the pressure in the balloon varies linearly with volume from 100 kPa (V = 0) to the final 150 kPa. How much heat transfer did take place? **[V=0.0667m^3; Q = 13.334 kJ]**

17. In a steam generator, compressed liquid water at 10 MPa, 30°C, enters a 30-mm diameter tube @ 3 L/s. Steam at 9 MPa, 400°C exits a tube of same diameter. Find heat transfer rate to the water. **[8973 kW]**

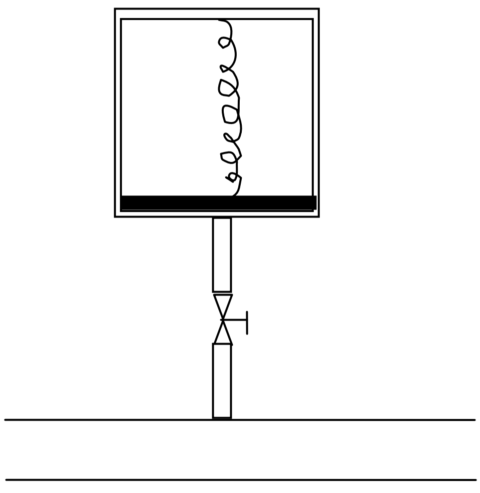
18. An insulated tank of volume 1 m^3 contains saturated steam at 1 bar. This tank is connected to a line carrying superheated steam at 2 MPa and 300^0C and filled to a pressure of 2 MPa. Determine the state and quantity of steam in the tank at the end of the filling operation. **[6.43 kg; P = 2 MPa, T = 418 ^{0}C]**

19. Consider a piston-cylinder containing 0.2m^3 of gas at 0.3MPa. Atmospheric pressure (0.1MPa) and an external spring holds the piston at equilibrium initially. The gas is heated to a state P=0.6MPa, V^t=0.5m^3. Assuming ideal gas, calculate work needed and the potential energy change for the spring. **[0.135MJ]**

20. An insulated piston-cylinder system has air at 400kPa & 500K. Through an inlet pipe to the cylinder air at certain temperature T(K) and pressure P (kPa) is supplied reversibly into the cylinder till the volume of the air in the cylinder is 3 times the initial volume. The expansion occurs isobarically at 400kPa. At the end of the process the air temperature inside the cylinder is 400K. Assume ideal gas behaviour compute the temperature of the air supplied through the inlet pipe. **[91^{0}C]**

21. An adiabatic air compressor takes in air at 25C and 0.1MPa and discharges at 1MPa. If the compressor efficiency is 80% find the exit air temperature, assuming ideal gas behaviour. **[372^{o}C].**

22. An insulated & evacuated tank has a piston and spring as shown in the figure; it is connected to a steam line carrying steam at 2 MPa and 300^0C. Initially the spring is just touching the piston exerting no force. When the valve is opened steam enters the tank till the pressure rises to 2.0 MPa. Determine the state of steam inside the tank. Chose the tank, the piston and spring as the control volume. **[364 ^{0}C]**



Steam: 2 MPa, 300^0C

23. A closed system containing an ideal gas initially at a temperature T_1 is compressed adiabatically till its temperature rises to T_2. At this temperature the gas receives heat Q_2 from a hot reservoir under isothermal conditions. Next it undergoes an adiabatic expansion till its temperature returns to T_1. At this temperature the gas releases Q_1 heat to another reservoir under isothermal conditions so that the gas returns to its initial state. If the efficiency of the cycle is defines as the ratio of the net work output to the net heat absorbed, show that it is = $1 - (T_1/ T_2)$.

24. A cylinder (volume 0.1m^3) contains nitrogen at 14.0MPa and 300K. The cylinder outlet valve develops a minute leak allowing the gas to escape slowly to the ambient atmosphere (pressure = 0.1MPa), till the gas cylinder pressure reduces to 2.0MPa, and a low-pressure alarm fitted to the

cylinder sounds. Determine the amount of gas that escapes the cylinder during the process. For simplification assume ideal gas behaviour and that the gas escaping from the cylinder has a constant temperature of $(T_i + T_f)/2$, where T_i and T_f are the initial and final temperatures of gas within the cylinder. For the gas $\gamma = 1.4$. **[428.5moles]**

25. An insulated gas cylinder containing N_1 moles of gas initially at P_1 and T_1 is filled with the same gas from a high pressure source at a constant pressure P_{in} and temperature T_{in}. Assuming ideal gas behaviour show that at any time during the filling process the cylinder pressure P and the temperature T are related by the following equation form: $P(t)/[\alpha + \beta P(t)] = T$; where $T(^0K)$. Determine the actual expressions for the constants in the above equation. $[\alpha = (P_1/T_1) - (P_1/\gamma T_i); \beta = 1/\gamma T_i]$

26. A water tank of volume $1.0m^3$ (with an inlet and an outlet) contains a substance whose concentration needs to be reduced to 1% of its initial concentration by allowing pure water to flow steadily through the tank. Assuming that the tank water is perfectly mixed, calculate the mass of water that needs to flow through the tank (Sp. Gravity = 1.0). **[4605kg]**