

Thermodynamics

Assignment Set 1. [First law of Thermodynamics]

1. Air at 200kPa, 30°C is contained in a cylinder-piston arrangement with initial volume 0.1m³. The inside pressure balances ambient pressure of 100kPa plus an externally imposed force that is proportional to V^{0.5}. Now heat is transferred to the system to a final pressure of 225kPa. Find the final temperature and work done in the process. **[11.9kJ, 258.9°C]**
2. A certain elastic balloon will support an internal pressure equal to $P_o = 100$ kPa until the balloon becomes spherical at a diameter of $D_o = 1$ m, beyond which $P = P_o + C(1-x^6)x$; $x = D_o/D$ because of the offsetting effects of balloon curvature and elasticity. This balloon contains helium gas at 250 K, 100 kPa, with a 0.4 m³ volume. The balloon is heated until the volume reaches 2 m³. During the process the maximum pressure inside the balloon is 200 kPa. (a). What is the temperature inside the balloon when pressure is maximum? (b) What are the final pressure and temperature inside the balloon? (c) Determine the work and heat transfer for the overall process. (R=2.0770kJ/kgK, $c_v=3.1156$ kJ/kgK). **[1731.25K, 196.15kPa & 2452K, 289.77kJ & 818kJ]**
3. A fluid is confined in a cylinder by a spring-loaded, frictionless piston so that the pressure in the fluid is a linear function of the volume ($p = a + bV$). The internal energy of the fluid is given by the following equation
$$U = 34 + 3.15 pV$$
where U is in kJ, p is in kPa, and V is in cubic meter. If the fluid changes from an initial state of 170 kPa, 0.03 m³ to a final state of 400 kPa, 0.06 m³, with no work other than that done on the piston, find the direction and magnitude of the work and heat transfer. **[8.55kJ, 68.085kJ]**
4. Air expands through a turbine from 10bar, 900K to 1bar, and 500K. The inlet velocity is small compared to the exit velocity of 100m/s. The turbine operates at steady state and develops a power output of 3200kW. Heat transfer between the turbine and its surroundings and potential energy effects are negligible. Calculate the mass flow rate of air, in kg/s and the exit area, in m². Take variable sp. heat of air, $C_p=0.921+2.2 \times 10^{-4}T$ kJ/kgK. **[7.53kg/s, 0.108m²]**
5. The stream of air and gasoline vapour, in the ratio of 14:1 by mass, enters a gasoline engine at a temperature of 30°C and leaves as combustion products at a temperature of 790°C. The engine has a specific fuel consumption of 0.3kg/kWh. The net heat transfer rate from the fuel-air stream to the jacket cooling water and to the surroundings is 35kW. The shaft power delivered by the engine is 26kW. Compute the increase in specific enthalpy of the fuel-air stream, assuming the changes in kinetic and potential energy to be negligible. **[-1877kJ/kg of mixture]**
6. An insulated 1.7m³ rigid tank contains air at 515kPa and 52°C. A valve connected to the tank is now opened, and air is allowed to escape until the pressure inside the tank drops to 206 kPa. The air temperature during this process is maintained constant by an electric resistance heater placed in the tank. Determine the electrical work done during this process. **[-526kJ]**
7. An elastic balloon behaves such that pressure is proportional to diameter and the balloon contains 0.5 kg air at 200 kPa, 30°C. The balloon is momentarily connected to an air line at 400 kPa, 100°C. Air is let in until the volume doubles, during which process there is a heat transfer of 50 kJ out of the balloon. Find the final temperature and the mass of air that enters the balloon. **[318.15K, 0.69kg]**
8. A pressure cylinder of volume V contains air at pressure p_0 and temperature T_0 . It is to be filled from a compressed air line maintained at constant pressure p_1 and temperature T_1 . Show that the temperature of the air in the cylinder after it has been charged to the pressure of the line is given by

$$T = \frac{\gamma T_1}{1 + \frac{p_0}{p_1} \left(\gamma \frac{T_1}{T_0} - 1 \right)}$$
