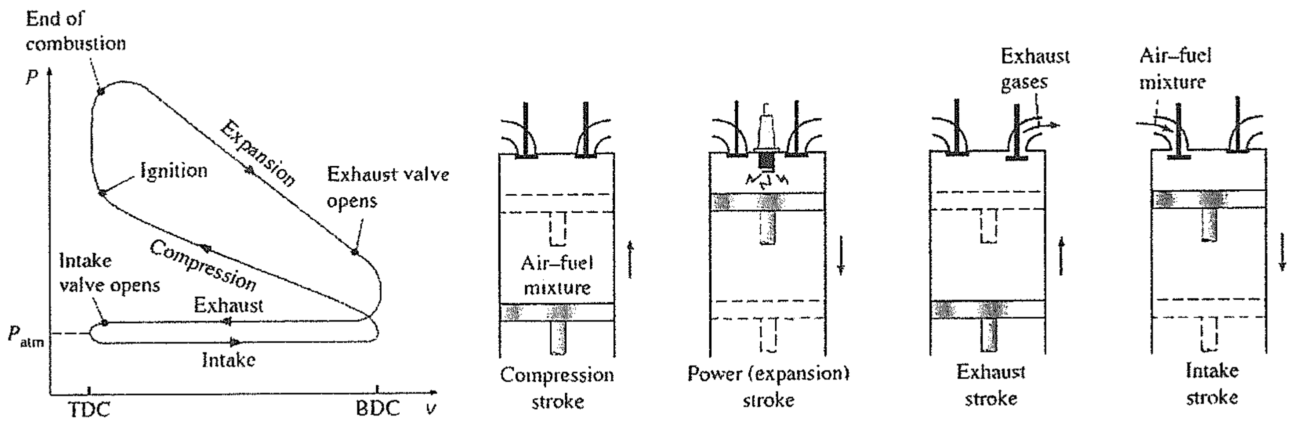
(1) Air is compressed steadily by a reversible compressor from an inlet state of temperature T_1 and pressure P_1 to an exit state of pressure P_2. Let us assume that the gas behaves as an ideal gas, and κ is the specific heat ratio. Determine the compressor work per unit mole for (a) isothermal compression (10%) and (b) isentropic compression (15%).

(2) Steam is leaving a 4-liter pressure cooker whose operating pressure is 150 kPa. It is observed that the amount of liquid in the cooker has decreased by 0.6 liter in 40 minutes after the steady operating conditions are established, and the cross-sectional area of the exit opening is 8 mm^2. Determine (a) the mass flow rate of the steam (10%), (b) the exit velocity (10%), and (c) the flow work per unit mass (5%). At 150 kPa, we know that the specific volume for saturated liquid water and saturated water vapor are $v_f = 0.001053$ m^3/kg and $v_g = 1.1594$ m^3/kg, respectively. The internal energy for saturated liquid water and saturated water vapor are $u_f = 466.97$ kJ/kg and $u_g = 2519.2$ kJ/kg, respectively. The enthalpy for saturated liquid water and saturated water vapor are $h_f = 467.13$ kJ/kg and $h_g = 2693.1$ kJ/kg, respectively.

(3) Heat engines are devices for converting thermal energy to work, and their performance are expressed in terms of thermal efficiency, $\eta_{th} = w_{net} / q_{in}$, where w_{net} is the work done, and q_{in} is the heat input per unit mass of the fluid medium (assumed ideal gas here).

(a) The most effective (also idealized) engine is operated under a Carnot cycle, which consists four processes: (1) Heat addition to the medium at a temperature, T_H; (2) Isentropic expansion of the medium to a lower temperature, T_L; (3) Heat rejection from the medium at temperature T_L; and (4) Isentropic compression of the medium back to temperature T_H. Plot the *T-s* (temperature-entropy) diagram and *p-v* (pressure-volume) diagram of the process, and derive the thermal efficiency. Discuss the assumptions made in the model. (15%)

(b) For the four-stroke spark-ignition engines employed in cars as shown in the figure below, Otto cycle is a more realistic model, with the heat addition and rejection processes at constant temperature in the Carnot cycle replaced by processes at constant volume (heat addition at volume TDC and heat rejection at volume BDC). Plot the *T-s* diagram and *p-v* diagram of the process for the "simplified (simpler than that shown below)" Otto cycle, and derive the thermal efficiency. Discuss the assumptions made in the Otto cycle, and the differences in efficiencies between the Carnot and Otto cycles. (15%)



(a) Actual four-stroke spark-ignition engine

(4) The Gibbs relations read $du = Tds - pdv$ and $dh = Tds + vdp$, where u is the internal energy, h is the enthalpy, T is the temperature, s is the entropy, p is the pressure, and v is the specific volume. In addition, the Helmholtz function $a = u - Ts$ and Gibbs function $g = h - Ts$.

(a) Derive the so-called Maxwell relations: $\left(\frac{\partial T}{\partial v}\right)_s = -\left(\frac{\partial p}{\partial s}\right)_v$, $\left(\frac{\partial T}{\partial p}\right)_s = \left(\frac{\partial v}{\partial s}\right)_p$, $\left(\frac{\partial s}{\partial v}\right)_T = \left(\frac{\partial p}{\partial T}\right)_v$, $\left(\frac{\partial s}{\partial P}\right)_T = -\left(\frac{\partial v}{\partial T}\right)_p$. (10%)

(b) Show that $\frac{p_2}{p_1} = \left(\frac{v_2}{v_1}\right)^{1/\kappa} = \left(\frac{T_2}{T_1}\right)^{\kappa/(\kappa-1)}$ for an isentropic process of an ideal gas relating state 1 and state 2, where κ is the specific heat ratio. (10%)

試題隨卷繳回