JULY 2010

APPLIED HEAT I

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. Air at a pressure of 1 bar and a temperature of 300K is compressed in an engine cylinder from a volume of $0.3m^3$ to a volume of $0.02m^3$. The index of compression is 1.52. Heat is then supplied at constant volume until the pressure is 80 bar.

   (a) Sketch the processes on p-V and T-S diagrams. (4)

   (b) Determine EACH of the following:

   (i) the temperature after compression; (2)

   (ii) the total work transfer; (3)

   (iii) the total heat transfer; (4)

   (iv) the total change in entropy. (3)

   Note: For air, $\gamma = 1.4$ and $R = 0.287$ kJ/kg K.

2. Air enters the compressor of a simple gas turbine plant at a pressure of 1 bar and a temperature of 300K. It is compressed to 6 bar with an isentropic efficiency of 85%. The hot gases leave the combustion chamber at a pressure of 6 bar and a temperature of 1200K, and the turbine exhausts at a pressure of 1 bar and a temperature of 810K.

   (a) Sketch the cycle on the T-s diagram. (3)

   (b) Determine EACH of the following:

   (i) the isentropic efficiency of the turbine; (4)

   (ii) the net work output per kg of gas; (6)

   (iii) the thermal efficiency of the cycle; (3)

   Note: For air, $\gamma = 1.4$ and $c_P = 1.005$kJ/kg K. For hot gas in combustion chamber and turbine, $\gamma = 1.33$ and $c_P = 1.150$kJ/kg K

3. Benzene (C_6H_6) is burned in 20% excess air.

Determine the volumetric analysis of the dry flue gases, given that they contain 2% carbon monoxide by volume. (16)

Note: Relative atomic masses: H = 1; C = 12; N = 14; O = 16
Air contains 21% oxygen by volume.

4. In a regenerative steam power plant, steam enters the turbine at a pressure of 120 bar and a temperature of 520°C. It expands to 0.05 bar with an isentropic efficiency of 80%. Some steam is bled from the turbine at a pressure of 2 bar and supplied to a direct mixing feed heater. There is no undercooling in the condenser, and the feed water leaves the feed heater at the saturation temperature of the bled steam.

(a) Sketch a line diagram of the plant. (3)

(b) On Worksheet Q4, plot the expansion process. To estimate the bled steam condition, it may be assumed that the process line on the h-s chart is straight. (5)

(c) Estimate the thermal efficiency of the cycle. The work required to drive the feed pump may be disregarded. (8)

5. In a two row velocity compounded impulse turbine stage, steam leaves the nozzles with a velocity of 1000m/s at an angle of 18° to the plane of rotation. The mean blade velocity is 200m/s. All the blade rows are symmetrical, and the blade velocity coefficient is 0.9 for both moving rows and for the fixed row.

Determine EACH of the following:

(a) the total blade work per kg of steam; (13)

(b) the diagram efficiency. (3)

6. A vapour compression refrigeration cycle uses R134a and operates between pressures of 2.006 bar and 10.163 bar. The refrigerant enters the compressor as dry saturated vapour and leaves at a temperature of 50°C. The temperature at outlet from the condenser is 35°C.

(a) Sketch the cycle on p-v and T-s diagrams. (6)

(b) Determine EACH of the following:

(i) the coefficient of performance of the cycle; (5)

(ii) the isentropic efficiency of the compressor. (5)

7. A wire of diameter 2mm carries an electric current, and each metre length generates 2 watts of heat. The surrounding air is at 25°C and the surface heat transfer coefficient is 10W/m^2 K.

(a) Determine the temperature of the wire. (5)

(b) Determine the new temperature of the wire if it is covered with insulation 1mm thick and of thermal conductivity 0.1 W/m K. The heat transfer coefficient at the outer surface may be assumed to remain the same. (6)

(c) Comment on the values of temperature obtained in Q7(a) and Q7(b). (5)

8. The free air capacity of a reciprocating air compressor is 15m^3/min. Free air and suction pressure and temperature are respectively 1 bar and 27°C. The delivery pressure is 9 bar. Compression is carried out in two stages with perfect intercooling. The stage pressure ratios are equal. The index of compression and expansion is 1.28.

(a) Sketch the p-V diagram for the compressor. (3)

(b) Determine EACH of the following:

(i) the total indicated power; (6)

(ii) the rate of intercooling; (3)

(iii) the power saved by intercooling. (4)

Note: For air, $R = 0.287$kJ/kg K and $c_P = 1.005$kJ/kg K.

9. (a) Explain the term *choked flow*, with reference to a convergent nozzle. (4)

(b) Air leaks from a pressure vessel to the surroundings which are at a pressure of 1.00 bar. The passage through which the air leaks may be considered as a convergent nozzle with exit area 0.5mm^2, and the flow within the passage may be assumed isentropic. The temperature in the vessel is constant at 25°C.

Determine the mass flow rate when the pressure in the vessel is:

(i) 2.00 bar; (6)

(ii) 1.5 bar. (6)

Note: For air, $\gamma = 1.4$ and $R = 0.287$kJ/kg K

