APPLIED HEAT I   Oct 11.

Attempt SIX questions only.

All questions carry equal marks.

Marks for each part question are shown in brackets.

1. A volume of 0.05 m^3 of a perfect gas for which R = 0.297 kJ/kg K and c_P = 1.04 kJ/kg K is compressed reversibly in a cylinder according to the law $pV^{1.33}$ = constant and then cooled at constant pressure. The initial temperature is 27°C and the final pressure is 8.5 times the initial pressure. The final volume is 0.007 m^3.

   (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 final temperature; (2)

   (iii) the net heat transfer per kg; (5)

   (iv) the net change in specific entropy. (3)

2. (a) Describe how the Morse Test is used to estimate the indicated power of a multi-cylinder engine. (4)

   (b) State ONE reason why the Morse Test may be less accurate than using engine indicators. (2)

   (c) A four cylinder two-stroke CI engine is run under test at a steady speed of 450 rev/min and delivers a brake torque of 12 kNm. The following measurements were then made with the engine running at 450 rev/min:

fuel shut off from cylinder No. 1	brake torque = 8.5 kNm
fuel shut off from cylinder No. 2	brake torque = 8.3 kNm
fuel shut off from cylinder No. 3	brake torque = 8.4 kNm
fuel shut off from cylinder No. 4	brake torque = 8.7 kNm

   Determine EACH of the following:

   (i) the brake power; (2)

   (ii) the indicated power; (3)

   (iii) the bore and stroke of each cylinder, given that the stroke/bore ratio is 1.2 and the indicated mean effective pressure in cylinder No. 1 is 7.6 bar. (5)

3. The mass analysis of a fuel is: carbon 80%; hydrogen 17%; sulphur 2.1%; water 3% (remainder ash).

Determine EACH of the following:

(a) the theoretical air/fuel ratio by mass; (6)

(b) the volumetric analysis of the dry products (ie excluding H_2O and soluble SO_2) when the fuel is burned completely in 25% excess air; (6)

(c) the dew point temperature of the combustion products if the total pressure is 1.01 bar. (4)

Note: atomic mass relationships: H = 1; C = 12; O = 16; N = 14; S = 32
Air contains 21% oxygen by volume and 23.3% oxygen by mass.

4. A gas turbine plant operates on the ideal air standard Joule cycle. The maximum temperature and pressure are 1200 K and 6 bar respectively. The minimum temperature and pressure are 300 K and 1 bar respectively.

The turbine exhaust passes through a heat exchanger and supplies heat to an ideal Rankine cycle steam plant which operates between pressures of 40 bar and 0.1 bar. The steam leaves the heat exchanger dry and saturated. The exhaust gas leaves the heat exchanger at the saturation temperature of the evaporating steam. Feed pump work in the Rankine cycle plant may be disregarded.

Determine EACH of the following:

(a) the mass of steam per kg of air; (6)

(b) the thermal efficiency of the combined plant. (10)

Note: For air, $\gamma = 1.4$ *and* $c_p = 1.005$ *kJ/kg K.*

5. (a) Define the term *degree of reaction* relating to a turbine stage. (2)

(b) In a 50% reaction turbine stage the steam leaves the fixed blades with a velocity of 300 m/s. The blade ring diameter is 0.8 m and the speed of rotation is 6000 rev/min. The blade inlet angle is 72°.

Determine EACH of the following:

(i) the blade outlet angle; (5)

(ii) the blade work per kg; (3)

(iii) the diagram efficiency. (6)

6. A heat pump cycle using Refrigerant R134a operates between pressures of 3.4966 bar and 32.433 bar. The refrigerant enters the compressor at a temperature of 8°C and leaves the condenser at a temperature of 85°C. The temperature at compressor outlet is 110°C.

(a) Sketch the cycle on p-h and T-s diagrams. (5)

(b) Determine the coefficient of performance of the cycle. (6)

(c) Determine the isentropic efficiency of the compressor. (5)

7. Wet steam at a pressure of 14.0 bar flows in a 6 m long pipe of inside diameter 40 mm and wall thickness 4 mm. The pipe is surrounded with a layer of lagging 20 mm thick. The thermal conductivity of the lagging is 0.045 W/m K and the outside surface heat transfer coefficient is 15 W/m^2 K. The outside air temperature is 21°C. The thermal resistances of the steam film and of the pipe wall may be disregarded.

Determine EACH of the following:

(a) the rate of heat loss; (7)

(b) the outside surface temperature of the lagging; (3)

(c) the increase in the rate of heat loss which would result if the thickness of the lagging were reduced to 10 mm. (6)

8. A single stage, single acting air compressor is used to charge a large air bottle. The bore diameter is 850 mm and the stroke length is 1000 mm. The clearance volume is 0.05 m^3 and the index of compression and expansion is 1.31. The mechanical efficiency is 89%. Suction pressure and temperature are 1.02 bar and 27°C respectively. The compressor runs at 200 rev/min.

(a) Determine, for a delivery pressure of 8 bar, EACH of the following:

(i) the power input required; (7)

(ii) the rate of jacket cooling. (3)

(b) Explain why the mass flow rate of air alters as the delivery pressure rises. (2)

(c) Determine the maximum delivery pressure which this compressor can achieve from the given suction conditions. (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 large 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 0.5 mm^2, and the flow within the passage may be assumed isentropic. The temperature in the vessel may be assumed constant at 28°C.

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

(i) 2.5 bar; (6)

(ii) 1.5 bar. (6)

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

$$p_c = p_0 \times \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)} ; \qquad a = \sqrt{\gamma R T}$$