Problems

09/12/2020

Question 1

Air at a pressure of P_1 and temperature of 25 °C is contained in a gas tight frictionless piston cylinder device. The initial volume that the air occupies at the initial state is $V_1 = 0.8\ m^3$. In an isochoric process the air is heated up to 500 K. If the mass of air in the cylinder is 5.2 kg (assume Rair = 0.287 kJ/kg.K).

A) Calculate the initial pressure, P_1 *(Answer: 5.56 bar)*

B) Calculate the final pressure, P_2 *(Answer: 9.33 bar)*

C) Find the work done in the process *(Answer: 0 Joule)*

Question 2

In a piston/cylinder device during a polytropic process, piston load is increased at such a rate that the gas compresses according to the relationship:

$$PV^{1.2} = constant$$

At the end of the process the final temperature of the gas is 400°C.

The initial state of the gas is

$$P_1 = 400 \text{ kPa}$$

$$T_1 = 110°C$$

$$V_1 = 0.3 \text{ m}^3$$

Determine the work done during the process.

Question 3

A gas undergoes two processes. First: constant volume @ 0.200 m^3, isochoric. Pressure increases from 2.00 × 105 Pa to 5.00 × 10^5 Pa. Second: Constant pressure @ 5.00 × 10^5 Pa, isobaric. Volume compressed from 0.200 m^3 to 0.120 m^3.

A) Show both processes in a pV diagram:

B) Calculate the work done during both the processes and the total work

(Answer: 0 Joule, -4 10^4 Joule, -4 10^4 Joule)

Question 1

A household fridge with a COP of 1.4 removes heat from the fridge space at a rate of 85 kJ/min.

(a) Sketch the basic components of a refrigeration system.

(b) Calculate the electric power consumed by the fridge.

(c) Calculate the rate of heat transfer to the kitchen air.

Anws b) 60.7 kJ/min, c) 145.7 kJ/min

Question 2

A household fridge that has a power input of 450W and a COP of 2.5 is to cool five large water melons, 10kg each to 8˚C. If the watermelons are initially at 20˚C determine how long it will take for the fridge to cool them? The watermelons can be treated as water whose specific heat is 4.2 kJ/kg.K.

Answer: 37.3 min

Question 3

An inventor claims to have developed a heat engine that receives 700kJ of heat from a source at 500K and produces 300kJ of net work while rejecting the waste heat to a sink at 290K? Is this a reasonable claim?

Answer: False

Question 4

A geothermal power plant uses geothermal water extracted at 160˚C at a rate of 440kg/s as the heat source and produces 22MW of net power. If the environment temperature is 25˚C, determine:

$$\left.\begin{array}{l} T_{source} = 160°C \\ x_{source} = 0 \end{array}\right\} h_{source} = 675.47 \text{ kJ/kg}$$

$$\left.\begin{array}{l} T_{sink} = 25°C \\ x_{sink} = 0 \end{array}\right\} h_{sink} = 104.83 \text{ kJ/kg}$$

a. The actual thermal efficiency

b. The maximum possible thermal efficiency

c. The actual rate of heat rejection from this power plant

Answer: a) 8.8% b) 31.2 % c) 229.1 MW

Question 5

The performance of a heat pump degrades (i.e. its COP decrease) as the temperature of the heat source decreases. This makes using heat pumps at locations with severe weather conditions unattractive. Consider a house that is heated and maintained at 20˚C by a heat pump during the winter. What is the maximum COP for this heat pump if heat is extracted from the outdoor air at

a. 10˚C,

b. -5˚C

c. -30˚C?

Answer: a) 29.3 b) 11.7 c) 5.86