Problems completed by Levi Lentz

Problem 4-4

3

1

2

Water

The diameters of the ports in the accompanying figures are 10 cm, 5 cm, and 1 cm at port 1, 2, and 3 respectively. At a given instant, water enters the tank at port 1 with a velocity of 2 m/s and leaves through port 2 with a velocity of 1 m/s. Assuming air in insoluble in water, determine(a) the mass flow rate of water in kg/s at the inlet (b) at the exit and (c) the rate at which water accumulates in the tank in kg/s. (d) Determine the mass flow rate of air in kg/s coming out of port 3. (e) Determine the velocity of air in m/s at port 3.

Solution Balance the mass-flow equations for an unsteady system.

Assumptions Density of water and air to remain constant at 1000 kg/3 and 1 kg/m3 respectively, the water and air do no mix.

Analysis Since the water and air do not mix, we can find the mass flow for the water. This can then be converted into volume flow. Since the volume of the tank is constant, the volume flow of the water must equal the volume flow of the air.

Since the volume of the tank is constant, this must also be the rate that air is expelled:

Given

Problem 36

A rigid chamber contains 100 kg of water at 500 kPa, 100oC. A paddle wheel stirs the water at 1000 rpm with a torque of 100 N.m. while an internal electrical resistance heater heats the water, consuming 10 amps of current at 110 Volts. Because of thin insulation, the chamber loses heat to the surroundings at 27oC at a rate of 1.2 kW. Determine (a) the rate of shaft work transfer in kW, (b) the electrical work transfer in kJ in 10 s, (c) what must be the rate of heat transfer in kW so that the system does not receive or lose any net energy? (You must include sign).

Solution Find work transfer across the boundary

Assumptions The volume of the chamber remains constant, the work transfer remains constant as stated.

Analysis Since the energy transfer due to the shaft and electrical work are independent of the heat transfer as well as the heat loss to the environment, we can find these to solve for (c).

(a)

With sign

(b)

With sign

(c)

Energy coming in by work:

+1.1 = 11.57kW

Problem 37

An insulated piston-cylinder device contains steam at 300 kPa, 200 deg-C, occupying a volume of 1 m3, and having a specific volume of 0.716 m3/kg. It is heated by an internal electrical heater until the volume of steam doubles due to an increase in temperature. (a) Determine the final specific volume of steam in m3/kg. (b) If the diameter of the piston is 20 cm and the outside pressure is 100 kPa, determine the mass of the weight placed on the piston to maintain a 300 kPa internal pressure. (c) Calculate the boundary work (magnitude only) done by the steam in kJ. (d) Calculate the amount of work (magnitude only) transferred into the weight in kJ. (e) If you are asked to choose one of the three values - 1300 kJ, 300 kJ, 200 kJ - as your guess for the magnitude of the electrical work transfer, which one will you pick? (enter magnitude only).

100kPa

Steam

Solution Use the free body diagram and accompanying information to deduce the formulas required for a-e

Assumptions No heat is lost to the surroundings due to the insulation and the mass of the system is constant

Analysis The solutions can be determined by examining the free body diagram of the piston

a)

Final Volume = and

b)

mg/1000

From the free body diagram of the piston:

c)

b

f

*P*

*~~V~~*

d)

The weight is displaced upward by a distance of

The work done:

e)

Since the steam temperature increases, it must be receiving more energy from the heater than it is delivering through work (300kJ). So my pick is 1300kJ

Problem 33

O2 : 2kg

H2 : 2 kmol

A chamber contains a mixture of 2 kg of oxygen and 2 kmol of hydrogen. (a) Determine the average molar mass of the mixture in kg/kmol. (b) If the specific volume of the mixture is 2 m3/kg, determine the volume of the chamber in m3.

Solution Use the relationship between molar mass to convert the given measurements to a single mass

Assumptions The mass and volume of the system remain unchanged

Analysis From the chemical definition of oxygen gas and hydrogen gas, we can determine the mass of the system.

Mass of O2 = 2 kg

Mole of O2 =

Mole of H2 = 2 kmol

Mass of H2:

For the mixture:

a)

b)

Since:

Problem 34

The nutrition label on a granola bar, which costs $1.00, reads - Serving size 42 g; Calories Per Serving 180. Determine (a) the heating value in MJ/kg, and (b) price in cents per MJ of heat release. (c) If gasoline with a heating value of 44 MJ/kg and a density of 750 kg/m3 costs $2.50 a gallon, what is the gasoline price in cents/MJ?

Solution Use the definition of heating value as well as fluids definitions to obtain the proper units.

Assumptions The values are not changing with time

Analysis We must use our intuition to determine the proper values, using mainly unit analysis

Heat released from kJ

a)

Heating Value =

b)

Heat released from a bar

Price per MJ:

c)

Mass of a gallon:

Problem 35

(a) What is a system with no mass transfer called?

(b) What is a system with no heat transfer called?

(c) What is a system with no mass or energy transfer called?

Solution Use the generic system diagram with the definition of thermodynamics terms to solve the problem

Assumptions The system is at steady state

a)

No mass transfer:

b)

No heat transfer:

c)

No mass or heat transfer:

Problem 38

Betz law states that only 53% of the kinetic energy transported by wind can be converted to shaft work by a perfect wind turbine. For a 50 m diameter turbine in a 20 mph wind, determine (a) the mass flow rate of air (in kg/s) intercepted by the turbine? (b) the specific kinetic energy of the flow (in kJ/kg), (c) the rate of transport of kinetic energy (kW), and (d) the maximum possible shaft power? Assume density of air as 1.1 kg/m3. (1 mph = 0.447 m/s).

Solution Use thermodynamic principles along with the given information to solve the problem

Assumptions The air velocity is not changing with time and the system is at steady state.

Analysis We must us the energy equations to convert the winds energy to shaft work using Benz’ law.

a)

b)

c)

d)

Since there only energy available to the shaft is the , the shaft work can be solved as follows:

Problem 39

A closed system interacts with its surroundings and the following data are supplied: Wdot\_sh= -10 kW, Wdot\_el = 5 kW, Qdot = -5 kW. If there are no other interactions, determine dE/dt.

Solution Use the energy balance equation with the proper sign convention to solve for dE/dt.

Assumptions As we are solving for dE/dt, we cannot assume it is steady or unsteady; because of this, the only assumption we can make is that we are solving the problem at this instance.

Analysis We will simply solve the energy balance equation

Since there is no other interactions, this implies that it is a closed system:

Problem 40

100kPa

200kPa

A gas trapped in a piston-cylinder device is heated as shown in figure. The load on the massless piston of area 0.2 m2 is such that the initial pressure of the gas is 200 kPa while the outside pressure is 100 kPa. Also, the initial temperature is 300 K. When the temperature of the gas reaches 600 K, the piston velocity is measured as 0.5 m/s and dE/dt is measured as 30 kW. At that instant, determine (a) the rate of boundary work transfer, (b) the rate of external work transfer, (c)the rate of heat transfer, and (d) the load (in kg) mass on the piston. Assume the ambient atmospheric pressure to be 100 kPa. (e) What type of system is this?

Solution We will use the energy balance equation along with the thermodynamic definition of work to solve the problem

Assumptions We are solving this problem for this instance only, every instance will have a different solution. The pressure inside the piston will not chance due to the equilibrium condition.

Analysis The piston will have the heat going into the system while performing boundary work as well as work to raise the mass.

We first need to determine the :

a)

b)

Since is the only work the system is doing

c)

The rate of heat transfer can be determined from the energy balance equation:

d)

mg/1000

From the force-balance equation:

e)

Problem 41

A rigid cylindrical tank stores 100 kg of a substance at 500 kPa and 500 K while the outside temperature is 300 K. A paddle wheel stirs the system transferring shaft work at a rate of 0.5 kW. At the same time an internal electrical resistance heater transfers electricity at the rate of 1 kW. (a) Do an energy analysis to determine the rate of heat transfer Qdot in kW for the tank. (b) Determine the absolute value of the rate at which entropy leaves the internal system (see attached diagram). (c) Determine the rate of entropy generation for the system's universe.

*m=*100*kg*

*T=*500*K*

*P=*500*kPa*

Solution Use the thermodynamic definitions to analyze the system

Assumptions Due to the way the system is setup, the tank can be assumed to be operating at steady-state. Since it is a ridged tank, there is also no mass transfer.

Analysis we will use the energy balance equation as well as the entropy balance equation to determine the numerical values.

a)

Since there is no mass transfer:

b)

c)

The rate of entropy generation in the systems universe will be when the heat reaches the ambient boundary:

Problem 42

A horizontal piston-cylinder device contains air at 90 kPa while the outside pressure is 100 kPa. This is made possible by pulling the piston with a hanging weight through a string and pulley arrangement. If the piston has a diameter of 20 cm, (a) determine the mass of the hanging weight in kg. (b) The gas is now heated using an electrical heater and the piston moves out by a distance of 20 cm. Determine the boundary work in kJ. (c) What fraction of the boundary work performed by the gas goes into the hanging weight?

Solution Use force balance equation to determine the mass of the weight and the definition of boundary work to determine the work done.

Assumptions The pressure in the piston remains constant and there is no mass transfer.

Analysis The problem has given us enough information to solve all required inputs in one step each.

a)

From the force balance equation:

mg/1000

b)

Since the internal pressure is not changing:

Since it is being done by the system:

c)

Since gravity is supplying the force on the weight, the boundary work is not going into the weight

Problem 43

Simplified view of our turbine:

Steam flows into a steady adiabatic turbine at 10 MPa, 600°C and leaves at 58 kPa and 90% quality. The mass flow rate is 9 kg/s. Additional properties at the exit that are known are: A = 1.143 m2, v = 2.54 m3/kg, u = 2275.2 kJ/kg, e= 2275.4 kJ/kg, h=2422.4 kJ/kg. If the turbine produces 1203 kW of shaft power, determine at the exit (a) the velocity in m/s. (b) the rate of flow of kinetic energy, (c) the rate of transfer of stored energy, and (d) the rate of transfer of flow energy. Neglect potential energy.

Solution Apply thermodynamic equations to the given properties to determine the given values

Assumptions The turbine is operating at steady state and we can assume the given values to be constant and not changing with time. The turbine is also not losing heat to the environment.

Analysis After drawing a free-body diagram, we can determine the numerical solutions for the problem.

a)

b)

c)

d)

Test 1-3

*T*=300K

*T*=400K

An electric motor, operating at steady state, produces 100 kW of shaft output while consuming electricity at the rate of 120 kW. (a) Determine Qdot (include sign). (b) The rate at which entropy enters the surroundings (in kW/K) if the motor surface temperature is 400 K and the ambient temperature is 300 K. (c) Determine the rate at which entropy is generated (in kW/K) in the system's universe. (d) What is the energetic efficiency of the motor (in percent)?

Solution Balance thermodynamic equations for a steady system

Assumptions Since we would not design a motor to work unsteady, the system is assumed to be steady

Analysis We are given enough information to solve the energy and entropy balance equations since it is operating at steady-state.

a)

b)

Since we are looking for the entropy entering the surrondings, we need the temp of the surroundings to find the entropy.

c)

Once again, since we are looking for the entropy generation in the universe, T=300K:

d)

Test 1-4

300K

300K

2000K

200K

A heat engine with a 40% thermal efficiency operate between a 2000 K reservoir and atmosphere at 300 K. The output of the engine is used by a refrigeration system with a COP of 2, which operates between the atmosphere and a 200 K cold storage. Determine the cooling load ( in kW) of the refrigerator if 50 kW of heat is supplied to the heat engine.

Solution Use the efficiency equations to solve for the heat transferred from the cold side of the refrigeration cycle.

Assumptions Both engines are operating at steady state and all losses are accounted for.

Analysis Since we know the efficiency for the heat engine and the COP of the refrigeration engine, we do not need to employ the energy equations.

For the heat engine:

For the refrigeration engine:

Test 1-8

A piston inside a rigid cylinder, closed at both ends, separates two chambers: one contains a two-phase mixture of H2O and the other contains a two-phase mixture of R-134a. If the temperature inside the chamber containing H2O is 85.9 C, determine the temperature inside the other chamber.

H2O

R-134a

Solution Use the equilibrium conditions to find the temperature of the R-134a chamber

Assumptions Each side of the piston is isolated from the other so no heat is transferred across the boundary or to the surroundings. Since it is in equilibrium, the pressures on either side are equal.

Analysis Since both sides are said to be a two-phase mixture, this implies that both sides are between their respective f- and g-points.

Since we know the temperature of the H2O side, we need to determine the pressure of the H2O using the Saturation Table:

This will be the saturation pressure of R-134a, which will yield the saturation temperature from the Saturation Table: