Problems- 4

4.1 Steam enters a turbine at 600kPa and 500°C with velocity of 130m/sec, and leaves as saturated vapor at 0.05MPa. the turbine pipe has a diameter of 0.6m and the outlet diameter is 3.5m. Determine (a) the flow rate in kg/hr, and (b) the exit velocity in m/sec.

4.2 Steam at a rate of 48000kg/h leaves a device at 10kPa and 90% quality. Calculate the area of the exit in square meters for a mean velocity of 160m/sec.

4.3 Steam enters a turbine at 3MPa pressure 450°C, at a velocity of 100m/sec and through an area of 0.05m^2. it expands to a pressure of 20kPa, a quality of 90%, and a velocity of 200m/sec. Determine (a) the mass flow rate through the turbine in steady state, in kg/sec, and (b) the exist area.

4.4 Air with a density of 1.13kg/m^3 enters steady-flow device through a duct 0.2m^2 in area with a velocity of 4m/sec. If the outlet density is 2.84kg/m^3, (a) determine the flow rate in kg/sec, and (b) determine the area of the discharge duct in square meters if the outlet velocity is 6m/sec.

4.5 An ideal gas enters a steady-flow device at 100kPa and 27°K. The inlet to the system has a diameter of 20cm, and the velocity at that point is 10m/sec. At the outlet, the diameter is 7cm, and the density of the fluid at that section is 4 kg/m^3. If the molar mass of the gas is 30, determine the velocity in m/sec at the out let and the mass flow rate in kg/sec.

4.6 An ideal gas with molar mass of 48 enters a steady-flow device at 300kPa, 157°C, and 180m/sec through an area of 20cm^2. At the exit of the device the pressure is 150kPa, velocity is 120m/sec, and the exit area is 4ocm^2. Determine (a) the density of the gas, (b) the mass flow rate, and (c) the exit temperature.

4.7 Carbon dioxide enters a steady-flow device at 27°C with a velocity of 25m/sec through an area of 4800cm^2. At the exit of the device the pressure and temperature are 140kPa and 47°C, respectively, and the gas moves with velocity of 9m/sec through an area of 7500cm^2. Determine (a) the mass flow rate in kg/sec, and (b) the inlet pressure. Assume ideal-gas behavior.

4.8 Water at 20°C flows through a long, plastic tube which not have a constant diameter. At position 1 in the tube the internal diameter is 0.1m and the velocity is 3m/sec. At position 2 downstream from position 1 the internal diameter is 0.2m. The temperature remains constant. (a) determine the mass flow rate in kg/min, (b) determine the velocity at position 2?

4.9 Air enters a diffuser at 100kPa and 30°C, with a velocity of 150m/sec. The exit temperature is 40°C. If a heat loss of 0.4 kJ/kg occurred find the exit velocity.

4.10 Air enters diffuser at 70kPa, 57°C, with a velocity of 200m/sec. At the outlet, where the area is 20 percent greater than at the inlet, the pressure is 100kPa. Determine the outlet temperature and the velocity (a) if the process is adiabatic, and (b) if the fluid gains 40kJ/kg in heat transfer as it passes through.

4.11 Air enters a diffuser at 80kPa and 20°C and leave at 95kPa with a negligible velocity. If the inlet velocity is 300m/sec and the flow is adiabatic at a rate of 25kg/sec, compute (a) the exit temperature and (b) the inlet area

4.12 Steam enters an adiabatic diffuser as a saturated vapor at 95°C with a velocity 350m/sec. At the exit the pressure and temperature are 1 bar and 120°C, respectively. If the exit area is 50cm^2, determine (a) the exit velocity, and (b) the mass flow rate.

4.13 Water vapor at 1500kPa and 300°C enters a nozzle with an initial velocity of 125m/sec. The enthalpy of steam at exit is 2800kJ/kg, and the heat loss is 25kJ/kg. What is the exit velocity?

4.14 Air expands through a nozzle from 500kPa, 157°C, t0 100kPa, 47°C. neglect the inlet velocity and compute the exit velocity if the heat gain is 6kJ/kg, state any necessary assumptions.

4.15 Steam enters an adiabatic nozzle at 0.5MPa, 300°C, with a velocity of 70m/sec. It expands to a pressure of 100kPaand a temperature of 125°C.determine the exit velocity.

4.16 Air enters a converging nozzle at 0.18MPa, 67°C, and 40m/sec. At the outer of the adiabatic passage the pressure is 100kPa and velocity is six times its initial value. If the inlet area is 100cm^2, determine the exit area of the nozzle and the outlet temperature of the air using the table of air properties.

4.17 Water vapor at 1MPa, 200°C, enters an adiabatic nozzle with a velocity of 20m/sec. The exit conditions are 700kPa, 175°C. Determine the ratio of inlet to exit area A_i/A_e.

4.18 Air enters a turbine at 300kPa pressure, a temperature of 47°C, and a velocity of 60m/sec. At the outlet, the pressure is 1.2 bar, the temperature is 7°C, and the velocity is 150m/sec. The shaft work delivered by the turbine is 45kJ/kg. What are the magnitude and direction of heat transfer in kJ/kg?

4.19 Steam enters a turbine at 15bar and 400°C and exhausts as a saturated vapor at 100kPa. The inlet velocity is 60m/sec and the exit velocity is 170m/sec. For a mass flow rate of 27000kg/h. the output is 3850kW. Determine the quantity and direction of heat transfer in kJ/kg.

4.20 Air enters a turbine at 600kPa and 277°C and leaves at 100kPa. The flow rate is 50kg/min, and the power output is 180 kW. If the heat transfer removed from the air is 30kJ/kg, compute the exit temperature in °C?

4.21 Steam flows steadily to a turbine at a rate of 20000kg/h, entering at 40bars, 450°C, and leaving at 0.20bars with 90% quality. A heat loss amounts to 30kJ/kg. The inlet pipe has a 10cm diameter, and the exhaust section is rectangular with dimensions of 0.6m by 0.7m. Calculate turbine output power in kW.

4.22 Steam enters an adiabatic turbine at 15MPa and 500°C and leaves at 10kPa with quality of 90%. Neglecting the changes in kinetic and potential energies, determine the mass flow rate required for a power output of 6MW.

4.23 Steam enters an adiabatic turbine at 10MPa and 450°C at a rate of 3kg/sec and leaves at 20kPa. If the power output of the turbine is 2MW, determine the temperature (or quality, if saturated) of the steam at the turbine exit. Neglect kinetic energy changes.

4.24 Argon gas enters steadily an adiabatic turbine at 9000kPa and 450°C with a velocity of 80m/sec and leaves at 150kPa with a velocity of 150m/sec. The inlet area of the turbine is 60cm^2.if the power output of the turbine is 250kW, determine the exit temperature of the argon.

4.25 Steam enters a turbine with a negligible velocity at 80bars and 525°C and leaves at 0.05bars with 90% quality and with a velocity of 240m/sec. The turbine delivers 7000kW, and the cross-sectional area of the exhaust is $0.6m^2$. Determine the heat transfer from the steam in kJ/kg.

4.26 Air inters a steady-state compressor at 1bar and 27°C at a rate of 1.0kg/min, and leaves at 7bars and 227°C. The power required to operate the compressor is 3.58 kW. Determine the magnitude (in kJ/h) and direction of any heat transfer.

4.27 An air compressor handing $300m^3$/min increases the pressure from 100kPa to 2.3kPa, and heat is removed at the rate of 1700kJ/min. the inlet temperature is 17°C, and at the exit the temperature is 137°C and the area is $200cm^2$. find the power input necessary if the inlet velocity is neglected.

4.28 A centrifugal compressor is supplied with dry saturated steam at 0.2 bar. 500kg of steam are compressed per hour to 1bar and 160°C. during the process 4000kJ/h are removed from the steam by cooling. What power, in kJ/s, is required to operate the compressor?

4.29 A steam compressor is supplied with 50kg/h of saturated vapor at 0.04bar and discharges at 1.5bar and 120°C. the power required is measured to be 2.4 kW. What is the rate of heat transfer from the steam in kJ/min?

4.30 Air enters a compressor at 40m/sec through an area of $100cm^2$ with a pressure and temperature of 1.0bars and 27°C, respectively. A heat loss of 7.0 kJ/kg occurs during its passage through the compressor, and the outlet conditions are 12bars, 107°C, and 100m/sec.
(a) determine the shaft work required in magnitude and direction
(b) determine the mass flow rate through the device
(c) determine the power required

4.31 Carbon dioxide enters an adiabatic compressor at 100kPa and 300K at a rate of 0.5kg/sec and leaves at 600kPa and 450K, neglecting kinetic energy changes, determine (a) the volume flow rate of the carbon dioxide at the compressor inlet and (b) the power input to the compressor.

4.32 A heavily insulated throttle valve receives steam at 3000kPa, 240°C, and exhausts at 8bars. Velocities are low enough to be neglected. Determine the exit temperature.

4.33 Dry saturated steam at 800kPa enters a long, insulated pipe. At a point downstream from the entrance where the pressure is 3bar, determine the quality or the final temperature of the steam, whichever is appropriate.

4.34 Water is heated in an insulated heat exchanger by mixing it with steam. The water enters at a rate of 100kg/min at 20°C and 3bars. The steam enters at 300°C and 3bars. The mixture leaves the heat exchanger or mixing chamber at 40°C and 3bars. How much steam is needed.

4.35 An open feed water heater operates at 5bars pressure. Superheated steam id bled from a turbine and enters the open heater at 200°C. Compressed liquid at 35°C. enters the heater at another position. Determine the ratio of the mass flow rate of steam bled from the turbine to the total mass flow rate leaving the heater.

4.36 A hot-stream at 60°C enters a mixing chamber with mass flow rate of 1kg/sec where it mixed with a stream of cold water at 15°C. If it is desired that the mixture leave the chamber at 40°C, determine the mass flow rate of the cold-water stream. Assume all the streams are at a pressure of 250kPa.

4.37 Liquid water at 200kPa and 20°C is heated in a chamber by mixing it with superheated stream at 200kPa and 350°C. cold water enters the chamber at a rate of 3kg/sec. If the mixture leaves the mixing chamber at 70°C, determine the mass flow rate of the superheated steam required.

4.38 In steam power plants, open feed water heaters are frequently utilized to heat the feed water by mixing it with steam bled off the turbine at some intermediate stage. Consider an open feed water heater that operates at a pressure of 800kPa. Feed water at 40°C and 800kPa is to be heated with superheated steam at 250°C and 800kPa. In an ideal feed water heater, the mixture leaves the heater as saturated liquid at the feed water pressure. Determine the ratio of the mass flow rates of the feed water and the superheated vapor for this case.

4.39 Water at 25°C and 300kPa is heated in a chamber by mixing it with saturated water vapor at 300kPa. If both streams enter the mixing chamber at the same mass flow rate, determine the temperature and the quality of the exiting stream.

4.40 Steam enters a heat exchanger at 1.5MPa and 300°C, where it condensers on the outside of some tubes. The condensed steam leaves the heat exchanger as a saturated liquid at 1500kPa with a flow rate of 5000kg/h. The steam is condensed by passing cool water through the inside of the tubes. The cooling water enters at a temperature of 20°C and experiences a temperature rise of 20°C before leaving the heat exchanger. What flow rate of cooling water is required.

4.41 In a steam heating system, air is heated by being passed over some tubes through which steam flows steadily. Steam enters the heat exchanger at 200kPa and 200°C at a rate of 8kg/min, and it leaves at 180kPa and 100°c. air enters at 100kPa and 25°C and leaves at 47°C. determine the volume flow rate of air at the inlet.

4.42 Steam enters the condenser of a steam power plant at 20kPa and a quality of 95% with a mass flow rate of 10000kg/h. It is to be cooled by water from a nearby river by circulating the water through the tubes within the condenser. To prevent thermal pollution, the river water is not allowed to experience a temperature rise above 10°C. If the steam is leave the condenser as saturated liquid at 20kPa. Determine the mass flow rate of cooling water required.

4.43 Liquid water flows over a dam and down into a vertical pipe of 20cm internal diameter and 160m long. The temperature of the fluid remains essentially constant, and heat losses are small determine the outlet velocity in m/sec.

4.44 An ideal gas with constant specific heats [Cp=0.86kJ/kg.K] flows through a long, horizontal pipe of constant diameter. The gas enters the pipe at 2.8bars and 37°C with a velocity of 70m/sec. The gas leaves the pipe at 1.4bars and 37°C. Determine (a) the mass flow rate, in kg/sec, (b) the exit velocity, and (c) the heat transfer rate.

4.45 Steam flows through a long, insulated pipe of constant cross-section area. At one point along the pipe the state is 2000kPa and 350°C. at another section further downstream the state is 1500kPa and 300°C. determine the velocity at the inlet.

4.46 Air flows through a horizontal, insulated pipe of constant diameter. The entrance conditions are 30°C, 300kPa, and 125m/sec. At the exit the velocity is 250m/sec. Determine the exit temperature and the exit pressure.

4.47 A house has an electric heating system that consists of a 500-W fan and electric resistance heating element placed in a duct. Air flows through the duct at a rate of 2kg/sec and experiences a temperature rise of 5°C. the rate of heat loss from the air in the duct is estimated to be 300W. determine the power rating of the electric resistance heating element.

4.48 A hair dryer is basically a duct in which a few layers of electric resistors are placed. A small fan pulls the air in and forces it through the resistors where it is heated. Air enters a 1200-W hair dryer at 100kPa and 22°C and leaves at 47^{o}C. the cross-sectional area of the hair dryer at the exit is 25cm^2. Neglecting the power consumed by the fan and the heat losses through the walls of the hairdryer, determine (a) the volume flow rate of air at the inlet and (b) the velocity of the air at exit.

4.49 The ducts of an air heating system pass through an unheated area. As a result of heat losses, the temperature of the air in the duct drops by 3^{o}C. If the mass flow rate of air is 150kg/min, determine the rate of heat loss from the air to the cold environment.

4.50 Air enters the duct of an air-conditioning system at 105kPa and 12^{o}C at a volume flow rate of 12m^3/min. the diameter of the duct is 20 cm, and heat is transferred to the air in the duct from the surroundings at a rate of 2kJ/sec. Determine (a) the velocity of the air at the duct inlet and (b) the temperature of the air at the exit.

4.51 Water is to be pumped from a well to the top of a 200m tall building. There is a 20kW pump available in the basement, and the water surface level in the well is 40m below ground level. Neglecting any heat transfer and frictional effects, determine the maximum flow rate of water than can be maintained by this pump.

4.52 The free surface of the water in a well is 20m below the ground level. This is to be pumped steadily to an elevation of 30jm above the ground level. Neglecting any heat transfer, kinetic energy changes, and frictional effects, determine the power input to the pump required for a steady flow of water at a rate of 1.5 m^3/min.

4.53 An insulated tank with a volume of 0.5m^3 contains air at 100kPa and 25^{o}C. the tank is connected through a valve to a large compressed air line, which carries air continuously at 700kPa and 120^{o}C. If the valve is opened and air is allowed to flow into the tank until the pressure reaches 500kPa, how much mass, has entered, and what is the final temperature in the tank.

4.54 A pressurized tank contains 1kg of water at 3MPa and 280^{o}C. Mass is allowed to flow from the tank until the pressure reaches 700kPa. However, during the process heat is added to the steam to keep it at constant temperature. How much heat was added during the process.

4.55 Two adiabatic tanks are interconnected through a valve. Tank a contains 0.2m^3 of air at 4MPa and 90^{o}C. Tank B contains 2m^3 of air at 100kPa and 30^{o}C. The valve is opened until the pressure in A drops to 1.5kPa. At this instant, (a) what are the temperature and pressure in both tanks, (b) how much mass has left tank A.

4.56 A rigid insulated tank is initially evacuated. Atmospheric air at 1bar and 20°C is allowed to leak into the tank until the pressure reaches 1bar. What is the final temperature of the air within the tank?

4.57 Consider the data of Prob.4.74, except that the tank initially contains air at 0.5 bar and 20°C. What is the final temperature?

4.58 An ideal gas is contained in a rigid tank of volume V, initially at P_1, and T_1. heat is supplied to the contents until the temperature reaches T_2. however, a relief valve allows gas to escape so that the pressure remains constant. Drive an expression for the heat transfer during the process.

4.59 A 0.2m^3 rigid tank initially contains saturated water vapor at 120°C. The tank is connected by a valve to a supply line that carries steam at 2MPa and 350°C. Now the valve is opened, and steam is allowed to enter the tank. Heat transfer takes place with the surroundings such that the temperature in the tank remains constant at 120°C at all times. The valve is closed when it is observed that one-half of the volume of the tank is occupied by liquid volume. Determine (a) the final pressure in the tank, (b) the amount of steam that has entered the tank, and (c) the amount of heat transfer.

4.60 A balloon initially contains 65m^3 helium gas at atmospheric condition of 100kPa and 20°C. The balloon is connected by a valve to a large reservoir that supplies helium gas at 150kPa and 25°C. Now the valve is opened, and helium is allowed to enter the balloon until the pressure equilibrium with the helium at the supply line is reached. The material of the balloon is such that its volume increases linearly with pressure. if no heat takes place during this process, determine the final temperature in the balloon.

4.61 A vertical piston-cylinder device initially contains 0.02m^3 of steam at 200°C. the mass of the frictionless piston is such that it maintains a constant pressure of 1000kPa inside. Now steam at 2MPa and 350°C is allowed to enter the cylinder from the cylinder from a supply line until the volume inside doubles. Neglecting any heat transfer that may have taken place during the process, determine (a) the final temperature of the steam in the cylinder and (b) the amount of mass that has entered.

4.62 An insulated, vertical piston-cylinder device initially contains 10kg of water, 7kg of which in the vapor phase. The mass of the piston is such that it maintains a constant pressure of 300kPa inside the cylinder. Now steam at 2MPa and 400°C is allowed to enter the cylinder from a supply line until all the liquid in the cylinder has vaporized. Determine (a) the final temperature in the cylinder and (b) the mass of the steam that has entered.

4.63 An insulated, vertical piston-cylinder device initially contains $0.3m^3$ of air at 180kPa and 23°C. At this state, a linear spring touches the piston but exerts no force on it. The cylinder is connected by a valve to a line that supplies air at 1MPa and 23°C. The valve is opened, and air from the high-pressure line is allowed to enter the cylinder. The valve is turned off when the pressure inside the cylinder reaches 700kPa. If the enclosed volume inside the cylinder doubles during this process, determine (a) the mass of air that entered the cylinder and (b) the final temperature of the air inside the cylinder.

4.64 A $0.4m^3$ rigid tank is filled with saturated liquid water at 250°C. A valve at the bottom of the tank is opened, and liquid is withdrawn from the tank. Heat is transferred to the water such that the temperature in the tank remains constant. Determine the amount of heat that must be transferred by the time two-third of the total mass has been withdrawn.

4.65 An insulated $2m^3$ rigid tank contains air at 500kPa and 57°C. A valve connected to the tank is now opened, and air is allowed to escape until the pressure inside drops to 200kPa. The air temperature during this process is maintained constant by an electric resistance heater placed in the tank. Determine the electric work done during this process.

4.66 A vertical piston-cylinder device initially contains $0.1m^3$ of air at 27°C. The mass of the piston is such that it maintains a constant pressure of 500kPa inside. Now a valve connected to the cylinder is opened, and air is allowed to escape until the volume inside the cylinder is decreased by one-third. Heat transfer takes place during the process, so that the temperature of the air in the cylinder remains constant. Determine (a) the amount of air that has left the cylinder and (b) the amount of the heat transfer.

4.67 Air is contained in the insulated cylinder. At this state the air is at 140kPa, 25°C, and the cylinder volume is 15L. The piston cross sectional area is $0.045m^2$. and the spring constant 40kn/m. the valve is opened, and air from the line at 800kPa, 25°C flows into the cylinder until the pressure reaches 800kPa, and then the valve is closed. Find the final temperature.

4.68 A spherical balloon is constructed of a material such that the pressure inside is proportional to the balloon diameter to the power 1.5. The balloon contains argon gas at 1200kPa, 700°C, at a diameter of 2.0m. A valve is now opened, allowing gas to flow out until the diameter reaches 1.8m, at which point the temperature inside is 600°C. the balloon then continues to cool until the diameter is 1.4m.

(a) how much mass was lost from the balloon?

(b) what is the final temperature inside?

(c) calculate the heat transferred from the balloon during the overall process.