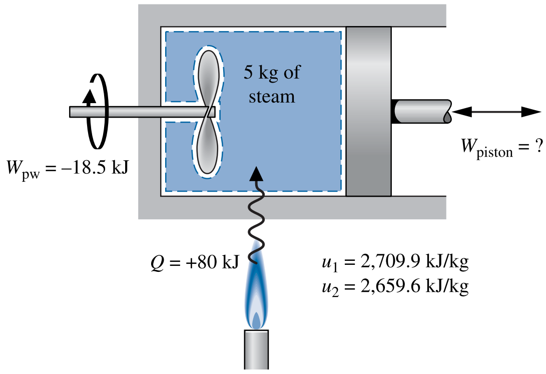
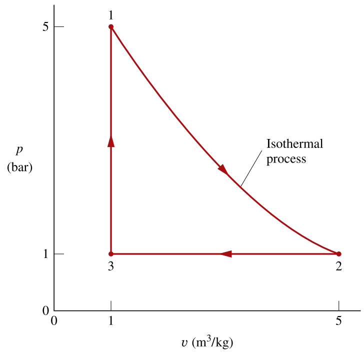
ME 6101: Classical Thermodynamics

Term Paper 01[2023] **Submission Date: 04 September 2023**

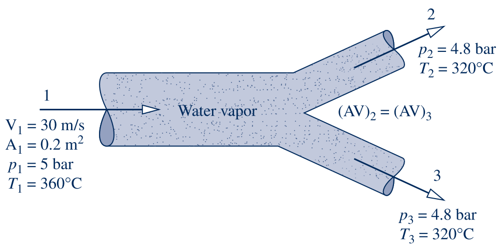
P-1: Estimate the work transfer to the piston.



P-2: Air contained in a piston-cylinder assembly undergoes the power cycle. Evaluate the thermal efficiency of the cycle.



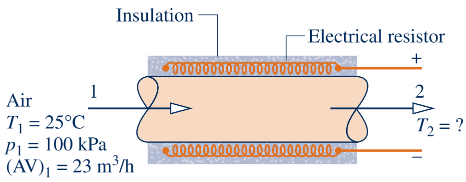
P-3: Determine the mass flow rate at the inlet and exits, each in kg/s.



P-4: A gas, within a piston-cylinder device is compressed at a constant pressure of 0.50 MPa from 1000 to 400 cm^3. The frictional force at the piston cylinder interface is 200 N, the piston surface area is 100 cm^2, the atmospheric air is 0.1 MPa. Determine the work transferred by the piston to the gas and the work supplied by the connecting rod.

P-5: Refrigerant 134a enters a horizontal pipe operating at steady state at 40°C, 300 kPa, and a velocity of 40 m/s. At the exit, the temperature is 50°C and the pressure is 240 kPa. The pipe diameter is 0.04 m. Determine (a) the mass flow rate of the refrigerant, in kg/s, (b) the velocity at the exit, in m/s, and (c) the rate of heat transfer between the pipe and its surroundings, in kW.

P-6: With a voltage of 120 V, the resistor draws a current of 4 amps. Determine (a) the mass flow rate of the air, in kg/h, and (b) the temperature of the air at the exit, in °C.



P-7: At steady state, air at 200 kPa, 52°C, and mass flow rate of 0.5 kg/s enters an insulated duct having differing inlet and exit cross-sectional areas. The inlet cross-sectional area is 2×10^{-3} m^2 . At the duct exit, the pressure of the air is 100 kPa and the velocity is 255 m/s. Determine

(a) the temperature of the air at the exit, in °C.
(b) the velocity of the air at the inlet, in m/s.
(c) the exit cross-sectional area, in m^2.

P-8: Steam enters a nozzle operating at steady state at 30 bar, 320°C, with a velocity of 100 m/s. The exit pressure and temperature are 10 bar and 200°C, respectively. The mass flow rate is 2.0 kg/s. Neglecting heat transfer and potential energy, determine

(a) the exit velocity, in m/s.
(b) the inlet and exit flow areas, in cm^2.

P-9: Air with a mass flow rate of 2 kg/s enters a horizontal nozzle operating at steady state at 445 K, 345 kPa, and velocity of 3 m/s. At the exit, the temperature is 317 K and the velocity is 460 m/s. Determine

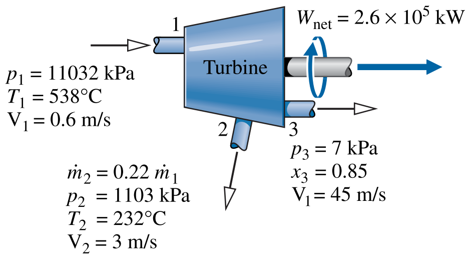
(a) the area at the inlet, in m^2.
(b) the heat transfer between the nozzle at its surroundings, in kW.

P-10: Steam enters a turbine operating at steady state at 2 MPa, 360°C with a velocity of 100 m/s. Saturated vapor exits at 0.1 MPa and a velocity of 50 m/s. The elevation of the inlet is 3 m higher than at the exit. The mass flow rate of the steam is 15 kg/s, and the power developed is 7 MW. Determine

(a) the area at the inlet, in m^2, and
(b) the rate of heat transfer between the turbine and its surroundings, in kW.

P-11: Determine

(a) the mass flow rate of the steam entering the turbine, in kg/h.
(b) the diameter of the extraction duct, in m.



P-12: Air enters a compressor operating at steady state at 1.05 bar, 300 K, with a volumetric flow rate of 12 m^3/min and exits at 12 bar, 400 K. Heat transfer occurs at a rate of 2 kW from the compressor to its surroundings. Assuming the ideal gas model for air and neglecting kinetic and potential energy effects, determine the power input, in kW.

P-13: Refrigerant 134a enters an air conditioner compressor at 3.2 bar, 10°C, and is compressed at steady state to 10 bar, 70°C. The volumetric flow rate of the refrigerant entering is 3.0 m^3/min. The work input to the compressor is 55.2 kJ per kg of refrigerant flowing. Neglecting kinetic and potential energy effects, determine the heat transfer rate, in kW.

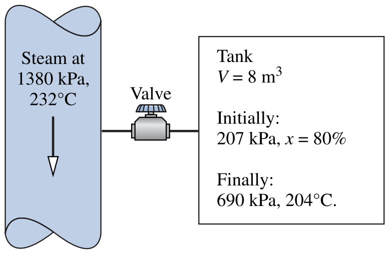
P-14: Steam enters a heat exchanger operating at steady state at 250 kPa and a quality of 90% and exits as saturated liquid at the same pressure. A separate stream of oil with a mass flow rate of 29 kg/s enters at 20°C and exits at 100°C with no significant change in pressure. If heat transfer from the heat exchanger to its surrounding is 10% of the energy required to increase the temperature of the oil, determine the steam mass flow rate, in kg/s.

P-15: A tiny hole develops in the wall of a rigid tank whose volume is 0.75 m^3, and air from the surroundings at 1 bar, 25°C leaks in. Eventually, the pressure in the tank reaches 1 bar. The process occurs slowly enough that heat transfer between the tank and the surroundings keeps the temperature of the air inside the tank constant at 25°C. Determine the amount of heat transfer, in kJ, if initially the tank

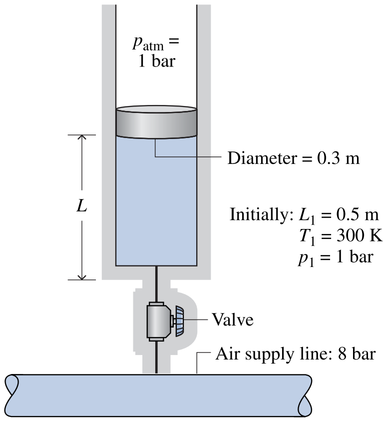
(a) is evacuated.

(b) contains air at 0.7 bar, 25°C.

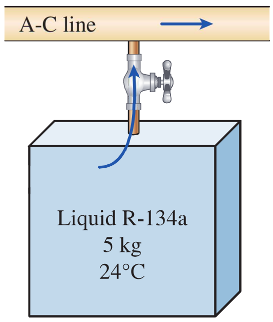
P-16: Determine the amount of mass, in kg, that enters the tank and the heat transfer between the tank and its surroundings, in kJ.



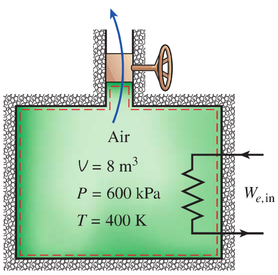
P-17: The valve is opened and air is admitted slowly until the volume of air inside the cylinder has doubled. The weight of the piston and the friction between the piston and the cylinder wall can be ignored. Estimate the final temperature, in K, and the final mass, in kg, of the air inside the cylinder for supply temperature of 500 K.



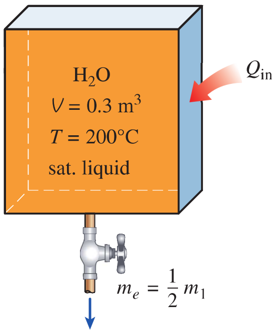
P-18: An air-conditioning system is to be filled from a rigid container that initially contains 5 kg of liquid R-134a at 24°C. The valve connecting this container to the air-conditioning system is now opened until the mass in the container is 0.25 kg, at which time the valve is closed. During this time, only liquid R-134a flows from the container. Presuming that the process is isothermal while the valve is open, determine the final quality of the R-134a in the container and the total heat transfer.



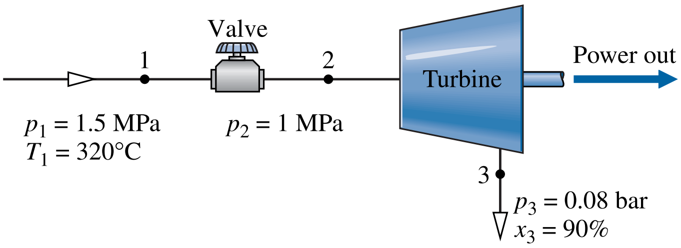
P-19: An insulated 8-m^3 rigid tank contains air at 600 kPa and 400 K. A valve connected to the tank is now opened, and air is allowed to escape until the pressure inside drops to 200 kPa. The air temperature during the process is maintained constant by an electric resistance heater placed in the tank. Determine the electrical energy supplied to air during this process.



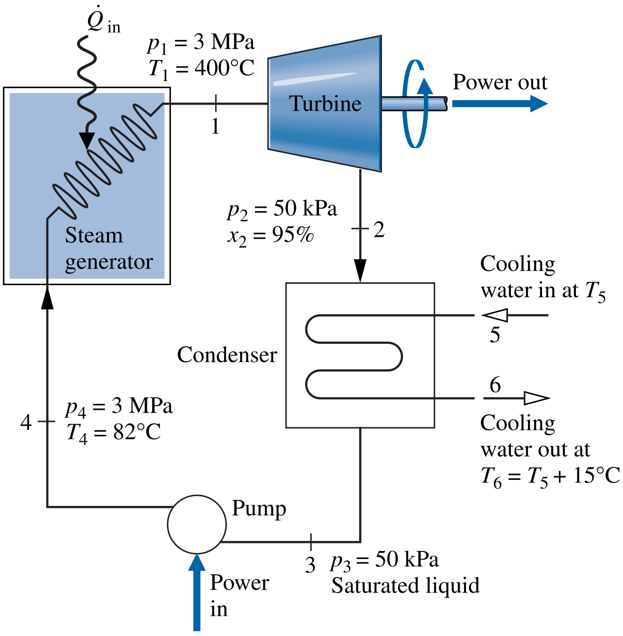
P-20: A 0.3-m^3 rigid tank is filled with saturated liquid water at 200°C. A valve at the bottom of the tank is opened, and liquid is withdrawn from the tank. Heat is transferred to the water such that the temperature in the tank remains constant. Determine the amount of heat that must be transferred by the time one-half of the total mass has been withdrawn.



P-21: Determine (a) the temperature at the turbine inlet, °C, and (b) the power developed by the turbine, in kJ/kg, of steam flowing.



P-22: Determine (a) the thermal efficiency and (b) the mass flow rate of cooling water through the condenser, in kg/s.



P-23: Throttling: Ammonia is throttled from 1.5 MPa, 35°C to a pressure of 300 kPa in a refrigerator system. Find the exit temperature and the specific entropy generation in this process.

P-24: Steam turbine: Steam at 5 MPa and 600°C enters an insulated turbine operating at steady state and exits as saturated vapour at 50 kPa. Kinetic and potential energy effects are negligible. Determine

(a) the work developed by the turbine per kg of steam flowing.

(b) the isentropic turbine efficiency.

P-25: Air Compressor: Air is compressed in an axial-flow compressor operating at steady state from 27°C, 1 bar to a pressure of 2.1 bar. The work input required is 94.6 kJ per kg of air flowing through the compressor. Heat transfer from the compressor occurs at the rate of 14 kJ per kg at a location on the compressor's surface where the temperature is 40°C. Kinetic and potential energy changes can be ignored. Determine

(a) the temperature of the air at the exit.

(b) the rate at which entropy is produced within the compressor.

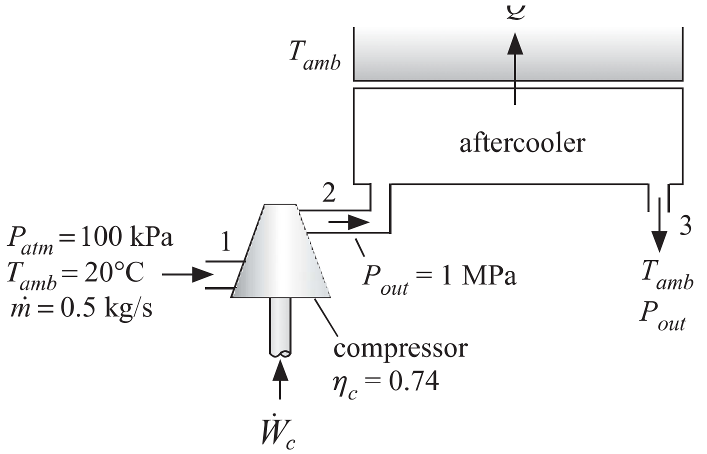
P-26: Intercooled Compressor: The aftercooler is a perfect heat exchanger that rejects heat to the ambient surroundings. Therefore, there is no pressure loss in the aftercooler and the exit temperature of the air is T_{amb}.

(a) Determine the power required by the compressor.

(b) Determine the rate of entropy generation in the compressor.

(c) Determine the rate of heat transfer from the aftercooler.

(d) Determine the rate of entropy generation in the aftercooler.



P-27: Pump: Liquid water at ambient conditions, 100 kPa, 25°C, enters a pump at the rate of 0.5 kg/s. Power input to the pump is 3 kW. Assuming the pump process to be reversible, determine the pump exit pressure and temperature.

P-28: Nozzle: Liquid water enters a nozzle at 4 bars and 30°C with a velocity of 5 m/s. The exit pressure is 1 bar. Irreversibilities lead to a temperature rise of of 0.015°C. Determine,

(a) the isentropic efficiency,

(b) the exit velocity.

P-29: Diffuser: Air enters an insulated diffuser operating at steady state at 1 bar, -3°C, and 260 m/s and exits with a velocity of 130 m/s. Employing the ideal gas model and ignoring potential energy, determine

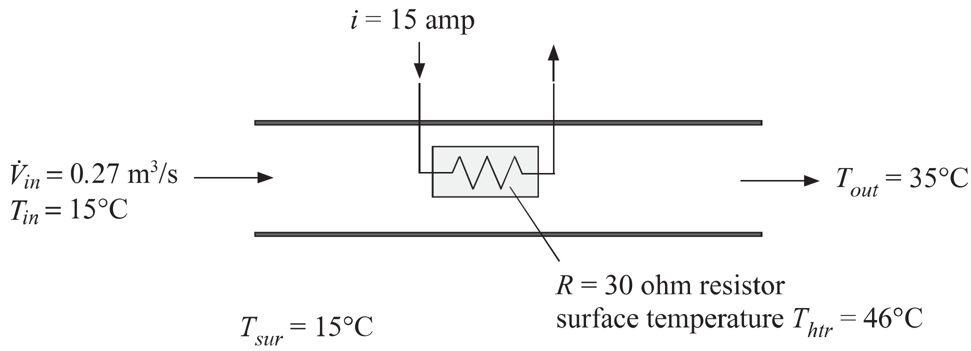
(a) the temperature of the air at the exit.

(b) the maximum attainable exit pressure.

P-30: Air-heater:

(a) Determine the heat transfer from the duct to the surroundings.

(b) Calculate the total rate of entropy generation for this process.



P-31: Condenser: A large condenser in a steam power plant dumps 15 MW by condensing saturated water vapour at 45°C to saturated liquid. What is the water flow rate and the entropy generation rate with an ambient at 25°C?

P-32: Heat Exchanger: A counterflow heat exchanger operates at steady state with negligible kinetic and potential energy effects. In one stream, liquid water enters at 15°C and exits at 23°C with a negligible change in pressure. In the other stream, Refrigerant 22 enters at 12 bar, 90°C with a mass flow rate of 150 kg/h and exits at 12 bar, 28°C. Heat transfer from the outer surface of the heat exchanger can be ignored. Determine

(a) the mass flow rate of the liquid water stream, in kg/ h.

(b) the rate of entropy production within the heat exchanger, in kW/K.

P-33: Mixing: Two flows of air are both at 200 kPa; one has 2 kg/s at 400 K, and the other has 1 kg/s at 290 K. The two flows are mixed together in an insulated box to produce a single exit flow at 200 kPa. Find the exit temperature and the total rate of entropy generation.

P-34: Feed Water Heater: Steam at 0.7 MPa, 355°C enters an open feedwater heater operating at steady state. A separate stream of liquid water enters at 0.7 MPa, 35°C. A single mixed stream exits as saturated liquid at pressure p. Heat transfer with the surroundings and kinetic and potential energy effects can be ignored. Determine the ratio of the mass flow rates of the incoming streams and the rate at which entropy is produced within the feedwater heater, in kJ/K per kg of liquid exiting.

P-35: Air at 600 kPa, 330 K enters a well-insulated, horizontal pipe having a diameter of 1.2 cm and exits at 120 kPa, 300 K. Applying the ideal gas model for air, determine at steady state (a) the inlet and exit velocities, each in m/s, (b) the mass flow rate, in kg/s, and (c) the rate of entropy production, in kW/K.

P-36: Two insulated tanks are connected by a valve. One tank initially contains 0.45 kg of air at 93°C, 1 bar, and the other contains 0.9 kg of air at 38°C, 2 bar. The valve is opened and the two quantities of air are allowed to mix until equilibrium is attained. Employing the ideal gas model with c_v = 0.7 kJ/kg'K, determine

(a) the final temperature, in °C.

(b) the final pressure, in bar.

(c) the amount of entropy produced, in kJ/K.

P-37: A rigid, insulated vessel is divided into two equal-volume compartments connected by a valve. Initially, one compartment contains 1 m^3 of water at 20°C, $x = 50\%$, and the other is evacuated. The valve is opened and the water is allowed to fill the entire volume. For the water, determine the final temperature, in °C, and the amount of entropy produced, in kJ/K.

P-38: Air enters a compressor operating at steady state with a volumetric flow rate of 8 m^3/min at 23°C, 0.12 MPa. The air is compressed isothermally without internal irreversibilities, exiting at 1.5 MPa. Kinetic and potential energy effects can be ignored. Evaluate the work required and the heat transfer, each in kW.

P-39: A pump operating at steady state receives saturated liquid water at 50°C with a mass flow rate of 20 kg/s. The pressure of the water at the pump exit is 1 MPa. If the pump operates with negligible internal irreversibilities and negligible changes in kinetic and potential energy, determine the power required in kW.

P-40: The ducts are well insulated and the pressure is very nearly 1 bar throughout. Assuming the ideal gas model for air, determine (a) the temperature of the air at the exit, in °C, (b) the exit diameter, in m, and (c) the rate of entropy production within the duct, in kJ/min.