1. A Rankine cycle has a fixed turbine inlet temperature and condenser pressure. If the boiler pressure is increased do the following increase, decrease or remain the same?:
   a. Pump work input
   b. Turbine work output
   c. Heat supplied
   d. Heat rejected
   e. Cycle efficiency
   f. Moisture content at turbine outlet.

2. A Rankine cycle with refrigerant (R-134a) as the working fluid is to be used to produce work with heat added from a lower temperature source than a steam power cycle. The boiler pressure is 1.6 MPa and the condenser pressure is 0.4 MPa. The temperature of the R-134a at the turbine inlet is 80 °C, and the quality at the turbine outlet is 0.98. Calculate
   a. The mass flow rate of R-134a required to produce 750 kW power
   b. The thermal efficiency of the cycle

3. A steam power plant using a Rankine cycle has a net power output of 45 MW. Steam enters the turbine at 7 MPa and 500 °C and is cooled in the condenser at a pressure of 10 kPa by running cooling water from a lake through the tubes of the condenser heat exchanger at a rate of 2,000 kg/s.
   a. Show the cycle on a T-s diagram
b. Calculate the thermal efficiency of the cycle
c. Determine the mass flow rate of the steam
d. Determine the temperature increase of the cooling water

4. Compare the efficiency and net work output of a Carnot heat engine and a Rankine cycle with steam as the working fluid. In both cases, steam enters the turbine at 5 MPa and as saturated vapor and the condenser pressure is 50 kPa. In the Rankine cycle the water at the condenser exit is saturated liquid. In the Carnot cycle, the boiler inlet state is saturated liquid.
   a. Draw the T-s diagram for both cycles.
   b. Calculate the efficiency and net work output for both cycles.
   c. Calculate the entropy generated in the surroundings for both cycles.

![T-s DIAGRAM FOR WATER](image)

5. R-134a enters the coils of the evaporator of a refrigeration system as a saturated liquid vapor mixture at a pressure of 160 kPa. The refrigerant absorbs 170 kJ of heat from the cooled space, which is maintained at –5 °C and exits the evaporator as saturated vapor at the same pressure. Determine:
   a. The entropy change of the refrigerant
   b. The entropy change of the cooled space
   c. The total entropy change for the process

6. A Rankine reheat cycle has water as the working fluid. The boiler pressure for the first turbine is 15 MPa, and the reheater pressure is 2 MPa. The condenser pressure is 100 kPa. The temperature of the steam is 450 °C at the entrance to both the high- and low-pressure turbines. The mass flow rate of steam is 1.74 kg/s. Determine:
   a. The power used by the pump
b. The net power produced by the cycle
c. The rate of heat transfer in the reheater
d. The thermal efficiency of this system
e. Compare the efficiency to a Rankine cycle without reheat with the boiler pressure at 15 MPa and the same turbine inlet temperature, condenser pressure and steam mass flow rate.

7. An ideal vapor compression refrigeration cycle with R-134a as the working fluid is used to satisfy a 400 kw cooling load. The condenser pressure is 1 MPa and the refrigerant in the evaporator is at 4 °C.
   a. What is the COP?
   b. What is the power requirement?

8. An industrial refrigerator with R-134a is used to keep the cooled space at -30 °C. Heat is rejected to cooling water flowing at 0.25 kg/s that enters the condenser heat exchanger at 18 °C and leaves at 26 °C. The R-134a enters the condenser at 1.2 MPa and 65 °C and leaves at 42 °C. The R-134a at the compressor inlet is 60 kPa and -34 °C, and the compressor gains heat from the surroundings at a rate of 450 w. Determine
   a. The quality of the R-134a at the evaporator inlet.
   b. The rate of cooling
   c. The COP
   d. The theoretical maximum cooling rate for the same power input to the compressor.

9. A heat pump operates on the ideal vapor-compression refrigeration cycle with R-134a as the working fluid. This heat pump is used to keep a space at 25 °C by absorbing heat at a rate of 2.7 kw from geothermal water flowing through the evaporator heat exchanger. The evaporator operates at 20 °C, and the condenser pressure is 1.4 MPa. The compressor receives work at a rate of 20 kJ/kg.
   a. Show the process on a T-s diagram
b. Determine the rate of heat transfer to the heated space.
c. Determine the COP

10. A water heater is operated using a heat pump that heats the water by removing heat from the room air and transferring it to the water. The heat pump has a COP of 3.4 and consumes 6 kW power. Determine if the heat pump can be used to cool the room for “free” by absorbing heat from the air in the room. The rate of heat gain in the house is less than 45,000 kJ/hr.

11. An ice producing plant operates on an ideal vapor-compression refrigeration cycle using R-134a as the working fluid. The evaporator pressure is 140 kPa and the condenser pressure is 1.2 MPa. The R-134a in the condenser is cooled by water flowing at a rate of 200 kg/s, and the cooling water temperature increases by 10 °C during condensation of the refrigerant. To produce ice, potable water is supplied to the chiller section of the cycle. For each kg of ice produced, 333 kJ of heat must be removed from the potable water supply.

   a. Determine the mass flow rate of refrigerant in kg/s
   b. Determine the mass flow rate of the potable water supply (and ice produced) in kg/s

12. In an attempt to reduce the required work input, a heat exchanger is added to a vapor-compression refrigeration cycle that superheats the R-134a entering the compressor and at the same time subcools the R-134a exiting the condenser. The evaporator temperature is -10.1 °C, and the condenser pressure is 800 kPa. The subcooled refrigerant at the throttling valve inlet is at 20 °C. Assume the refrigerant leaves the evaporator as a saturated vapor and the compressor is isentropic. What is the COP of the refrigerant?