Qualifying Examination Spring 2020

Thermodynamics

Logistics Notes:

- Duration: 2.5 hours.
- Open book (the textbook provided during the exam).
- Calculator is allowed.
- Laptops, cell phones, and similar electronic devices are **not allowed**.
- State your assumptions for each problem.

Problem 1 (35 points) A rocket engine is cooled with propane supplied from a continuously pressurized tank as shown in Fig. 1. Propane in the tank is at 10 bar in the saturated liquid state (State 1). During steady-state operation, this cooling system removes energy from the rocket engine wall by heat exchange at the rate $\dot{Q}$ = 10MW. Propane leaves the cooling system at State 2 with p = 5 bar and T = 373.16 K.

- Determine the mass flow rate through the cooling system.

- An initial idea was to simply dump propane at State 2 after cooling the engine. Investigate whether one can instead utilize isentropic expansion of propane to State 3 with p = 1 bar to drive a turbine, which requires 3 MW for operating.

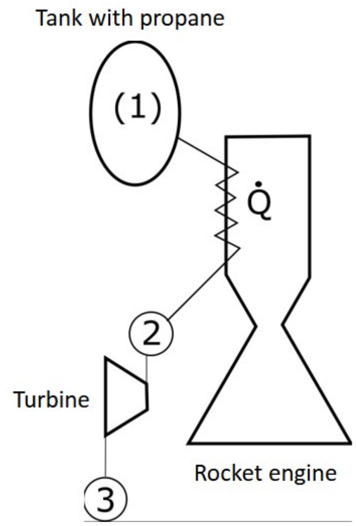

Fig. 1

Problem 2 (30 points) The heat pump cycle shown in Fig. 2 operates at steady state and provides energy by heat transfer at a rate of 15 kW to maintain a dwelling at 22°C when the outside temperature is -22°C. The manufacturer claims that the power input required for this operating condition is 3.2 kW. Applying energy and entropy rate balances evaluate this claim.

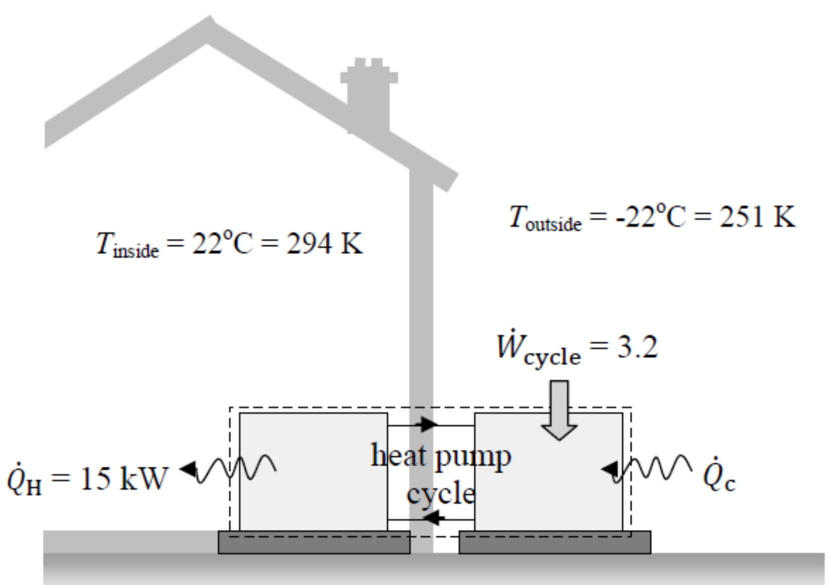

Fig. 2

Problem 3 (35 points)

As shown in Fig. 3, an insulated box is initially divided into halves by a frictionless, thermally conducting piston. On one side of the piston is 1.0 m^3 of air at 400 K, 3 bar. On the other side is 1.0 m^3 of air at 400 K, 1.5 bar. The piston is removed then and equilibrium is attained. Employing the ideal gas model for the air, determine

(a) the final temperature of the air, in K.

(b) the final pressure of the air, in bar.

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

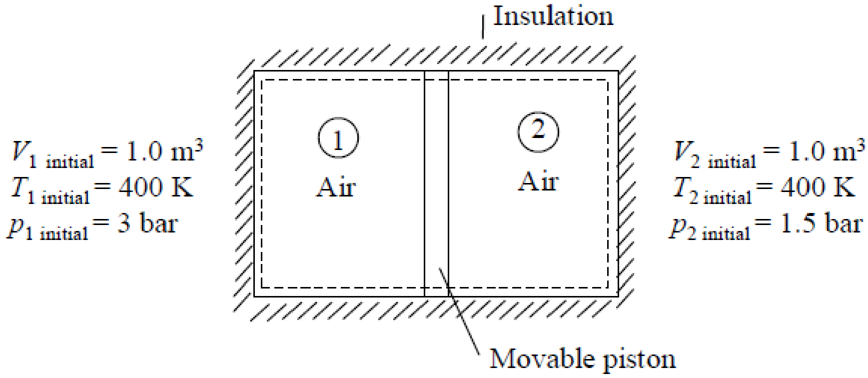

Fig. 3