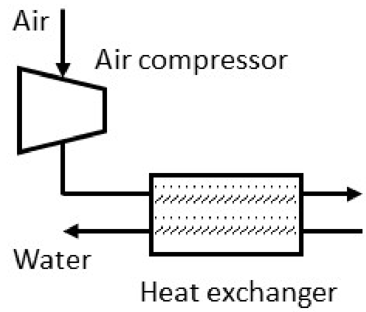
Thermodynamics - 2

A steady-flow compressed air system for is shown in the adjacent figure and consists of an air compressor and a heat exchanger. Air (c_v = 0.718 kJ/kg-K; c_p = 1.005 kJ/kg-K; R = 0.287 kJ/kg-K) enters the air compressor at a rate of 0.6 kg/s and conditions of 100 kPa and 300 K. The air is compressed to 1000 kPa and 550 K and then flows through an insulated heat exchanger, which reduces the air temperature to 310 K at the outlet. Water (ρ = 1000 kg/m^3; c = 4.18 kJ/kg-K) flows through the heat exchanger in the counterflow direction, entering at 300 K. The thermometer at the water outlet indicates 320 K.



The compressor is enclosed in a well-insulated cabinet to reduce noise and can be assumed adiabatic.

(a) **[15 pts]** Determine the compressor power.
(b) **[20 pts]** Determine the isentropic efficiency of the compressor.
(c) **[10 pts]** On a p-v diagram, sketch the process the air follows as it passes through the compressor. For reference, sketch and label the process the air would follow if the compressor were isentropic. Shade the area corresponding to the compressor work per unit mass for the isentropic process.

(d) **[15 pts]** Determine the mass flow rate of the water through the heat exchanger.
(e) **[10 pts]** Determine the entropy change of the air as it passes through the heat exchanger. Does the result violate the second law of thermodynamics? Explain.
(f) **[20 pts]** Determine the entropy generation within the heat exchanger. Does the heat exchanger violate the second law of thermodynamics? Explain.

One of your coworkers has proposed removing the insulated cabinet because it interferes with maintenance and because noise is not a concern. Another coworker says that insulation saves energy and the cabinet should be left in place.

(g) **[10 pts]** If the cabinet is removed will the compressor power (circle best answer):

INCREASE DECREASE STAY THE SAME

Justify your response.

Possibly useful information for an ideal gas:

$$pv = RT; \quad du = c_v dT; \quad dh = c_p dT; \quad ds = c_p \frac{dT}{T} - R\frac{dp}{p}; \quad ds = c_v \frac{dT}{T} + R\frac{dv}{v}$$

Possibly useful information for an incompressible liquid:

$$du = cdT; \quad dh = cdT + vdP$$