4.42 Final
December 14, 2004
Open Book

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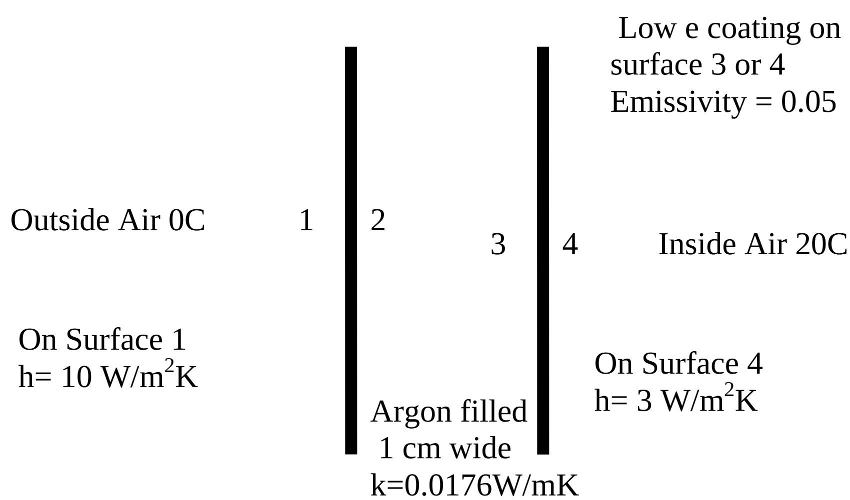
1(25). A double glazed window is filled with Argon gas with a conductivity of 0.0176W/mK. The two glass layers are 1 cm apart and convective motion within the Argon is negligible. A low emissivity coating is to be applied to the glass sheet adjacent to the room. The infrared emissivity is 0.05 for the low e coating. The other glass surfaces can be assumed to be black bodies. The low e coating can be applied on the surface, labeled 3, facing the outside glass or it can applied to the surface facing the room, labeled 4. You are asked to assess the comfort and energy implications of the choice. Take the air temperature inside the room as 20 $^{o}$C and the outside air as 0 $^{o}$C. The convective heat transfer coefficient between the inside glass and the room is 3 W/m$^2$K and the heat transfer coefficient from the outside glass to the outside air is 10 W/m$^2$K. Do all the work for night conditions so solar radiation can be ignored.

a) What is the inside glass temperature for the two cases with the different locations of the low e coating?

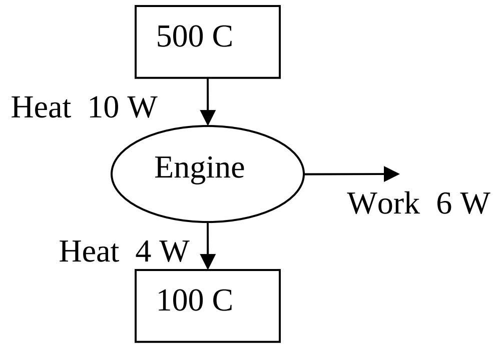
b) Which case leads to greater comfort for persons close to the glass surface (i.e. less radiation heat transfer)? Assume the person's skin and clothes are black bodies at 33$^{o}$C and are in the IR.

c) Which choice leads to less night heat loss through the window?

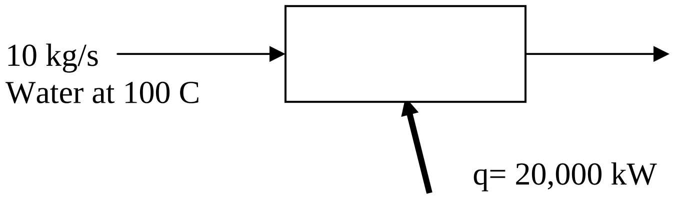


2 (25). For each case indicate if the system or process is possible or impossible
Briefly indicate the basis for your answer.

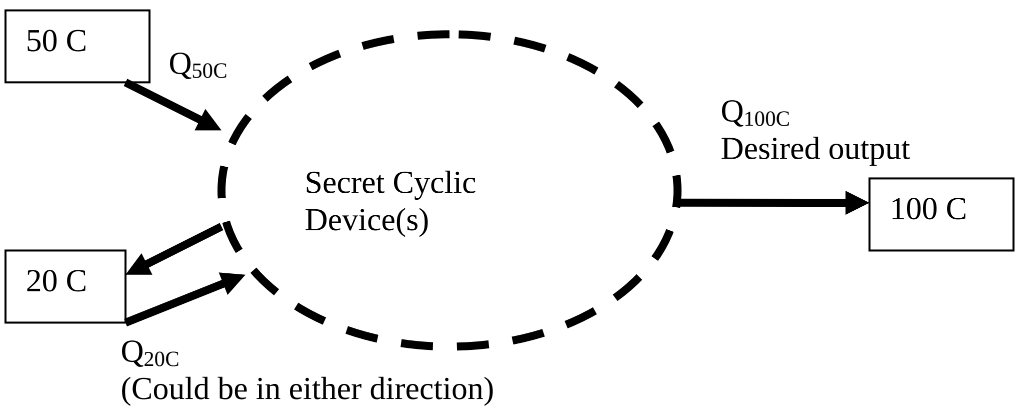
a) An engine operates in a cycle as shown



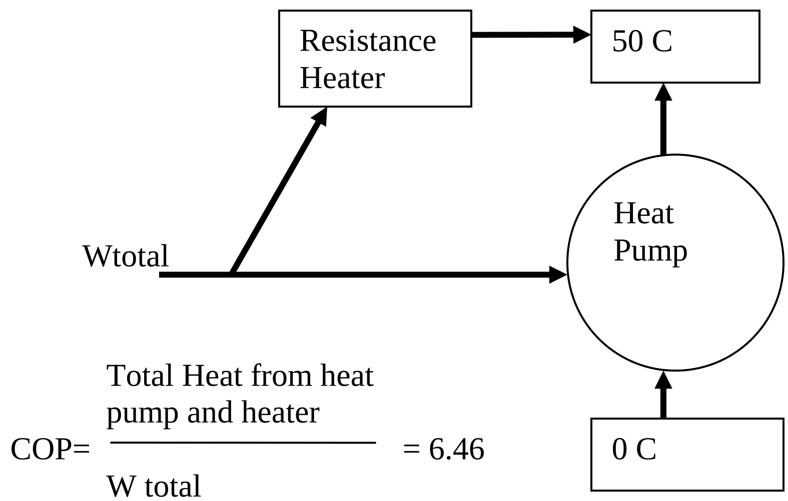

b) A steady state heat transfer process for water at constant temperature and pressure




c) Heat transfer between supplies at 50 C and 20 C are used to produce heat at 100 C using a secret device that operates in a cycle. (If this is possible, show a cyclic process.)



d) A heat pump supplies heat from 0 $^oC$ to 50 $^oC$. Part of the electrical energy is used with resistance heaters to supplement the 50 $^oC$ heat output. The COP, defined as [total heat output (from heat pump and resistance coil) at 50$^oC$] / [total electrical input] is 6.46.



3 (25). In your review of the proposed air-conditioning system design made by a partner firm for a new office-building project, you will need to make a few calculations. The building will be leased to a consulting firm, where each employee has their own 25 $m^2$ office with a window of 1$m^2$. The following heat inputs will be present in each office:

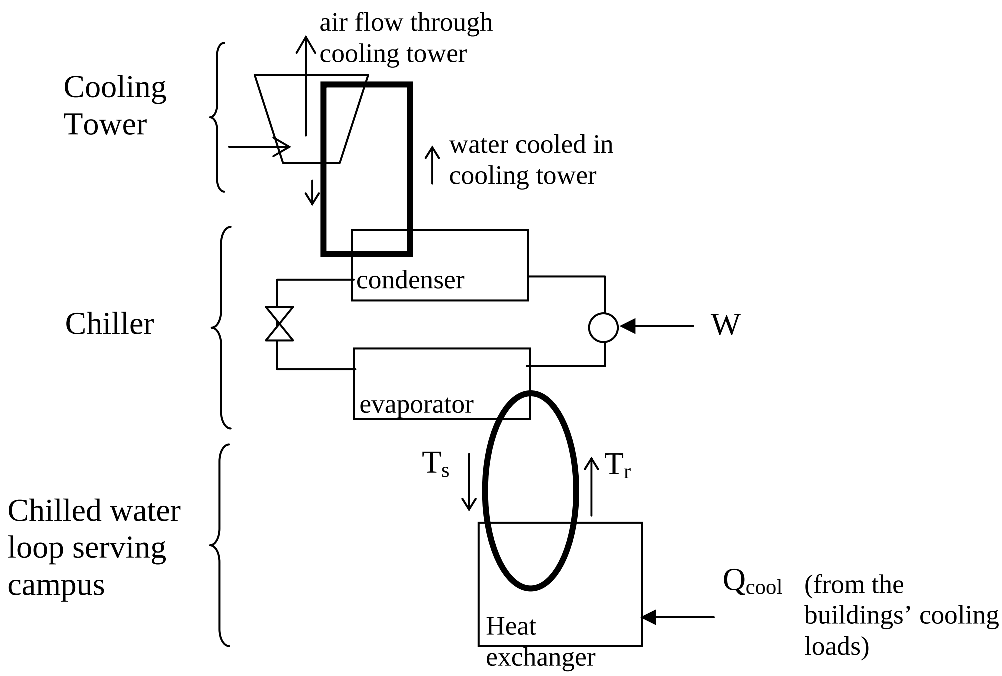
Lap-top computer (40 W)
Lighting (15 $W/m^2$)
1 person (75 W of sensible heat)
Solar heat gain through windows of 15 $W/m^2$ of window area at peak
Conductive heat gain/loss through exterior facade

The façade and wall construction have already been designed. The calculated overall heat transfer coefficient for the exterior facades (window and opaque area included) is 0.25 $W/m^2\text{-}^oC$. To keep the consultants comfortable, the thermostat will be set at 22$^o$C. For a warm summer day of 30$^o$C, 50% RH, you will need to calculate the following in your review:

a) Determine the peak rate of heat gain in a typical office on the warm summer day. Assume a center office, with only a single façade (10 $m^2$) exposed to the outdoor conditions. (All other faces of the office can be assumed to be adiabatic.) Also, draw the system and label the heat flows.
b) Determine the volumetric airflow rate to meet peak conditions by assuming that air will be supplied at 13$^o$C. Add the labels for heat flow via air-flow to your diagram from part (a).
c) If fresh air requirements are 10 L/s/person, what percentage of the required air-flow for cooling must consist of fresh, outdoor air?
d) Knowing that the outdoor condition is 30$^o$C, 50% RH, draw the conditioning process on the pyschrometric chart for bringing the outdoor air to the 13$^o$C, 50% RH input, or supply, state. Label the different parts of the process. Determine the amount of energy per kg of dry air to condition the outdoor air.

4 (25). The MIT Central Utilities Plant provides chilled water to buildings on campus for use in air-conditioning systems. The system is nearing peak capacity on hot summer days, and the proposed addition of a new building on campus means that the plant engineers must consider the necessity of adding another chiller and cooling tower. The decision will depend on the cooling loads of the new building and on the efficiency of the current equipment.

The current cooling tower, chiller, and chilled-water loop system is pictured below. On a hot day, the outdoor, ambient air is 30$^oC$ and 40% RH. The outdoor air is pulled through the cooling tower via a fan at a rate of 30 kg/s. The air exiting the cooling tower is 30$^oC$ and 100% RH. Water is cooled via the cooling tower to supply the condenser for the Central Plant's chiller. The mass flow rate of water in the cooling tower is 50 kg/s. Water enters the cooling tower at 38$^oC$ and exits at 32 $^oC$. The COP of the already highly-efficient chiller is 4.0. The chilled water loop serves the buildings. At each building site, a simple heat exchanger provides the means of conditioning the air.




a) What is the entire cooling load ($Q_{cool}$) that the current system can provide for?

b) What is the supply temperature ($T_s$) of the chilled water loop if the return temperature ($T_r$) is 15 $^oC$ and the mass flow rate is 100 kg/s.

c) If the chilled water loop is currently running at 90% capacity (i.e. 90% of the cooling calculated in part a is being demanded by existing buildings), how much energy for cooling will be available per square foot for the new 10,000 SF building?

4.42J / 1.044J / 2.66J Fundamentals of Energy in Buildings
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