Approach

The approach below gives a guideline in how to solve the problems presented during this course. Correctly applying this approach will lead to a good understanding of the concepts presented in this course.

Analysis

1. Explain the problem: which physical phenomena are important in this problem?
2. Make a sketch of the problem
3. Give the known variables (with the appropriate units!)

Approach

1. Explain the assumptions you make to solve the problem
2. Show the solution method for solving the problem

Elaboration

1. Show the calculation steps and explain the equations you use
2. Give references if values are found online or in tables

Evaluation

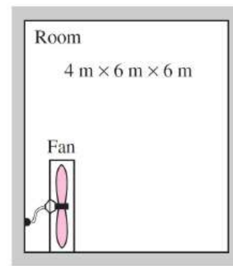
1. Check the units of your solution
2. Is the answer realistic/expected?
3. Did you answer all the questions asked?
4. Iterate if this is required

Lecture 2

2.1 Energy balance of a student room

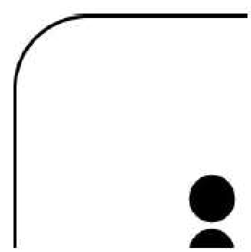
a) Consider two identical rooms, one with a refrigerator in it and the other without one. If all the doors and windows are closed, will the room that contains the refrigerator be cooler or warmer than the other room? Why?

b) A student living in a 4-m x 6-m x 6-m dormitory room turns her 150-W fan on before she leaves her room on a summer day hoping that the room will be cooler when she comes back in the evening. Assuming all the doors and windows are tightly closed and disregarding any heat transfer through the walls and the windows, determine the temperature in the room when she comes back 10 hours later. Use specific heat values at room temperature and assume the room to be at 15 °C in the morning when she leaves.



2.2 Shopping centre escalator

An escalator in a shopping centre is designed to move 30 people, 75 kg each, at a constant speed of 0.8 m/s at 45° slope. Determine the minimum power input needed to drive this escalator. What would be your answer if the escalator velocity were to be doubled?



2.3 Energy balance of a fitness centre

An exercise room of 20-m x 20-m x 3-m has eight weight-lifting machines that have no motors and four treadmills (NL: "loopband") each equipped with a 2.5-hp (NL: "paardenkracht") shaft output motor. The motors operate at an average load factor of 0.7, at which their efficiency is 0.77. During peak evening hours, all 12 pieces of exercising equipment are used continuously, and there are also two people doing light exercises while waiting in line for one piece of the equipment. Assume the average rate of heat dissipation from people in an exercise room is 300 W.

a) Determine the rate of heat gain of the exercise room from people and the equipment at peak load conditions.

b) The peak evening hours usually run from 18:00 – 22:00 (4 hours). At 18:00 the temperature in the room is 20 °C. Estimate the room temperature at the end of the evening disregarding all heat losses through the walls and windows.

c) Luckily, the fitness centre owner has installed an air-conditioning system. Calculate, using an energy balance, the required cooling power if the room temperature should not increase by more than 5 °C during the peak evening hours.

2.4 Microwave

A microwave can be used to heat up food and beverages. It is however unclear what a typical efficiency is. To determine this, the functioning of an 800 Watt microwave is examined.

a) How can the efficiency of a microwave be determined? Formulate a model and explain.

b) A 250 mL cup of milk at 20 °C is placed in a microwave. After two minutes the milk starts to boil. Determine what amount of energy has been transferred to the milk. Give the assumption(s) that you have to make to calculate this.

c) Determine the efficiency of this particular microwave.

To generate electricity, coal is burnt in a power plant. The overall efficiency of generating electricity by burning coal is around 50%.

d) Discuss what an efficiency of 50% means. In other words: how will this efficiency be defined?

Transmitting electricity through the electricity grid is not without loss. About 7% of the energy is lost on average.

e) What is the overall efficiency of heating up fluids if the efficiency in the power plant and transmission through high voltage lines is taken into account?

f) What does this number express? Explain in words.

2.5 Heat loss from an oven

After a long day with a lot of lectures, a student buys a pizza at the COOP supermarket and puts it in the oven. When the oven is operating at steady conditions, he measures the inside and outside surface temperatures of the glass panel in the oven door. They are 180 °C and 50 °C, respectively.

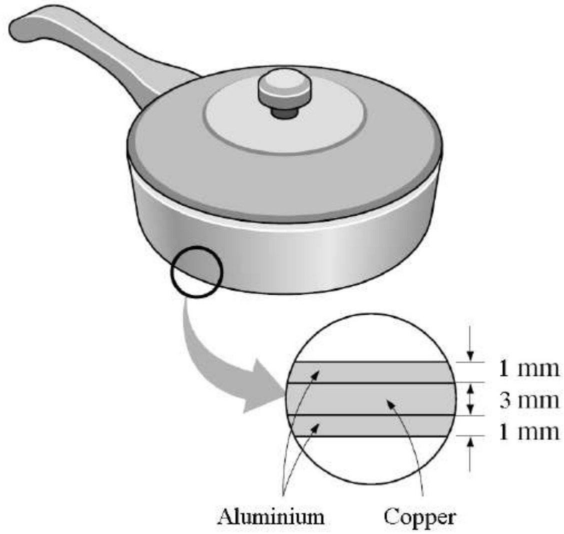
The glass window has a width of 0.25 m, a height of 0.15 m and a thickness of 5 mm. The thermal conductivity of glass is 0.70 $\mathrm{W\,m^{-1}\,K^{-1}}$. Determine the rate of heat loss through the glass panel of the oven door.

2.6 Heat conduction through the bottom of a pan

The bottom of a pan is made of a 4 mm thick aluminium layer. In order to increase the rate of heat transfer, someone proposes a design of the bottom that consists of a 3 mm thick copper layer sandwiched between two 1 mm thick aluminium layers. The thermal conductivity k of aluminium is 237 $\mathrm{W\,m^{-1}\,K^{-1}}$, for copper this is 390 $\mathrm{W\,m^{-1}\,K^{-1}}$.

a) Show by calculation whether the new design will conduct heat better or not.

b) Determine the maximum temperature of the copper layer when the pan bottom is 200 °C at its lower surface and 175 °C at its upper surface.



2.7 Temperature profiles

In the lecture sheets, the temperature profile in the wall of a hot water tube has been discussed.

a) Give a sketch of the temperature profile of the contrary situation: a tube with cold water in a warmer environment, like in a water boiler of a central heating system. Explain the shape of the profile, using theory of heat conduction.

b) Sketch the temperature profile in the cross section of a refrigerator door, consisting of two thin metal plates with an insulating (NL: isolerend) material in between.

2.8 Ski jacket - <u>Hand in</u>

Clothing made of several thin layers of fabric with trapped air in between, often called ski clothing, is commonly used in cold climates because it is light, fashionable, and a very effective thermal insulator. So it is no surprise that such clothing has largely replaced thick and heavy old-fashioned coats. Consider a jacket made of five layers of 0.10 mm thick synthetic fabric (k = 0.13 W/mK) with 1.5 mm thick air space (k = 0.026 W/mK) between the layers. Assume that the inner surface of the jacket is 28 °C, the surface area is 1.1 m^2 and the temperature at the outer surface of the jacket is -5 °C.

a) Sketch the temperature profile through the jacket.

b) Determine the rate of heat loss through the jacket.

c) What would be the rate of heat loss if the jacket is made of a single layer of 0.50 mm thick synthetic fabric?

d) What should be the thickness of a single layer of wool fabric (k = 0.035 W/mK) if the person is to achieve the same level of thermal comfort wearing a thick wool coat instead of a multilayer ski jacket?

e) Determine in which air or fabric layer the temperature is 0 °C.