

# 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

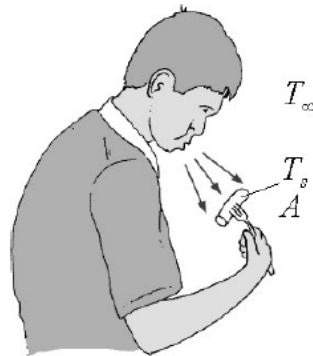
1. Check the units of your solution
2. Is the answer realistic/expected?
3. Did you answer all the questions asked?
4. Iterate if this is required

# Lecture 6

## 6.1 Blowing man with a carrot

A perfectly cylindrical carrot with a length of 7 cm and a diameter of 2 cm is cooled by a handsome young man blowing over it. The heat transfer coefficient  $h = 15 \text{ W m}^{-2} \text{ K}^{-1}$ . The thermal conductivity of the carrot is  $k = 0.80 \text{ W m}^{-1} \text{ K}^{-1}$ , the specific heat is  $c_p = 3.60 \text{ kJ kg}^{-1} \text{ K}^{-1}$  and the density is  $\rho = 1100 \text{ kg m}^{-3}$ . Initially, the carrot is at a uniform temperature of  $100^\circ \text{C}$  and the ambient temperature is  $20^\circ \text{C}$ .

- a) What is the temperature of the carrot after one minute of blowing?
- b) How long should the man blow to cool the carrot from  $100^\circ \text{C}$  to  $80^\circ \text{C}$ ?



## 6.2 Cooling a copper sphere

A solid copper sphere of 10 cm diameter (density  $\rho = 8954 \text{ kg m}^{-3}$  and  $c_p = 383 \text{ J kg}^{-1} \text{ K}^{-1}$  and  $k = 386 \text{ W m}^{-1} \text{ K}^{-1}$ ), initially at a uniform temperature  $T_i = 250^\circ \text{C}$ , is suddenly immersed in a well-stirred fluid maintained at a uniform temperature  $T_a = 50^\circ \text{C}$ . The heat transfer coefficient between the sphere and the fluid is  $h = 200 \text{ W m}^{-2} \text{ K}^{-1}$ . Determine the temperature of the copper block at  $t = 5 \text{ min}$  after the immersion.

## 6.3 Cooling a copper sphere under forced convection conditions - Hand in

One of the steps in material processing could be curing a material. Curing is a heat treatment process used to accelerate a chemical reaction.

In this case, a plastic film is wrapped around a copper sphere with a diameter of 10 mm, and is placed in an oven at  $75^\circ \text{C}$ . After removal from the oven, the sphere is exposed to an air stream at 10 m/s and  $23^\circ \text{C}$ .

Estimate the time taken to cool the sphere to  $35^\circ \text{C}$  using Lump theory. Use the correlation

$$\text{Nu} = 2 + \left[ 0.4(\text{Re})^{0.5} + 0.06(\text{Re})^{2/3} \right] (\text{Pr})^{0.4} \left( \frac{\mu_a}{\mu_s} \right)^{0.25}$$

for determination of correlation coefficient  $h$ . Use the following properties of air and copper:

- Copper:
  - $\rho = 8933 \text{ kg m}^{-3}$ ,  $k = 400 \text{ W m}^{-1} \text{ K}^{-1}$ ,  $c_p = 380 \text{ J kg}^{-1} \text{ K}^{-1}$
- For air at 23 °C
  - $\mu = 18.16 \cdot 10^{-6} \text{ N s m}^{-2}$ ,  $\nu = 15.36 \cdot 10^{-6} \text{ m}^2 \text{ s}^{-1}$
  - $k = 0.0258 \text{ W m}^{-1} \text{ K}$ ,  $\text{Pr}=0.709$
  - $\mu_s = 19.78 \cdot 10^{-6} \text{ N s m}^{-2}$  at 35 °C