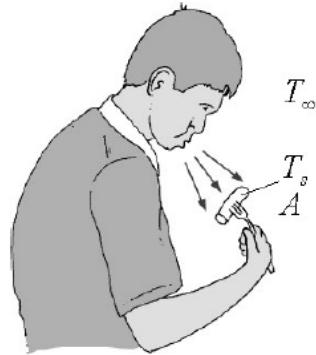


Lecture 7

7.1 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 °C and the ambient temperature is 20 °C.

- What is the temperature of the carrot after one minute of blowing?
- How long should the man blow to cool the carrot from 100 °C to 80 °C?



7.2 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 $T_i = 250 \text{ }^\circ\text{C}$, is suddenly immersed in a well-stirred fluid maintained at a uniform temperature $T_a = 50 \text{ }^\circ\text{C}$. 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.

7.3 Cooling a copper sphere under forced convection conditions

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 °C. After removal from the oven, the sphere is exposed to an air stream at 10 m/s and 23 °C.

Estimate the time taken to cool the sphere to 35 °C using Lump theory. Use the correlation

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

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
 - $\mu = 18.16 \cdot 10^{-6} \text{ N sm}^{-2}$, $\nu = 15.36 \cdot 10^{-6} \text{ m}^2 \text{ s}^{-1}$
 - $k = 0.0258 \text{ W m}^{-1} \text{ K}$, $Pr=0.709$
 - $\mu_s = 19.78 \cdot 10^{-6} \text{ N sm}^{-2}$ at 35 °C