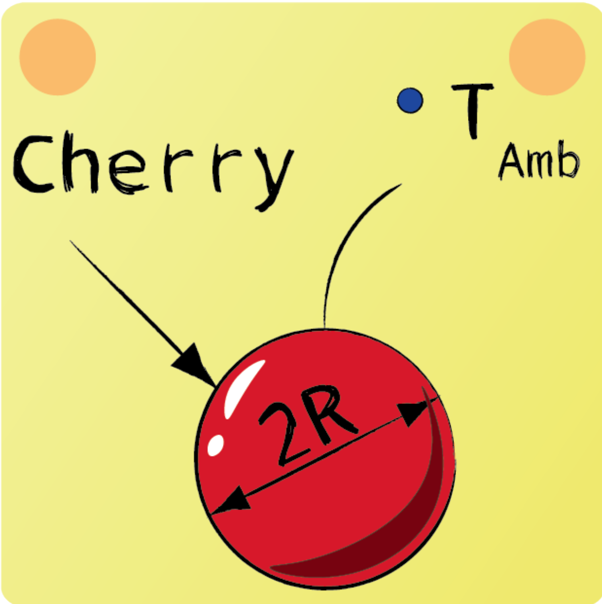
Exam Preparation Conduction 01



Consider a cherry with radius R. It gets in a freezer with a constant temperature T_{Amb}. The cherry has a homogeneous starting temperature of T_0. At what point in time does the cherry reach a temperature of $T = 0$ °C in its center?

The problem can be considered as a flow around a cylinder. Assuming still air(hence the flow velocity and Reynolds number being zero) yields the Nusselt number as follows:

$$\overline{Nu}_{\mathrm{d}} \approx 2 = \frac{\alpha \cdot 2 \cdot R}{\lambda}$$

The time to reach the desired temperature in the middle of the cherry can be determined using diagram 7 in the formulary and the already given temperature in the middle of the cherry. The following variables are required for this:

$$\frac{T_m - T_a}{T_o - T_a} = \frac{0°\mathrm{C} - (-20°\mathrm{C})}{20°\mathrm{C} - (-20°\mathrm{C})} = 0,5$$

The thermal conductivity of the air at $-20°\mathrm{C}$ can be taken from the formulary:

$$\lambda = 22,6 \cdot 10^{-3} \frac{W}{m \cdot K}$$

$$\alpha = \frac{2 \cdot \lambda}{2 \cdot R}$$

$$\frac{1}{Bi} = \frac{\lambda_C}{\alpha \cdot R} = \frac{0,36 \frac{W}{m \cdot K}}{2,26 \frac{W}{m^2 \cdot K} \cdot 0,01m} = 16$$

Using diagram 7 with $\frac{T_m - T_a}{T_o - T_a} = 0,5$ and $\frac{1}{Bi} = 16$ the Fourier number can be determined to $Fo = 4$.

$$Fo = 4 = \frac{a \cdot t}{R^2} = \frac{\lambda \cdot t}{\rho \cdot c_{\mathrm{p}} \cdot R^2}$$

This yields the time t to reach the temperature in the middle of the cherry.

$$t = \frac{4 \cdot R^2 \cdot \rho \cdot c_{\mathrm{p}}}{\lambda} = 4657s = 1,29h$$