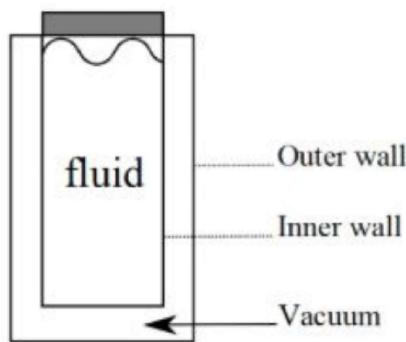


## Exam Preparation - Radiation 2



A thermos flask can be used to keep drinks cool. The flask has two walls separated by a vacuum so as to minimize heat transfer by convection. For a day of hiking you take along your aluminium vacuum flask with a cold soda. At the start of the hike the soda is at a temperature of 6 °C. Between the two walls, i.e. inside the vacuum compartment, heat is transferred by radiation only. The problem can be considered as a two surface enclosure. Let the outside wall temperature be 30 °C. The flask has an inner diameter of 3 cm, an inner height of 20 cm and an outer diameter of 5 cm and an outer height of 22 cm. Assume that the walls behaves as a black body and that the fluid has the properties of water.

- A)** Determine the view factor  $\Phi_{oi}$  from the outer wall to the inner wall.
- B)** Compute the net rate of heat transfer by radiation from the outer wall to the inner wall at the given temperatures.
- C)** Use your answer given at **B)** to estimate the time to heat up the soda by 1 degree Celsius.

Thermos flask. Given: all dimensions and temperatures:

$$D_i = 3 \cdot 10^{-2} \text{ m}$$

$$D_o = 5 \cdot 10^{-2} \text{ m}$$

$$L_i = 20 \cdot 10^{-2} \text{ m}$$

$$L_i = 22 \cdot 10^{-2} \text{ m}$$

Question: how much heat is going from outside to inside the heat beverage and how quickly does it heat up one degree?

Strategy: Assume a 2 surface enclosure:

$$\dot{Q}_{oi} = A_o \Phi_{oi} \sigma (T_o^4 - T_i^4)$$

Determine view factor → use summation rule and reciprocity rule.

Assume them to be black surfaces.

Time to heat up one degree =  $\dot{Q}$



a) Summation rule:  $\Phi_{oo} + \Phi_{oi} = 1$

Inside does not radiate onto itself:  $\{\Phi_{ii} = 0, \Phi_{io} = 1\}$

$$\Phi_i F_{io} = \Phi_o \Phi_{oi}$$

$$\Rightarrow \Phi_{oi} = \frac{A_i \Phi_{io}}{A_o} = \frac{A_i}{A_o}$$

$$A_i = \pi D_i L_i + \frac{\pi}{4} D_i^2 = \pi 0.03 \cdot 20 \cdot 10^{-2} + \frac{\pi}{4} 0.03^2 = 0.01885 + 7.06 \cdot 10^{-4} = 0.0196 \text{ m}^2$$

$$A_o = \pi D_o L_o + \frac{\pi}{4} D_o^2 = \pi 0.05 \cdot 22 \cdot 10^{-2} + \frac{\pi}{4} 0.05^2 = 3.77 \cdot 10^{-2} = 0.0377 \text{ m}^2$$

$$\Phi_{oi} = \frac{A_i}{A_o} = \frac{0.0196}{0.0377} = 0.530$$

b)  $\dot{Q}_{rad} = \dot{Q}_{oi} = \Phi_{oi} A_o \sigma (T_o^4 - T_i^4) = 3.77 \cdot 10^{-2} \cdot 0.53 \cdot 5.67 \cdot 10^{-8} (303^4 - 279^4) = 2.69 \text{ W}$

c) Energy to heat up 1 degree:

$$Q_{heating} = m C_p \Delta T$$

$$m = \rho V = 9.999 \text{ kg/m}^3 \cdot \frac{\pi}{4} D_i^2 L_i = 1.41 \cdot 10^{-4} \text{ m}^3 \Rightarrow m = 0.14 \text{ kg}$$

$$C_p = 4217 \text{ J/kgK}$$

$$\Rightarrow Q_{heating} = 0.14 \cdot 4217 \cdot 1 = 596 \text{ W}$$

$$\text{Heating time: } \frac{Q_{heating}}{\dot{Q}_{rad}} = \frac{596}{2.631} = 226.6 \text{ s} = 3 \text{ min and } 46 \text{ sec}$$