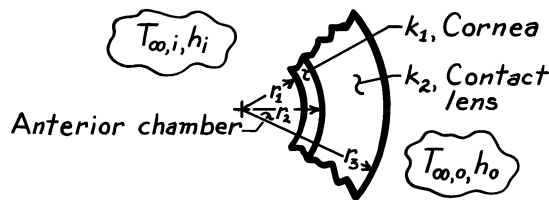


PROBLEM 3.73

KNOWN: Representation of the eye with a contact lens as a composite spherical system subjected to convection processes at the boundaries.

FIND: (a) Thermal circuits with and without contact lens in place, (b) Heat loss from anterior chamber for both cases, and (c) Implications of the heat loss calculations.

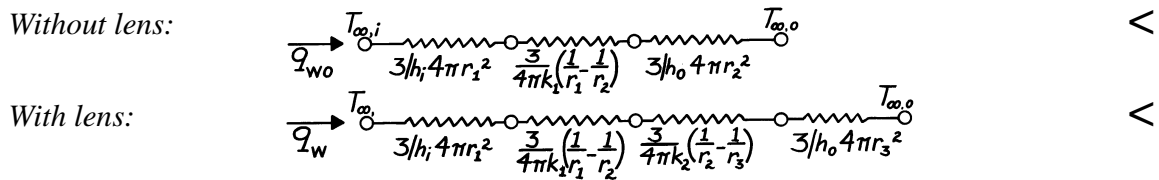
SCHEMATIC:



$$\begin{aligned} r_1 &= 10.2 \text{ mm} & k_1 &= 0.35 \text{ W/m}\cdot\text{K} \\ r_2 &= 12.7 \text{ mm} & k_2 &= 0.80 \text{ W/m}\cdot\text{K} \\ r_3 &= 16.5 \text{ mm} \\ T_{\infty,i} &= 37^\circ\text{C} & h_i &= 12 \text{ W/m}^2\cdot\text{K} \\ T_{\infty,o} &= 21^\circ\text{C} & h_o &= 6 \text{ W/m}^2\cdot\text{K} \end{aligned}$$

ASSUMPTIONS: (1) Steady-state conditions, (2) Eye is represented as 1/3 sphere, (3) Convection coefficient, h_o , unchanged with or without lens present, (4) Negligible contact resistance.

ANALYSIS: (a) Using Eqs. 3.9 and 3.41 to express the resistance terms, the thermal circuits are:



(b) The heat losses for both cases can be determined as $q = (T_{\infty,i} - T_{\infty,o})/R_t$, where R_t is the thermal resistance from the above circuits.

$$\begin{aligned} \text{Without lens: } R_{t,wo} &= \frac{3}{12 \text{ W/m}^2 \cdot \text{K} 4\pi (10.2 \times 10^{-3} \text{ m})^2} + \frac{3}{4\pi \times 0.35 \text{ W/m}\cdot\text{K} \left[\frac{1}{10.2} - \frac{1}{12.7} \right]} \frac{1}{10^{-3}} \text{ m} \\ &+ \frac{3}{6 \text{ W/m}^2 \cdot \text{K} 4\pi (12.7 \times 10^{-3} \text{ m})^2} = 191.2 \text{ K/W} + 13.2 \text{ K/W} + 246.7 \text{ K/W} = 451.1 \text{ K/W} \end{aligned}$$

$$\begin{aligned} \text{With lens: } R_{t,w} &= 191.2 \text{ K/W} + 13.2 \text{ K/W} + \frac{3}{4\pi \times 0.80 \text{ W/m}\cdot\text{K} \left[\frac{1}{12.7} - \frac{1}{16.5} \right]} \frac{1}{10^{-3}} \text{ m} \\ &+ \frac{3}{6 \text{ W/m}^2 \cdot \text{K} 4\pi (16.5 \times 10^{-3} \text{ m})^2} = 191.2 \text{ K/W} + 13.2 \text{ K/W} + 5.41 \text{ K/W} + 146.2 \text{ K/W} = 356.0 \text{ K/W} \end{aligned}$$

Hence the heat loss rates from the anterior chamber are

$$\text{Without lens: } q_{wo} = (37 - 21)^\circ\text{C} / 451.1 \text{ K/W} = 35.5 \text{ mW} \quad <$$

$$\text{With lens: } q_w = (37 - 21)^\circ\text{C} / 356.0 \text{ K/W} = 44.9 \text{ mW} \quad <$$

(c) The heat loss from the anterior chamber increases by approximately 20% when the contact lens is in place, implying that the outer radius, r_3 , is less than the critical radius.