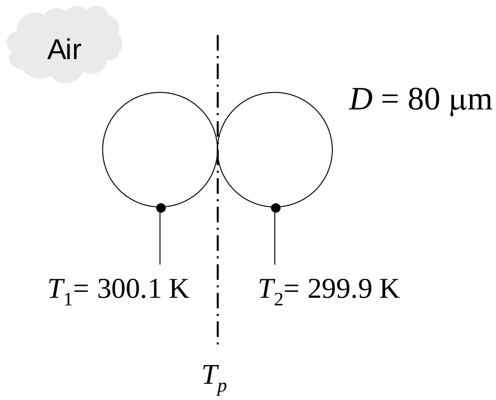
PROBLEM 4.11

KNOWN: Diameters and temperatures of spherical particles that are in contact.

FIND: Heat transfer rate.

SCHEMATIC:



ASSUMPTIONS: (1) Constant properties, (2) Isothermal particles.

PROPERTIES: Table A.4, Air (300 K): k = 0.0263 W/m·K.

ANALYSIS: By symmetry, the vertical plane at the particle contact point is at temperature $T_p = (T_1 + T_2)/2$ = 300 K. Therefore, conduction between the particles q_{12} is equal to conduction from particle 1 to the plane, $q_{1p} = Sk(T_1 - T_p)$. The shape factor is that of Case 1 of Table 4.1 evaluated at $z = D/2$ yielding $S = 4\pi D$. Therefore,

$$q_{12} = q_{1p} = 4\pi Dk\left(T_1 - \frac{T_1 + T_2}{2}\right) = 4\pi \times 80 \times 10^{-6}\,\text{m} \times 0.0263\ \text{W/m} \cdot \text{K} \times 0.1\ \text{K} = 2.6 \times 10^{-6}\ \text{W} = 2.6\mu\text{W} \quad <$$

COMMENTS: (1) The air thermal conductivity in the vicinity of the contact point would be reduced by nanoscale effects such as those described in Chapter 2. In applying the shape factor of Case 1 of Table 4.1 to the $z = D/2$ situation we have implicitly assumed that nanoscale effects are negligible. See B. Gebhart, *Heat Conduction and Mass Diffusion*, McGraw-Hill, 1993 for an appropriate treatment of nanoscale phenomena for this geometry. (2) The effective thermal conductivity of porous media composed of high thermal conductivity particles, such as packed metal powder layers, may be estimated by accounting for the particle size and packing distribution and using an analysis such as the one presented here.