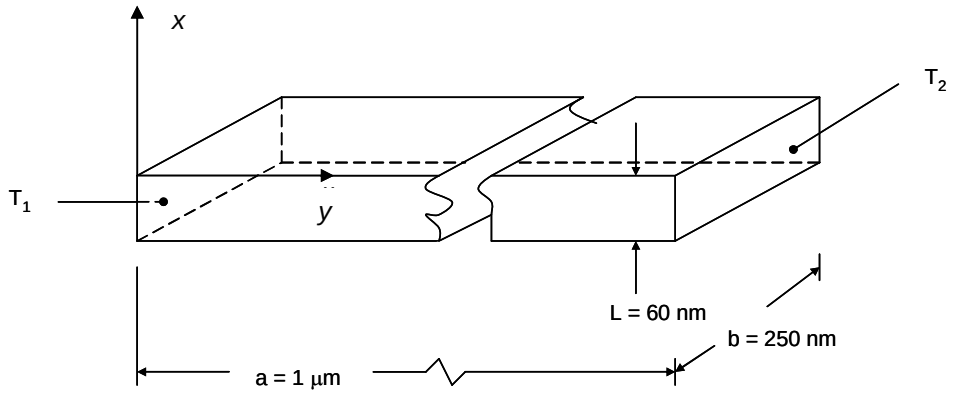
PROBLEM 3.178

KNOWN: Dimensions of and temperature difference applied across thin gold film.

FIND: (a) Energy conducted along the film, (b) Plot the thermal conductivity along and across the thin dimension of the film, for film thicknesses $30 \le L \le 140$ nm.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional conduction in the x- and y-directions, (2) Steady-state conditions, (3) Constant properties, (4) Thermal conductivity not affected by nanoscale effects associated with 250 nm dimension.

PROPERTIES: Table A.1, gold (bulk, 300 K): $k = 317$ W/m·K.

ANALYSIS:
a) From Fourier's law,

$$q_y = -kA\frac{dT}{dy} = k_y Lb\left[\frac{T_1 - T_2}{a}\right] \tag{1}$$

From Eq. 2.9b,

$$k_y = k\left[1 - 2\lambda_{mfp} / (3\pi L)\right] \tag{2}$$

Combining Eqs. (1) and (2), and using the value of $\lambda_{mfp} = 31$ nm from Table 2.1 yields

$$q_y = k[1 - 2\lambda_{mfp} / (3\pi L)]Lb\left[\frac{T_1 - T_2}{a}\right]$$

$$= 317\frac{W}{m\cdot K} \times \left[1 - \frac{2\times 31\times 10^{-9}\ m}{3\times\pi\times 60\times 10^{-9}\ m}\right] \times 60 \times 10^{-9} m \times 250 \times 10^{-9} m \times \frac{20°C}{1 \times 10^{-6}\ m}$$

$$= 85 \times 10^{-6}\ W = 85\ \mu W \quad <$$

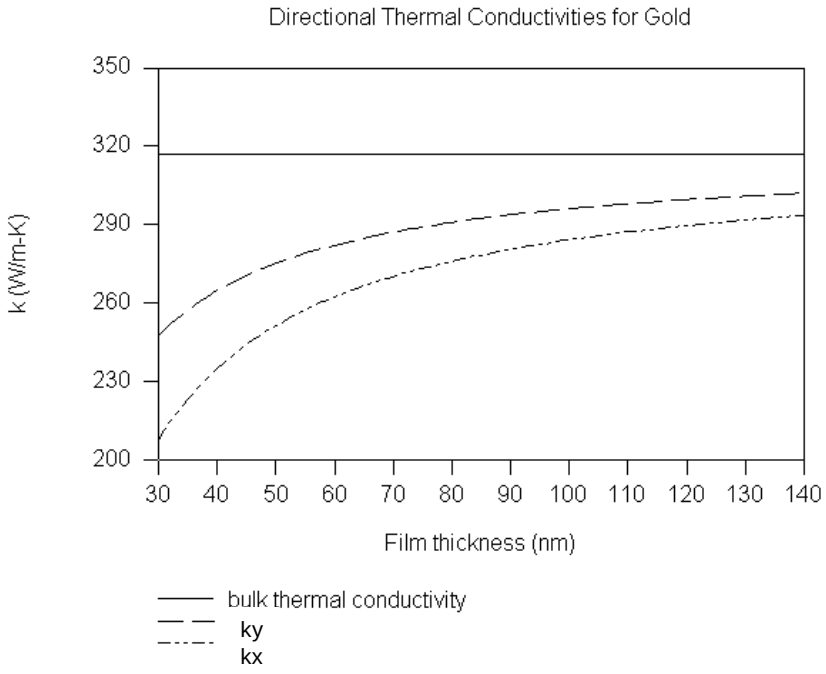
(b) The spanwise thermal conductivity may be found from Eq. 2.9a,

$$k_x = k[1 - \lambda_{mfp} / (3L)] \tag{3}$$

Continued…

PROBLEM 3.178 (Cont.)

The plot is shown below.



COMMENT: Nanoscale effects become less significant as the thickness of the film is increased.