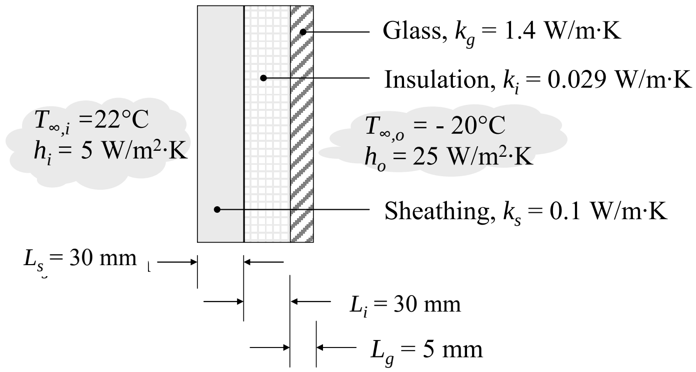
PROBLEM 3.5

KNOWN: Thermal conductivities and thicknesses of original wall, insulation layer, and glass layer. Interior and exterior air temperatures and convection heat transfer coefficients.

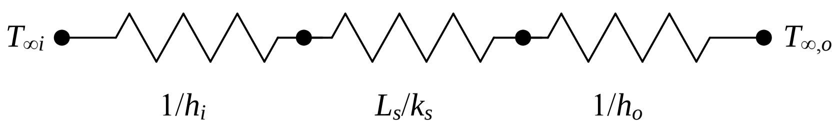
FIND: Heat flux through original and retrofitted walls.

SCHEMATIC:



ASSUMPTIONS: (1) One-dimensional conduction, (2) Steady-state conditions, (3) Constant properties, (4) Negligible contact resistances.

ANALYSIS: The original wall with convection inside and outside can be represented by the following thermal resistance network, where the resistances are each for a unit area:



Thus the heat flux can be expressed as

$$q'' = \frac{T_{\infty,i} - T_{\infty,o}}{\dfrac{1}{h_i} + \dfrac{L_s}{k_s} + \dfrac{1}{h_o}} = \frac{22°\text{C} - (-20°\text{C})}{\dfrac{1}{5\ \text{W/m}^2\cdot\text{K}} + \dfrac{0.030\ \text{m}}{0.1\ \text{W/m}\cdot\text{K}} + \dfrac{1}{25\ \text{W/m}^2\cdot\text{K}}} = 77.8\ \text{W/m}^2$$

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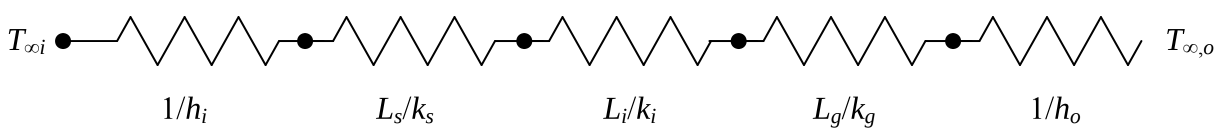
The retrofitted wall has three layers. The thermal circuit can be represented as follows:



Thus the heat flux can be expressed as

$$q'' = \frac{T_{\infty,i} - T_{\infty,o}}{\dfrac{1}{h_i} + \dfrac{L_s}{k_s} + \dfrac{L_i}{k_i} + \dfrac{L_g}{k_g} + \dfrac{1}{h_o}}$$

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$$= \frac{22°\text{C} - (-20°\text{C})}{\dfrac{1}{5\ \text{W/m}^2\cdot\text{K}} + \dfrac{0.030\ \text{m}}{0.1\ \text{W/m}\cdot\text{K}} + \dfrac{0.030\ \text{m}}{0.029\ \text{W/m}\cdot\text{K}} + \dfrac{0.005\ \text{m}}{1.4\ \text{W/m}\cdot\text{K}} + \dfrac{1}{25\ \text{W/m}^2\cdot\text{K}}} = 26.6\ \text{W/m}^2$$

COMMENTS: The heat flux has been reduced to approximately one-third of the original value because of the increased resistance, which is mainly due to the insulation layer.