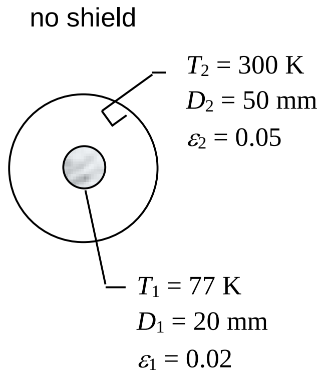
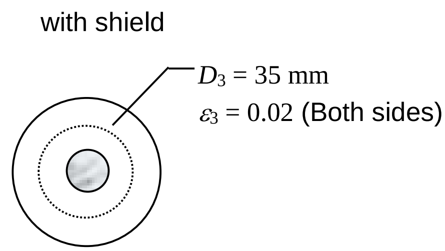
Example

A cryogenic fluid flows through a long tube of 20 mm diameter, the outer surface of which is diffuse and gray with $\varepsilon_1 = 0.02$ and $T_1 = 77$ K. (Ooh, that's cold!) The tube is concentric with a larger tube of 50 mm diameter, the inner surface of which is diffuse and gray with $\varepsilon_2 = 0.05$ and $T_2 = 300$ K. The space between the surfaces is evacuated. If the tube is 1 m long (into the paper)

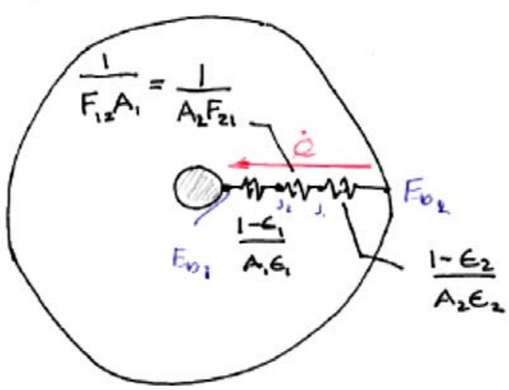
(a) calculate the heat gain by the cryogenic fluid.
(b) If a thin radiation shield of 35 mm diameter and $\varepsilon_3 = 0.02$ on both sides is inserted midway between the inner and outer surfaces, calculate the heat gain by the cryogenic fluid. What is the percentage change in heat gain?





L = Length into page.
= 1 m (for "per unit length")

a)



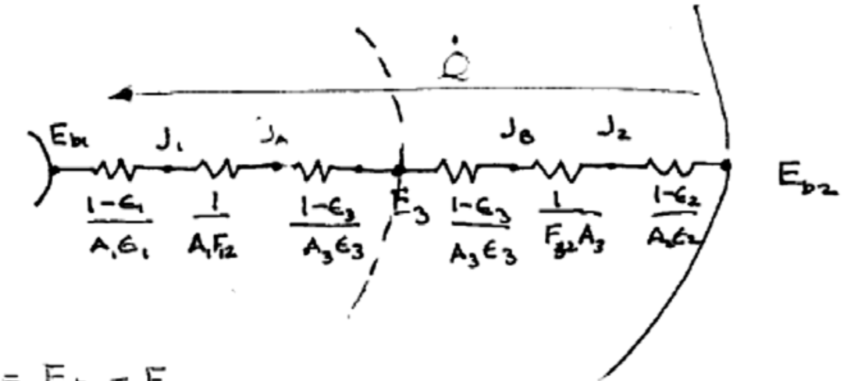
$$\dot{Q} = \frac{E_{b2} - E_{b1}}{\frac{1-\epsilon_2}{A_2\epsilon_2} + \frac{1}{F_{12}A_1} + \frac{1-\epsilon_1}{A_1\epsilon_1}}$$

NOTE THAT $F_{12} = 1$

$$\dot{Q} = \frac{\sigma T_2^4 - \sigma T_1^4}{\frac{1-\epsilon_2}{\pi D_2 L \cdot \epsilon_2} + \frac{1}{(1)(\pi D_1 L)} + \frac{1-\epsilon_1}{\pi D_1 L \cdot \epsilon_1}}$$

$\dot{Q} = \ldots =$ **0.499 W**

b) RADIATION SHIELD ADDS SEVERAL MORE RESISTANCES



$$\dot{Q} = \frac{E_{b_2} - E_{b_1}}{\frac{1-\epsilon_2}{A_2\epsilon_2} + \frac{1}{F_{32}A_3} + \frac{1-\epsilon_3}{A_3\epsilon_3} + \frac{1-\epsilon_3}{A_3\epsilon_3} + \frac{1}{A_1F_{12}} + \frac{1-\epsilon_1}{A_1\epsilon_1}}$$

$$= \frac{\sigma T_2^4 - \sigma T_1^4}{\frac{1-\epsilon_2}{\pi D_2 L\epsilon_2} + \frac{1}{(1)\pi D_3 L} + \frac{1-\epsilon_3}{\pi D_3 L\epsilon_3} + \frac{1-\epsilon_3}{\pi D_3 L\epsilon_3} + \frac{1}{\pi D_1 L(1)} + \frac{1-\epsilon_1}{\pi D_1 L\epsilon_1}}$$

$= \ldots$ **0.252 W**

$\dot{Q}_{decrease} \doteq 50\%$