ROSE-HULMAN Institute of Technology
DEPARTMENT OF MECHANICAL ENGINEERING

ME302-Heat transfer
Quiz 8

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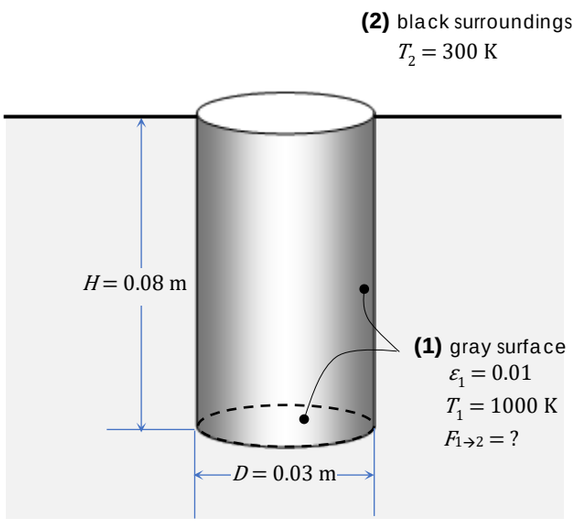
Name

Grade: _____/20

Problem 1 [20 pts]

A circular hole of diameter D=3.0 cm and depth H=8.0 cm has been cut into a highly reflective material (ε=0.01). The material is maintained at a constant temperature of T_1=1000 K, while the surroundings are modeled as black at T_2=300 K.



(a) [5 pts] *Without using any figures or tables* (i.e., using only inspection and the rules of view factor algebra) find the view factor from surface (1) to surface (2), $F_{1\to2}$.

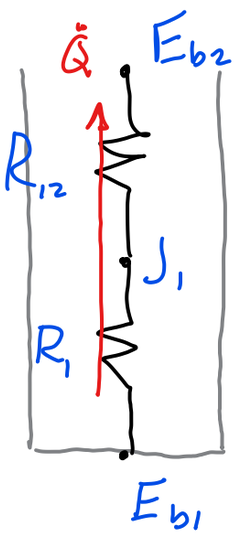
$F_{2\to1} = 1$

$A_1 F_{1\to2} = A_2 F_{2\to1}$ (RECIPROCITY)

$$F_{1\to2} = \frac{A_2}{A_1} F_{2\to1} = \frac{\frac{\pi}{4}D^2}{\left(\frac{\pi D}{4}\right)^2 + \pi D H} \quad (1)$$

$$= \frac{D}{D + 4H} = \frac{0.03\ \text{m}}{(0.03 + 4\cdot 0.08)\ \text{m}} = 0.0857$$ ← ANS

(b) [10 pts] Assume the answer to part (a) is $F_{1\to2}$=0.07. (It isn't.) Find the net rate of radiation heat transfer to or from surface (1) and indicate its direction.



$$\dot{Q} = \frac{E_{b1} - E_{b2}}{R_1 + R_{12}}$$

$$R_1 = \frac{1-\varepsilon_1}{A_1 \varepsilon_1} = \frac{1-0.01}{\left(\frac{\pi 0.03^2}{4} + \pi\cdot 0.03\cdot 0.08\right)\text{m}^2} = 12005\ \text{m}^{-2}$$

$$R_{12} = \frac{1}{A_1 F_{12}} = \frac{1}{\left(\frac{\pi\cdot 0.03^2}{4} + \pi\cdot 0.03\cdot 0.08\right)\text{m}^2 \cdot 0.07} = 1732\ \text{m}^{-2}$$

$$\dot{Q} = \frac{\sigma(T_1^4 - T_2^4)}{R_1 + R_{12}}$$

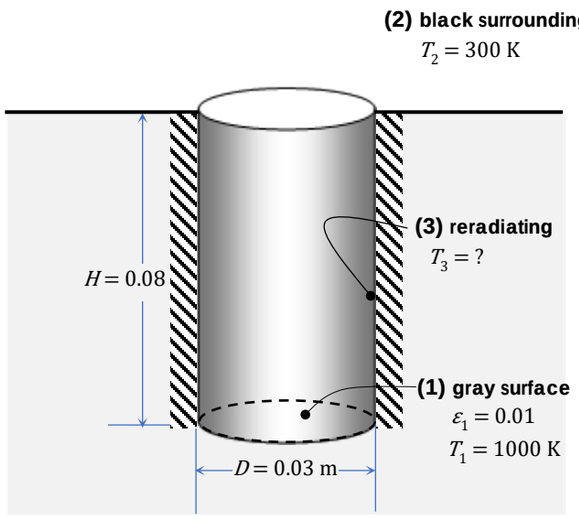
$$= \frac{5.67\times10^{-8}\ \frac{W}{m^2 K^4}\left(1000^4 - 300^4\right) K^4}{(12005 + 1732)\ \frac{1}{m^2}}$$

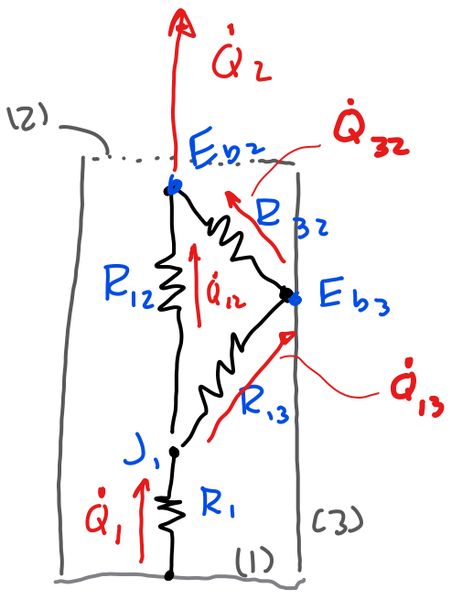
$$= 4.09\ W$$ ← ANS

(c) [5 pts] Rather than treating the sides and bottom of the hole as a single surface, the sides of the hole are modeled as a separate, *reradiating* surface.

In the space below, draw a new resistor network that could be used to solve for unknown temperatures, rates of heat transfer, etc. Label *all* node "voltages," resistors, and "currents" in the figure.

Assume all surface areas and view factors are known.





NOTE THAT $\dot{Q}_3 = 0$ SINCE IT IS RERADIATING. SURFACE RESISTANCE R_3 THEREFORE NOT NEEDED.

$R_1 = (1-\varepsilon_1)/(\varepsilon_1 A_1)$

$R_{12} = 1/A_1 F_{12}$

$R_{13} = 1/A_1 F_{13}$

$R_{32} = 1/A_3 F_{32}$

Bonus [+1 pt, no penalty for failure to answer]

If you were to solve the equations resulting from part (c), could you do it without having been given the value of ε_3? Explain your answer.