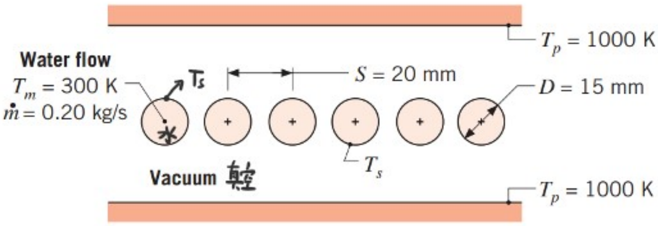
ME 320 Homework 9

13.37 Water flowing through a large number of long, circular, thin-walled tubes is heated by means of hot parallel plates above and below the tube array. The space between the plates is evacuated, and the plate and tube surfaces may be approximated as blackbodies.

Hint: Need to consider internal flow in each pipe. Thin wall means no need to consider the conduction resistance of the pipe wall. Need to find the view factor from the table. The final equation involving T_s cannot be solved easily, need to trial-and-error a value of T_s and repeat until the difference in temperature before the current and previous run is less than a 1 K.



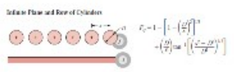
(a) Neglecting axial variations, determine the tube surface temperature, T_s, if water flows through each tube at a mass rate of $\dot{m} = 0.20$ kg/s and a mean temperature of $T_m = 300$ K.

根据 Table A-6，假 $\bar{T} = T_m = 300K$ 时

$\mu_{水} = 855 \times 10^{-6}\ Ns/m^2$

$k_{水} = 0.613\ W/m \cdot K$

$P_r = 5.83$

计算辐射角系数 

$$F_{p-s} = 1 - \left[1 - \left(\frac{D}{S}\right)^2\right]^{\frac{1}{2}} + \left(\frac{D}{S}\right) \cdot \tan^{-1}\left[\sqrt{\frac{S^2 - D^2}{D^2}}\right]$$

$$= 1 - \left[1 - \left(\frac{3}{4}\right)^2\right]^{\frac{1}{2}} + \frac{3}{4} \cdot \tan^{-1}\left[\sqrt{\frac{7}{9}}\right]$$

$$= 0.88$$

计算雷诺数 $Re = \frac{u \cdot D}{\mu} = \frac{4\dot{m}}{\pi D \mu} = 19855.58$

计算努塞尔数 $Nu = 0.023\, Re^{\frac{4}{5}}\, Pr^{\frac{2}{5}} = 128$

计算传热系数 $h = \frac{k}{D} \cdot Nu = \frac{0.613\ W/m \cdot K}{0.015m} \times 128$

$= 5230\ W/m^2 \cdot K$

单根水管的能量守恒

$q_{辐射} = q_{对流}$

$$A_p \cdot F_{p-s} \cdot \sigma \cdot (T_p^4 - T_s^4) = h \cdot A_s \cdot (T_s - T_m)$$

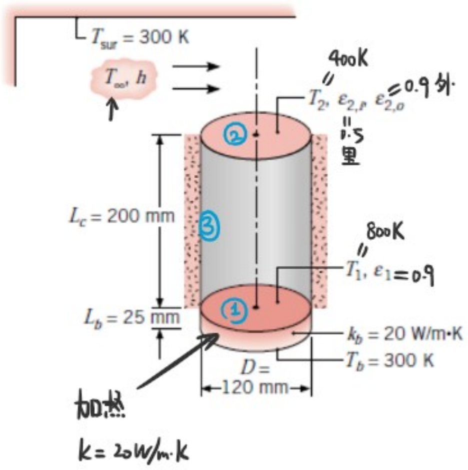
$\Downarrow$

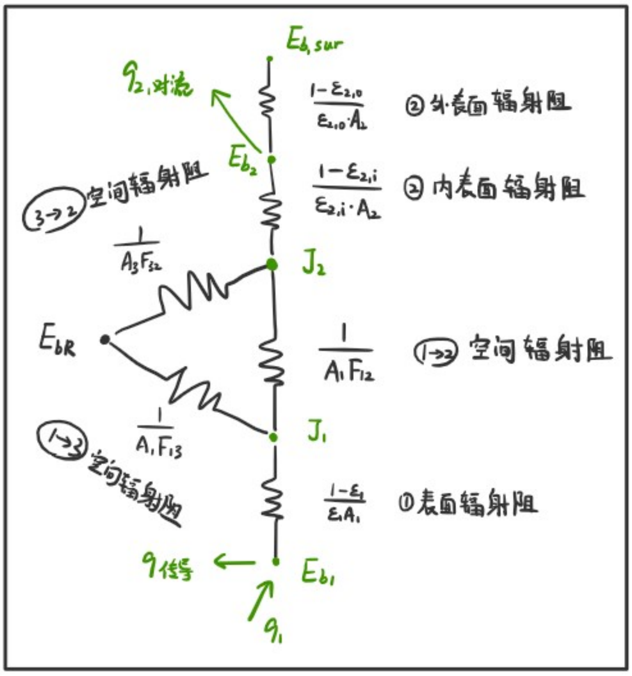
$\boxed{T_s = 308\ K}$

要迭代 $T_f = \frac{T_m + T_s}{2}$ 吗？

13.96 Coated metallic disks are cured by placing them at the top of a cylindrical furnace whose bottom surface is electrically heated and whose sidewall may be approximated as a $\boxed{\text{reradiating}}$ surface. Curing is accomplished by maintaining a disk at $T_2 = 400$ K for an extended period. The electrically heated surface is maintained at $T_1 = 800$ K and is mounted on a ceramic base material of thermal conductivity $k = 20$ W/m · K. The bottom of the base material, as well as the ambient air and large surroundings above the disk, are maintained at a temperature of 300 K. Emissivities of the heater and the disk inner and outer surfaces are $\varepsilon_1 = 0.9$, $\varepsilon_{2,i} = 0.5$, and $\varepsilon_{2,o} = 0.9$, respectively.

Assuming steady-state operation and neglecting convection within the cylindrical cavity, determine the electric power that must be supplied to the heater and the convection coefficient h that must be maintained at the outer surface of the disk in order to satisfy the prescribed conditions.





Note: There is heat generation and heat conduction at the bottom of the cylinder. There is only radiation insider the cylinder. There is convection and radiation on the top of the cylinder.

根据波兹曼定律

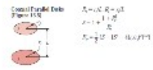
$$E_{b_1} = \sigma T_1^4$$

$$E_{b_2} = \sigma T_2^4$$

根据热阻分析

$$q_1 = \frac{E_{b_1} - E_{b_2}}{\frac{1-\varepsilon_1}{\varepsilon_1 A_1} + \frac{1-\varepsilon_{2,i}}{\varepsilon_{2,i} A_2} + \left[\left(\frac{1}{A_1F_{12}}\right)^{-1} + \left(\frac{1}{A_1F_{13}} + \frac{1}{A_2F_{23}}\right)^{-1}\right]^{-1}} + k\cdot A\cdot\frac{\Delta T}{\Delta x}$$

根据角系数公式



~~F_{11}~~	$F_{21} = F_{12}$ $=0.0768$	F_{31}
$F_{12}=0.0768$	~~F_{22}~~	F_{32}
$F_{13}=1-F_{12}$ $=0.923$	$F_{23}=1-F_{21}$ $=0.923$	F_{33}

$$F_{12} = \frac{1}{2}\left(S - \sqrt{S^2 - 4\left(\frac{r_2}{r_1}\right)^2}\right)$$

$$= \frac{1}{2}\left(13.1 - \sqrt{13.1^2 - 4}\right) = 0.0768$$

$$F_{13} = 1 - F_{12} = 0.923$$

$$F_{23} = 1 - F_{21} = 1 - F_{12} = 0.923$$

$$\therefore q_1 = 4521\,W + 82.9\,W = \boxed{4604\ W}$$

$$q_{辐射} = q_{对流} + \frac{E_{b_2} - E_{sur}}{\frac{1-\varepsilon_{2,o}}{\varepsilon_{2,o}\cdot A_2}}$$

$$\Downarrow$$

$$82.9\,W = h_o\cdot A_2\cdot(T_2 - T_\infty) + \varepsilon_{2,o}\cdot A_2\cdot\sigma\cdot(T_2^4 - T_{sur}^4)$$

$$\Downarrow$$

$$h_o = \frac{q_{辐射} - \varepsilon_{2,o}\cdot A_2\cdot\sigma\cdot(T_2^4 - T_{sur}^4)}{A_2\cdot(T_2 - T_\infty)}$$

$$= \frac{82.9 - 0.9\times\pi(0.06)^2\times5.67\times10^{-8}\times(400^4 - 300^4)}{\pi(0.06)^2\cdot 100}$$

$$= 64.37\ W/m^2\cdot K$$