Heat Transfer Questions & Answers

Question by Student 201527110

Professor, in my opinion it'll be better to use film temperature density ρ_f in the mass conservation $\dot{m}_1 = \dot{m}_2$ what we used in lecture to get maximum velocity u_{max} for higher accuracy answer in the case of tube banks. In the lecture, you dervived it with same density as ρ_∞ but if the temperature is risen by the tubes, density will be changed automatically and even also we consider it as a film temperature T_f properties like ρ_f, k_f, ETC. Or the error accured by using ρ_∞ in mass conservation is acceptable in this case?

You need to analyze the problem a bit more. Please find an estimate of the height of the thermal layer and compare it to the distance between cylinders. Is this ratio high or low? Do so below, I'll reward you for sharing your efforts with the class.

Question by Student 201527121

Professor, I have question about using Nusselt number. In Question 4-(a) we need to find the Nusselt Num. in shpere for getting h. But there are not only one but three ways to do it. It makes me confusing. 1st. Through Groshof number range and get Nusselt number.[table "summary of free conv. H-T relations"] 2nd. Through Re.Number directly.[table "Summary of conv. crerelations for external flow across cyl. , banks, and shperes"] 3rd. Assuming Irregular solids forms. ["table "summary of free conv. H-T relations"] Which one is the best choice and why? Thank you.

Well first determined if this is forced or free convective heat transfer. If it's forced, it shouldn't involve a Rayleigh or Grashoff number. If it's free, choose the free convective heat transfer correlation that is the best suited (only choose irregular solid if you can not find a better way). 1 point bonus.

Question by Student 201427115

Professor, when I find Nu_D in question#4 in assignment7. I used $Nu_D = hD/K$.In this equation, should I use K_f? If yes, T_s is changing. How do I determine T_f?

Whether you use T_f or not is indicated in the instructions accompanying the Nusselt number correlation. If you need to use T_f but don't know T_s to start with, then you need to proceed iteratively: guess a T_s, then find T_f, then solve the problem and find a new T_s which can be used as the new guess for T_s and repeat as many times as necessary. 1 point bonus.

Question by Student 201427115

I have a question in Assignment 7 Q #5. On the wall, it has 3 phases considered by Heat transfer; front, right side, back wall. But we don't know width of the right side. Can I assume width is much smaller than L and just neglect the right side even it is exposed by sun? And also, when I get local Nu_x, Can I just find $Nu_{y=H}$? Or should I also consider condition of $x = L$?

You should assume a 2D problem. Thus, the depth (what you refer to as "width") is infinite. Thus, you cannot neglect heat transfer on the right side. In fact, this is what you have to find. As for your second question, the answer is within the problem statement (see the stated assumptions). Good questions. 2 points bonus.

Question by Student 201527110

Professor, I had thought about the using ρ_f instead of ρ_∞ for the tube banks.

First of all, U_{max} calculated with ρ_f is $U_max = 7.48 m/s$ in question #1 of Assignmet #7 where the U_{max} calculated with ρ_∞ is $U_{max} = 6.75 m/s$. It shows 9.76 % relative difference between those of two. Using these values, the final answers (T_2) are 30.6° C, 31.3° C and the relative difference is just 2.2 %. (For the case of problem #1)

To compare the accuracy of using two cases of densities, we have to consider thermal boundary layer thickness as you mentioned before. For the in-line tube banks case, the U_{max} take place at the middle of cylinders where the vertical distance between two cylinders is denoted by S_n. Here is the relation between thermal layer thickness and vertical distance to make using ρ_∞ is valid for U_{max}.

$$\frac{S_n - D}{2} >> \delta_T$$

Where D is diameter of cylinder and δ_T is thickness of thermal boundary layer.

After all, to compare thermal boundary layer with vertical distance using abouve relation, have to calculate the thermal boundary layer thickness. From the article "Fluid flow around the and heat transfer from on infinite circular cylinder" by W.A. Khan, J.R. Culham, and M.M. Yovanovih, boundary layer around the circular cylinder can be defined as follow.

$$\frac{\delta}{D} = \frac{0.5}{RE_D}\sqrt{\frac{\lambda}{cos\theta}}$$

Where theta is angle between the point where we want to calculate and x-axis. Also λ is the pressure gradient parameter which can be defined as follow.

$$\lambda = \frac{\delta^2}{\nu}\frac{dU(s)}{ds}$$

Where $dU(s)$ is the potential flow velocity outside the boundary layer. Here used curbilinear coordinates where η is perpendicular to the surface of the circle and S is tangential to the surface of the circle.

After that, use the same boundary conditions used in lecture, can get the temperature distribution as follow.

$$\frac{T - T_a}{T_w - T_a} = 1 - \frac{3}{2}\eta_T + \frac{1}{2}\eta_T^3$$

Hence the form of the Temperature distribution is same with what we derived in lecture except the coordinate, I think it will be okay to use the same relation between boundary layer and thermal boundary layer as follow.

$$\delta_T = 0.976 P_R^{-\frac{1}{3}} D \frac{0.5}{RE_D}\sqrt{\frac{\lambda}{cos\theta}}$$

These are what I've done. I tried to calculated exat thickness of thermal boundary layer and compare with the vertical distance using the realtion above, but I can't calculate the pressure gradient parameter accurately. If you don't mind, please let me no how to get further to compare. (Actually I think it is okay to use $\rho_i nfty$ because the thermal boundart layer will be very thin nonlogically.) Thank you.

This is a very good analysis, more detailed than I expected. I'll give you right away 2 points bonus for the effort. You determine boundary layer height using the correlation by Khan et al, but this is overkill in this case. There's no need to try to get such a precise boundary layer thickness over a cylinder because this will only be accurate for the cylinders on the first row of the tube bank. For the cylinders part of the second row, it will be off considerably. What you need to do here is an order of magnitude analysis. Simply find approximately the average thermal layer height within the tube bank. You can use the thermal layer height relationship we derived in class over a flat plate of length L and simply set L to a characteristic length (you can try to set L to $\frac{\pi}{2}D \times \frac{1}{2}N_r$ with N_r the number of rows). This will give you a quite good estimate, more than precise enough for an order of magnitude analysis.

Question by Student 201327139

Professor, In Assignment #8, Q.4, I found 3 equations,
1) $q = hA_s(\overline{T_b} - T_w)$,
2) $q = \frac{\Delta T}{\Sigma R} = \frac{T_w - T_s}{\frac{1}{kSF}}$ (using Resistance analogy),
3) $q = \dot{m}c_p(T_{b1} - T_{b2})$.
I have 4 unknowns, $T_{b2}, T_w, q, \dot{m}$, but I have only 3 equations. How could I get the last equation ? Thank you.

Hm, the last equation you need is within the problem statement.. You have to make sure the water doesn't freeze and turn to ice. 0.5 point bonus.