Heat Transfer Questions & Answers

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 $\rho_i n f t y$ 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.

Question by Student 201800128

Dear Professor
I have a question regarding the equations used for the friction number f in pipes. In this course we are using the Moody diagram which in the turbulent region is based on Colebrook's equation:

$$\frac{1}{\sqrt{f}} = -2.0 log_{10}(\frac{\frac{\varepsilon}{D}}{3.7} + \frac{2.51}{Re\sqrt{f}})$$

I am aware of another equation to find the friction number in the turbulent region which is Haaland's equation:

$$\frac{1}{\sqrt{f}} = -1.8 log_{10}[(\frac{\frac{\varepsilon}{D}}{3.7})^{1.11} + \frac{6.9}{Re}]$$

As I recall Haaland's equation has an error of about 10% from Colebrook's, but considering that Colebrook's is already off by around 30% from exact values the error from Haaland's is slim. And when taking into consideration the vast human error when reading the Moody diagram this error would be negligable or even more accurate. So, to the question: Is there any reason why the Haaland's formula is not used in this course?
Cheers

This is a very good question, very well researched. But one issue I have with your question is that the 30% error you outline is not the difference between the correlation and the exact solution but rather the difference between the correlation and some average friction factor obtained from lots of experiments of turbulent flows in pipes. An error of 10-30% is not bad at all (and on target) when dealing with turbulent flows. An error of 3-5 times would be considered off.

Thus, you can think of Haaland's and Colebook's correlations as being essentially the same: both will yield an error of 30% or so when compared with experiments. 2 points bonus.

Question by Student 201227125

I have question of shape factors from heat transfer tables. At Isothermal cylinder of radius r buried in semi-infinite medium having isothermal surface. There are three shape factors that

$$\frac{2\pi L}{cosh^{-1}(D/r)},\frac{2\pi L}{ln(2D/r)},\frac{2\pi L}{ln\frac{L}{r}[1-\frac{ln(L/2D}{ln(L/r)}]}.$$

Each shape factor has restrictions. But restrictions are overlapped. at assignment 8 - #3, L>>r, D>3r. I can use both $\frac{2\pi L}{cosh^{-1}(D/r)}$ *and* $\frac{2\pi L}{ln(2D/r)}$. *What should I use in this case? I got the correct answer using* $\frac{2\pi L}{cosh^{-1}(D/r)}$. *but, at assignment 8 - #3, Should* $\frac{2\pi L}{ln(2D/r)}$ *be used to obtain more accurate values?*

And I have another question. A>>B means that is A is 10times larger than B? or 100times? I'm not clear that how much larger or lower value makes the sign << or >> .

I don't think switching from one shape factor formula to another will make much of a difference — you should get a very similar result. Just make sure that the restrictions are applicable to your case. I'm not sure what $A \gg B$ means exactly. This is highly case dependent. But I would guess at least 5-10 times larger. 1 point bonus.