Heat Transfer Course Project

(10 marks)

Part one: Experimental solution [10 Marks]

"*An experiment is a procedure, carried out to support, refute, or validate a hypothesis.*" The heat transfer coefficient correlations, available in literature, can be considered as hypotheses that need validation.

1. Design a neat apparatus to validate experimentally the correlations that calculate the heat transfer coefficient for a specific geometry, for forced AND/OR natural convection.
2. Compare the experimental results with the predictions of the manual solution using the correlations taught in the course in this particular flow.
3. Vary the velocity U_∞, in the forced convection case, and plot in one graph the velocity vs the heat transfer coefficient for both experimental results and correlations results.
4. Vary the angle of orientation, in the natural convection case, and plot in one graph the angle vs the heat transfer coefficient for both experimental results and correlations results.

Part two: Numerical solution [10 Marks]

Q (1) [**4 Marks**] During the heat transfer course, many correlations have been used to calculate the convective heat transfer coefficient for forced flow. These correlations are to be validated in respect to its accuracy with numerical prediction.

[Select one of the following two cases]

1. The top surface of a train is 2.8 m wide and 8 m long. The top surface is absorbing solar radiation at a rate of 200 W/m^2, and the temperature of the ambient air is 20 °C. Assuming the roof of the car to be perfectly insulated and the radiation heat exchange with the surroundings to be small relative to convection.
   - **1.1.** Plot the velocity of the air from 0 to 40 m/s with step of 10 m/s vs the average temperature of the upper surface of the train and the average heat transfer coefficient on the same graph.
   - **1.2.** Plot the velocity of the air vs the drag force and the drag force coefficient on the same graph.
   - **1.3.** Compare the results of **1.1** and **1.2** with the predictions of the manual solution.

2. A tube bank uses an inline arrangement of 10-mm diameter tubes with $S_T = S_L$, or staggered arrangement with $S_T = S_D$. There are 20 rows of tubes with 20 tubes in each row. Consider an application for which cold water flows through the tubes, maintaining the outer surface

temperature at 27 °C, while flue gases at 427 °C and a velocity of 5 m/s are in cross flow over the tubes.

2.1. Plot the pitch ratio of 1.2, 1.25, 1.33, and 1.5 vs the total rate of heat transfer per unit length of the tubes in the bank for both arrangements.

2.2. Plot the pitch ratio of 1.2, 1.25, 1.33, and 1.5 vs the pressure drop for both arrangements.

2.3. Compare the results of **2.1** and **2.2** with the predictions of the manual solution using the famous correlations.

Q (2) [**3 Marks**] The correlations of the natural convection heat transfer coefficient are to be compared with the numerical predictions:

[Select one of the following two cases]

1. A 0.5-m-long thin vertical copper plate is insulted on one side and the other side is exposed to air at 25 °C.

1.1. Plot the temperature of this plate of 50 °C to 400 °C with a step of 50 °C vs the rate of heat transfer from this plate.

1.2. For T_{plate} = 250 °C, plot the angle of inclination θ for an inclined plate from 0 to 90° with a step of 10°.

1.3. Compare the results of **1.1** and **1.2** with the predictions of the manual solution using both of the correlations available in literature.

2. Consider a rectangular enclosure consisting of two surfaces separated by a 0.1-m air gap at 1 atm. If the surface temperatures across the air gap are 30 °C and –10 °C.

2.1. Plot the height of the enclosure from 0.1 m to 4 m vs the heat transfer rate.

2.2. For H = 1.2 m, plot the angle of inclination from the horizontal, θ, from 0 to 180° with a step of 10° vs the heat transfer rate.

2.3. Compare the results of **2.1** and **2.2** with the predictions of the manual solution using both of the correlations available in literature.

Q (3) [**3 Marks**] Engineering problems often require extensive *parametric studies* to understand the influence of some variables on the solution in order to choose the right set of variables and to answer some "what-if" questions. This is an *iterative process* that is extremely tedious and time-consuming if done by hand. Numerical methods are ideally suited for such calculations.

1. An ordinary egg can be approximated as a 5-cm diameter sphere whose properties are roughly k = 0.6 W/m·°C and $\alpha = 0.14\times 10^{-6}\ \mathrm{m^2/s}$. The egg is initially at a uniform temperature of 5 °C and is dropped into boiling water at 99 °C. Taking the convection heat transfer coefficient to be h = 3000 W/m^2·°C.

1.1. Plot the time vs the temperature of the egg center and vs the temperature of the egg surface on the same graph.

1.2. Compare the results with the predictions of the manual solution.

Instructions:

1. At least choose the question of part 1 [**10 Marks**] OR the three questions of part 2 [**10 Marks**].
2. For part 1, the error analysis must be performed, i.e. the uncertainty in the estimated heat transfer coefficient. Consult this tutorial for more information.
3. For part 2, the mesh dependence study, the time step dependence study, and the domain dependence study must be performed and submitted with the report.
4. For part 2, the temperature distribution, the isothermal lines, the heat flow lines, the velocity distribution and the streamlines are to be submitted with the report.
5. For part 2, you may use EES, Matlab, or any other software to help you with the manual solutions.
6. For part 2, you may consult the manual or the following channel for deeper understanding of COMSOL Multiphysics, for instance, you may follow this tutorial as a kick-start in this software.
7. You may consult, Yunus, Holman, or Incropera for deeper understanding of the heat transfer.
8. Number of students per group should be between 6 and 10.

NOTE: Bonus of a maximum of 3 marks is granted for excellent reports and demonstrations both in the numerical and experimental cases. A date will be set by Prof. Osama, Dr Mohamed, and Dr. Mahmoud to arrange for these presentations.