CONVECTION HEAT TRANSFER
TUTORIAL

External Flow

1. Consider atmospheric air at 25 ºC in parallel flow at 5 m/s over both surfaces on a 1-m long flat plate maintained at 75 ºC.
   (a) Determine the velocity boundary layer thickness, and the heat flux at the trailing edge.
   (b) Determine the total heat flux from the plate per unit width of the plate.

2. Engine oil at 100 ºC and velocity of 0.1 m/s flows over both surface of a 1-m long flat plate maintained at 20 ºC. Determine:
   (a) the velocity boundary layer thickness at the trailing edge.
   (b) the local heat flux at the trailing edge.
   (c) the heat transfer per unit width of the plate.

3. A fan that can provide air speeds of up to 50 m/s is to be used in a low speed wind tunnel with atmospheric air at 25 ºC. If one wishes to use the wind tunnel to study flat plat boundary layer behavior up to Reynolds number of 10^8, what is the minimum plate length? At what distance form the leading edge would transition occur, if the critical Reynolds number is 5×10^5?

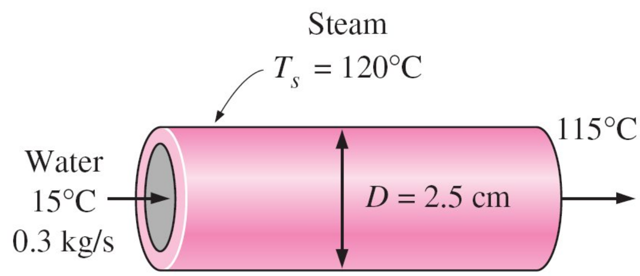
4. Consider steady, parallel flow of atmospheric air over a flat plate. The air has a temperature and free stream velocity of 300 K and 25 m/s respectively.
   (a) Evaluate the velocity boundary layer thickness at distance x = 1, 10 and 100 mm from the leading edge. If a second plate were installed parallel to and at a distance of 3 mm form the first plate, what would be the distance form the leading edge at which the boundary layer merger would occur?

5. A circular cylinder of 25 mm diameter is initially at 150 ºC and is quenched by immersion in an 80 ºC oil bath, which moves at a velocity of 2 m/s in cross flow over the cylinder. What is the initial rate of heat loss per unit length of cylinder?

6. An uninsulated steam pipe is used to transport high-temperature steam from one building to another. The pipe is 0.5 m diameter, has a surface temperature of 150 ºC and is exposed to ambient air at -10 ºC. The air moves in cross flow over the pipe with a velocity of 5 m/s. What is the heat loss per unit length of pipe?

Internal Flow

7. Water enters a 2.5-cm-internal-diameter thin copper tube of a heat exchanger at 15 °C at a rate of 0.3 kg/s, and is heated by steam condensing outside at 120 °C. If the average heat transfer coefficient is 800 $W/m^2 \cdot K$, determine the length of the tube required in order to heat the water to 115°C.



8. A system for heating water from an inlet temperature of $T_{m,i}$ = 20 ºC to an outlet temperature of $T_{m,o}$ = 60 ºC involves passing water through a thick walled tube having inner and outer diameters of 20 mm and 40 mm. The outer surface of the tube is well insulated, and electrical heating within the wall provides for a uniform generation rate of 10^6 W/m^3.

   (a) For water mass flow rate of 0.1 kg/s, how long must the tube be to achieve the desired outlet temperature?

   (b) If the inner surface temperature of the tube is 70 ºC at the outlet, what is the local heat transfer coefficient

9. Steam condensing on the outer surface of a thin-walled circular tube of 50-mm diameter and 6-m length maintains a uniform surface temperature of 100 ºC. water flows trough the tube at a rate of 0.25 kg/s, and its inlet and outlet temperatures are 15 ºC and 5 ºC respectively. What is the average convection coefficient associated with the water flow?

10. A thick walled stainless steel pipe of inside and outside diameter D_i = 20 mm and D_o = 40 mm is heated electrically to provide a uniform heat generation rate of 10^6 W/m3. The outer surface of the pipe is insulate while water flow through the pipe at a rate of 0.1 kg/s. If the water inlet temperature is 20 ºC and the desired outlet temperature is 40 ºC, what is the required pipe length?

11. The surface of a 50 mm diameter, thin walled tube is maintained at 100 °C. In one case air is in cross flow across the tube with a temperature of 25 °C and an upstream velocity of 30 m/s. In another case air is in fully developed flow through the tube with a temperature of 25 ºC and a mean velocity of 30 m/s. Calculate the heat flux from the tube to the air for the two cases.