1. **(Problem 8.23 in the Book)** An experimental nuclear core simulation apparatus consists of a long thin-walled metallic tube of diameter \(D\) and length \(L\), which is electrically heated to produce the sinusoidal heat flux distribution:

\[
q_s(x) = q_0 \sin \left( \frac{\pi x}{L} \right)
\]

where \(x\) is distance measured from the tube inlet. Fluid at an inlet temperature, \(T_{m,i}\), flows through the tube at a rate of \(m\). Assuming the flow is turbulent and fully developed over the entire length of the tube, develop expressions for:

a. the total rate of heat transfer, \(q\), from the tube to the fluid,

b. the fluid outlet temperature, \(T_{m,o}\),

c. the axial distribution and position of the highest wall temperature, \(T_s(x)\),

d. the magnitude and position of the highest wall temperature,

e. Consider a 40-mm-diameter tube of 4-m length with a sinusoidal heat flux distribution for which \(q^*=10,000 \text{ W/m}^2\). Fluid passing through the tube has a flow rate of 0.025 kg/s, a specific heat of 4180 kJ/kgK, an entrance temperature of 25°C, and a convection coefficient of 1000 W/m²K. Plot the mean fluid and surface temperatures as a function of distance along the tube. Identify important features of the distributions. Explore the effect of \(\pm 25\%\) changes in the convection coefficient and the heat flux on the distributions.

2. **(Problem 8.38 in the book)** An air heater for an industrial application consists of an insulated, concentric tube annulus, for which air flows through a thin-walled inner tube. Saturated steam flows through the outer annulus, and condensation of the steam maintains a uniform temperature \(T_s\) on the surface.

Consider conditions for which air enters a 50-mm-diameter tube at a pressure of 5 atm, a temperature of \(T_{m,i}=17^\circ\text{C}\), and a flow rate of \(\dot{m}=0.03\text{ kg/s}\), while saturated steam at 2.455 bars condenses on the outer surface of the tube. If the length of the annulus is \(L=5\) m, what are the outlet temperature \(T_{m,o}\) and pressure \(p_o\) of the air? What is the mass rate at which condensate leaves the annulus.

3. **(Problem 8.53 in the book)** Heated air required for a food-drying process is generated by passing ambient air at 20°C through long, circular tubes \((D = 50 \text{ mm}, L = 5 \text{ m})\) housed in
a steam condenser. Saturated steam at atmospheric pressure condenses on the outer surface of the tubes, maintaining a uniform surface temperature of 100°C.

a. If an air flow rate of 0.01 kg/s is maintained in each tube, determine the air outlet temperature $T_{m,o}$ and the total heat rate $q$ for the tube.

b. The air outlet temperature may be controlled by adjusting the tube mass flow rate. Compute and plot $T_{m,o}$ as a function of $\dot{m}$ for $0.005 \leq \dot{m} \leq 0.050$ kg/s. If a particular drying process requires approximately 1 kg/s of air at 75°C, what design and operating conditions should be prescribed for the air heater, subject to the constraint that the tube diameter and length be fixed at 50 mm and 5 m, respectively?

![Diagram](image)

4. **(Problem 8.61 in the book)** Consider a thin-walled tube of 10-mm diameter and 2-m length. Water enters the tube from a large reservoir at $\dot{m} = 0.2$ kg/s and $T_{m,i} = 47^\circ$C.

a. If the tube surface is maintained at a uniform temperature of 27°C, what is the outlet temperature of water, $T_{m,o}$? To obtain the properties of water, assume an average mean temperature of $\bar{T}_m = 300$ K.

b. What is the exit temperature of the water if it is heated by passing air at $T_{\infty} = 100^\circ$C and $V = 10$ m/s in cross flow over the tube? The properties of air may be evaluated at an assumed film temperature of $T_f = 350$ K.

c. In the foregoing calculations, were the assumed values of $\bar{T}_m$ and $T_f$ appropriate? If not, use properly evaluated properties and recomputed $T_{m,o}$ for the conditions of part (b).

![Diagram](image)