Problem Sheet on Heat Transfer: Forced convection through pipes and ducts

1. Water flows in duct of rectangular cross section of height of 6 mm and width of 12 mm with a bulk mean temperature of 30^{o}C. If the duct wall temperature is constant at 60^{o}C and fully developed laminar flow is experienced, calculate the heat transfer per unit length. [281.46 W]
2. Water at a rate of 0.5 kg/s is forced through a tube of 20 mm internal diameter. The inlet water temperature is 20^{o}C and outlet water temperature is 60^{o} C. The tube wall temperature is 15^{o} higher than the water temperature all along the length of the tube. Determine the length of the tube. Use Dittus Boelter equation. [12 m]
3. Cooling water at 25^{o}C enters a condenser tube at 4m/s velocity and leaves the tube at 35^{o}C. The inside diameter of the tube is 20 mm. Assuming fully developed turbulent flow, determine the average heat transfer coefficient and pressure drop per unit length of the tube.
4. Water at an average temperature of 20^{o}C flows at a rate of 0.25 kg/s through a tube of inner and outer diameter of 20 and 28 mm respectively. The tube material (Teflon) has a thermal conductivity of k= 0.30 W/mK. A thin electrical heating tape wrapped around the outer surface of the tube delivers a uniform heat flux of 2500 W/m^2. The heat is also convected from the outer surface to air at 35^{o}C. The convection heat transfer coefficient remains constant over the outer surface at 30 W/m^{2}K. Determine the percentage of power dissipated by the tape that is transferred to water. Also find the average outer surface temperature of the tube. [75.5%, 50.4^{o}C]
5. Mercury at a temperature of 150^{o}C with a velocity of 1 m/s enters a tube of 15 mm diameter. The inside surface temperature is maintained at 300 ^{o}C. Determine the length of the tube required to raise the mercury temperature to 250^{o}C.
6. Hot air at atmospheric pressure and 85^{o}C enters a 10 m long un-insulated square duct of 15 cm× 15 cm cross section and passes through the attic of a house at a rate of 0.1 m^3/s. The duct wall is nearly isothermal at 70^{o}C. Determine the exit temperature of the air and heat loss from the duct to the air space in the attic. [75.7 ^{o}C, 941 W]
7. Consider a hollow-core printed circuit board of 12 cm high and 18 cm long, dissipating a total heat of 20 W. The width of the air gap at the middle of the PCB is 0.25 cm. Cooling air enters the 12 cm wide core of the PCB at a temperature of 32 ^{o}C at a rate of 0.8 L/s. Assuming the heat generated to be uniformly distributed over the two sides of the PCB, determine (i) the temperature at which the air leaves the PCB core, and (ii) the highest temperature on the inner surface of the core. Where does this temperature occur? [(i) 54 ^{o}C, (ii) 72.8 ^{o}C]

Also, see the worked out examples of Incropera and DeWitt