Chapter 1

1. Refer to Figure 1.2 or Figure 1.3: Choose a test sample with a diameter around 1-inch and a length around 12-inch. Insert 4-5 thermocouples into the rod, wrap 1-inch thick insulation material, such as fiberglass, around the test sample, connect an electric heater to one end of the sample, supply electrical power to heat the test sample to a temperature around 50-60°C. The conductivity can be determined from the conduction formula with the given dimensions and measured quantities. The calculated conductivity values can be compared to the table available in the textbook.

$$\dot{Q} = k_{metal} A_c \frac{\Delta T}{\Delta x} \quad \rightarrow \quad k_{metal} = \frac{\dot{Q}}{A_c}\frac{\Delta x}{\Delta T}$$

Copper	$k \approx 400$ W/m-K
Aluminum	$k \approx 200$ W/m-K
Stainless Steel	$k \approx 15$ W/m-K
Carbon Steel	$k \approx 50$ W/m-K

2. Refer to Figure 1.6: Choose a copper plate with 6-inch width, 20-inch length in the flow direction, and ¼-inch thickness. Insert 5-6 thermocouples along the plate, glue a ⅛-inch diameter copper rod at the leading-edge region of the plate to maintain turbulent flow over the plate, add a thin electric heating matt under the copper plate and with 1-inch thick insulation material below the electric heater, turn on the wind tunnel flow to have a velocity level around 10-20 m/s, supply power to the electric heater to heat the surface to a temperature level around 50-60°C, and insert thermocouples to measure the air flow temperature. Heat transfer coefficients can be calculated from the convection formula with the given dimensions and measured quantities, the calculated h or Nu values vs velocity or Re number can be compared to the correlation available in the textbook.

$$Nu_x = 0.0308\, Re_x^{4/5} Pr^{1/3}$$ Local Nusselt Number with Turbulent Flow

$$Nu_x = \frac{h_x x}{k_{air}} \rightarrow h_x = \frac{Nu_x \cdot k_{air}}{x}$$ x measured from leading edge of plate

$$h_x = \frac{\left(\dot{Q}/A_s\right)}{\left(T_{w,x} - T_\infty\right)}$$

3. Refer to Figure 1.8: Choose a hollow copper tube with 2-inch outer diameter, 1-inch inner diameter, and 10-inch length. Insert 4-5 thermocouples along the tube wall, insert a 1-inch diameter rod-heater inside the hollow tube, turn on the wind tunnel flow to have a velocity level around 10-20 m/s, supply power to the electric heater to heat the tube to a temperature level around 50-60°C, and insert the thermocouples to measure the air flow temperature. Heat transfer coefficients can be calculated from the convection formula with the given dimensions and measured quantities, the calculated h or Nu values vs velocity or Re number can be compared to the correlation available in the textbook.

$$\overline{Nu_D} = 0.3 + \frac{0.62\, Re_D^{1/2}\, Pr^{1/3}}{\left[1+\left(\frac{0.4}{Pr}\right)^{2/3}\right]^{1/4}}\left[1+\left(\frac{Re_D}{282000}\right)^{5/8}\right]^{4/5}$$

Surface averaged Nusselt number for flow around a cylinder

$$\overline{Nu_D} = \frac{\bar{h}D}{k_{air}} \rightarrow \bar{h} = \frac{\overline{Nu_D}\cdot k_{air}}{D}$$

$$\bar{h} = \frac{\left(\dot{Q}/A_s\right)}{\left(\overline{T_w} - T_\infty\right)}$$

4. Refer to Figure 1.10: Choose a thin-wall, hollow, copper tube with 2-inch inner diameter and 30-inch length. Insert 5-6 thermocouples along the tube wall, wrap insulated electric heating wires around the entire tube, add 1-inch insulation material around the tube, turn on the air flow through the tube with a velocity level around 10-20 m/s (or based on proper air mass flow rate), supply power to the electric heater to heat the tube to a temperature level around 50-60°C, insert thermocouples to measure the inlet and outlet air flow temperatures. Heat transfer coefficients can be calculated from the convection formula with the given dimensions and measured quantities, the calculated h or Nu values vs velocity/flow rate or Re number can be compared to the correlation available in the textbook.

$$Nu = 4.36$$ Laminar, fully developed flow in a round tube

Or

$$Nu = 0.023\, Re^{0.8}\, Pr^{0.4}$$ Turbulent, fully developed flow in a round tube

$$Nu_D = \frac{hD}{k_{air}} \rightarrow h = \frac{Nu_D \cdot k_{air}}{D}$$

$$h = \frac{\left(\dot{Q}/A_s\right)}{\left(T_W - T_b\right)}$$

5. Refer to Figure 1.11: Choose a test sample plate with 5-inch width, 5-inch length, and ⅛-inch thickness. Insert two thermocouples into the test sample plate, add an electric heating matt beneath the test sample, supply power to the electric heater to heat the test sample to a temperature level around 50-60°C, use the calibrated IR camera or radiation pyrometer to capture or measure the radiation heat. The emissivity can be determined from the IR camera or radiation pyrometer by inputting the measured test sample temperature. The calculated emissivity of the copper, aluminum, carbon steel, and stainless steel test samples can be compared to the table available in the textbook.

$$\dot{Q} = \varepsilon\sigma A_s\left(T_s^4 - T_\infty^4\right) \quad \rightarrow \quad \varepsilon = \frac{\dot{Q}}{\sigma A_s\left(T_s^4 - T_\infty^4\right)}$$

Copper (polished)	$\varepsilon \approx 0.03$
Aluminum (polished)	$\varepsilon \approx 0.04$
Stainless Steel (polished)	$\varepsilon \approx 0.17$
Carbon Steel (cast & polished)	$\varepsilon \approx 0.53$

Chapter 2

1.
   a. 0 – 36 inH_2O (0 – 1.3 psig)
   b. 0 – 488 inH_2O (0 – 17.6 psig)
   c. 0 – 10 inH_2O (0 – 0.36 psig)
   d. 0 – 2 inH_2O (0 – 0.072 psig)
   e. 0 – 83000 inH_2O (0 – 3000 psig)

   Values may vary slightly.

2. 4 inH_2O (996.4 Pa = 0.145 psig)

3. As described in the text, static "pressure taps" can be used at points 1 and 2. A hole can be drilled through the pipe wall, and small tubes (inner diameter ~ 1/16") can be inserted through the holes. The small, rigid tubes should be affixed to the pipe, so the end of the tube is flush with the inside of the pipe (not protruding into the flow). The two taps can be connected to a differential, U-tube manometer to provide the pressure difference between the two locations within the pipe.

4. As described in the text, the Pitot-static probe should be inserted through the wall of the pipe. The probe should be oriented so it is aligned directly into the flow. The two pressure ports on the probe should be connected separately to pressure transducers to separately measure the total and static pressures.

5.

$$P_1 + \frac{1}{2}\rho V_1^2 + \gamma z_1 = P_2 + \frac{1}{2}\rho V_2^2 + \gamma z_2$$

$$z_1 = z_2$$

$$P_1 = P_S$$

$$P_2 = P_T \quad (V_2 = 0)$$

$$(P_T - P_S) = \frac{1}{2}\rho V^2$$

$$\mathbf{V = \sqrt{\frac{2 \cdot (P_T - P_S)}{\rho}}}$$

6.

$$P_S = 30\,\text{inH}_2\text{O} = 7473\,\text{Pa}\ \ \text{(gauge)}$$
$$P_S = \left(7473\,\text{Pa}\right) + \left(101\times10^3\ \text{Pa}\right) = 108500\ \text{Pa (absolute)}$$
$$\Delta P = 20\,\text{inH}_2\text{O} = 4982\,\text{Pa}$$

$$D_H = \frac{4A_c}{P}$$
$$D_H = \frac{4\left(0.5\,\text{m}\right)\left(1.0\,\text{m}\right)}{2\left(0.5+1\right)\text{m}}$$
$$D_H = 0.667\,\text{m}$$

$$P = \rho RT$$

$$\rho = \frac{P}{RT} = \frac{\left(108500\,\frac{\text{N}}{\text{m}^2}\right)}{\left(287\,\frac{\text{J}}{\text{kgK}}\right)\left(50+273\right)\text{K}}$$

(note temperature and pressure in absolute)

$$\rho = 1.17\,\frac{\text{kg}}{\text{m}^3}$$

$$V = \sqrt{\frac{2\cdot\left(P_T - P_S\right)}{\rho}} = \left[\frac{2\left(4982\,\frac{\text{N}}{\text{m}^2}\right)}{1.17\,\frac{\text{kg}}{\text{m}^3}}\left(\frac{\text{kgm}}{\text{Ns}^2}\right)\right]^{1/2}$$

$$\mathbf{V = 92.3\,\frac{m}{s}}$$

$$\dot{m} = \rho A_c V = \left(1.17\,\frac{\text{kg}}{\text{m}^3}\right)\left(0.5\,\text{m}\right)\left(1.0\,\text{m}\right)\left(92.3\,\frac{\text{m}}{\text{s}}\right)$$

$$\mathbf{\dot{m} = 54.0\,\frac{kg}{s}}$$

$$Re = \frac{\rho V D_h}{\mu} = \frac{\left(1.17\,\frac{\text{kg}}{\text{m}^3}\right)\left(92.3\,\frac{\text{m}}{\text{s}}\right)\left(0.667\,\text{m}\right)}{1.98\times10^{-5}\,\frac{\text{kg}}{\text{ms}}}$$

$$\mathbf{Re = 3.64\times10^{6}}$$