MAE126A/171A Winter Quarter 2006

ENVIRONMENTAL AND MECHANICAL ENGINEERING LABORATORY
Heat Transfer – Week 2.
DETERMINATION OF HEAT TRANSFER COEFFICIENTS

General description

The experiment consists of heated plate in an air flow. Heat is supplied to the plate to maintain it at a given temperature. By measuring the power required to maintain the plate temperature the heat flux is determined. The aim is to measure the *heat transfer coefficient* for a range of temperatures and air flow rates, covering *free convection, laminar and turbulent forced convection*.

The labview VI controls the heater so that the temperature rapidly reached the set value. Once this is reached the system is set to manual and the heater is maintained at a fixed power. The heat transfer coefficients and the Nusselt number are determined from the measurements of the power and the temperatures if the air and the plate.

Objectives

1. To measure the heat flux in free convection, laminar and turbulent forced convection
2. To determine the heat transfer coefficients
3. To plot Nusselt numbers against Reynolds numbers

Procedures

1. Measure the heat flux in free convection, laminar and turbulent forced convection

- Set the flow velocity to the desired speed
- Set the labview VI to Automatic and dial in the desired temperature

Exp #	1	2	3	4	5	5	7	8	9	10	11
Plate temp	40	50	60	70	80	60	60	60	60	80	80
Flow speed	0	0	0	0	0	0.5	1.0	1.5	2.0	1.0	2.0

Table 1: Test grid of plate temperatures and flow speeds.

- When the temperature is within 1-2$^{\mathrm{o}}$C of the required temperature set the VI to Manual
- Using the heater knob set the heat flux to hold the temperature steady (it does not have to be exactly the original desired temperature)
- In steady-state conditions, record the plate and air temperatures and the power to the heater
- Using the power calibration determine the actual heat flux to the plate

The heater will switch off if the plate temperature reaches 100$^{\mathrm{o}}$C. Run the fan during the calibration to avoid this.

2. Determine the heat transfer coefficients
Using the definitions below calculate the heat transfer coefficient h_c, the Nusselt number Nu and the Reynolds number Re of the flow.
Calculate the range of Reynolds numbers Re that can be achieved in the duct. The transition from laminar to turbulent flow takes place at $Re = 10^6$. Determine which flow speeds are laminar and which are turbulent.

3. Plot Nusselt numbers against Reynolds numbers
Plot the results both in a linear and a log-log plot. Compare the results with expected theory.

Parameter values

The following table gives the range of values that should be tested.

Error analysis

1. Calculate any systematic errors in the measurements you take.
2. Determine random errors from repeated samples.

3. Plot all data with appropriate error bars.

Definitions
The power P to the heater is given by

$$P = IV,$$

where P is in W, V is the voltage and I is the current.
The Reynolds number Re is

$$Re \equiv \frac{UD}{\nu},$$

where U is the flow speed, D is the hydraulic radius and ν is the kinematic viscosity of air. The hydraulic radius D is defined by

$$D \equiv \frac{4A}{P},$$

where A is the cross-sectional area of the duct and P is its perimeter. The kinematic viscosity for air is $\nu = 1.45 \times 10^{-5}$ m^{2}s^{-1}.
The heat transfer coefficient h_c is defined as

$$h_c \equiv \frac{H}{A_p \Delta T},$$

where H is the heat flux, A_p is the area of the plate and ΔT is the temperature difference between the plate and the air. The units of h_c are Wm^{-2}$^{\text{O}}$C^{-1}.
The Nusselt number Nu is defined as

$$Nu = \frac{h_c L}{k},$$

where k is the thermal conductivity of air ($k = 0.0262$ Wm^{-1}$^{\text{O}}$C^{-1}) and L is the length of the plate in the flow direction.
The flow in the duct is turbulent when $Re > 10^4$ (approx).