1 Part D Background and Theory

a. Symbol Directory:

Experimental Quantities:		
y	Position Perpendicular to Plate	mm
x	Position Along Plate from Leading Edge	mm
x_c	Centerstream X-Position	$8.0mm$
x_d	Downstream X-Position	$12.6mm$
δx	Uncertainty in X-Position Measurements	$0.05mm$
h_s	Static Pressure Head	m
h_p	Pitot Tube Pressure-Head	m
T_{amb}	Ambient Temperature	$22.8°C$
ρ_a	Density of Ambient Air	${}^{kg}/_{m^3}$
U_∞	Measured Free-Stream Velocity	${}^{m}/_{s}$

Constants and Thermophysical Properties:		
g	Acceleration due to Gravity	$9.807\frac{m}{s^2}$
ρ_f	Pitot Tube Fluid (water) Density	$^*997\frac{kg}{m^3}$
ν_a	Kinematic Viscosity of Air	$^*15.36 \times 10^{-6}\frac{m^2}{s}$

**Value taken from* Principles of Heat and Mass Transfer by Incropera, et al. Textbook at Ambient Temperature

Computed Quantities:		
$\delta\mathbf{X}$	Notation for Uncertainty in Some Measurement "**X**"	
$V_{\infty rel}$	Max. Flow Velocity Reached in a Measurement Cross-Section	$^m/_s$
Δh	Difference in Static and Pitot Pressure Heads	m
P_{dyn}	Dynamic Pressure	Pa
V_c	Computed Flow Velocity at Pitot Tube Opening	$^m/_s$
Re	Reynolds Number	
δ	Boundary Layer Thickness	mm
a, b, c	Velocity Curve Regression Parameters	
SE_V	Standard Error of Velocity Regression	$^m/_s$

b. Basic Calculations:

Uncertainty For each set of measurements requested by the assignment, 10 were taken so that the uncertainty caused by both inherent uncertainty in the instrumentation and environmental factors could be captured by the standard deviation in the measurements.
For some parameter χ which was directly measured $n = 10$ times, the value, X, used to represent this

parameter throughout subsequent calculations was determined as follows:

$$X = \frac{1}{n} \sum_{i=1}^{n} \chi_i \tag{1}$$

$$\bar{\chi} = \frac{1}{n} \sum_{i=1}^{n} \chi_i$$

$$\sigma_X = \sqrt{\frac{\sum_{i=1}^{n} (\chi_i - \bar{\chi})^2}{n-1}}$$

For 95% confidence:

$$\delta X = 2\sigma_X \tag{2}$$

*All uncertainties of derived values were determined by standard error propagation techniques.

Free-Stream Velocity In the FAQ of the assignment, it stated that it is important for Reynolds number and boundary layer calculations to use the free-stream velocity *in the cross-section where the measurements were taken* rather than the velocity measured upstream of the experiment provided by the data-logs, U_∞. As such, for these calculations the free-stream velocity was assumed to be the maximum of all calculated velocities for the experimental setup in question (ie, same plate, set speed, pitot tube x-position).

$$V_{\infty rel_i} = max\{V_c\}_i \tag{3}$$

Reynolds Number Reynolds number was computed using standard technique for flow over a flat plate:

$$Re_x = \frac{\rho_a V_{\infty rel} x}{\nu_a} \tag{4}$$