1 Part A Background and Theory

a. Symbol Directory:

Experimental Quantities:		
d	Pipe Diameter	m
L	Length of Tube across which Head Loss is Measured	m
Q	Volumetric Flow Rate	$\frac{m^3}{s}$
h_1	Upstream Head	m
h_2	Downstream Head	m
T	Fluid Temperature	$°C$

Computed Quantities:		
V_{av}	Average Fluid Velocity	$\frac{m}{s}$
$[Re]$	Reynold's Number	
h_K	Empirical Minor Head Loss	m
f	Friction Factor	
K	Minor Head Loss (Accessory) Coefficient	
L_{eq}	Equivalent Tube Length	m

Constants and Thermophysical Properties:		
g	Acceleration due to Gravity	$9.807\frac{m}{s^2}$
ρ	Fluid Density	$\frac{kg}{m^3}$
μ	Fluid Dynamic Viscosity	$\frac{N}{m^2 s}$
ν	Fluid Kinematic Viscosity	$\frac{m^2}{s}$
ε	Surface Roughness of Pipe	m
$\varepsilon_s = \varepsilon_{smooth,ideal}$	Surface Roughness of Ideal Smooth Pipe	$0m$

**All non-standard values extracted from relevant sections of assignment. Values not provided were either not needed or were determined as a function of some other variable.*

b. Basic Calculations:

Average Velocity Assuming an incompressible fluid, for flow through a given tube, the average velocity, V_{av} at any cross-section can be determined from the volumetric flow rate, Q, anywhere in the stream and the diameter of the tube, d at the cross-section of interest as:

$$V_{av} = \frac{Q}{A_c} = \frac{4Q}{\pi d^2} \tag{1}$$

Reynold's Number As given in equation 8 of the assignment, the Reynold's Number can be determined by:

$$[Re] = \frac{\rho V_{av} d}{\mu} = \frac{V_{av} d}{\nu} \tag{2}$$

Head Loss By definition, head loss can be computed as:

$$h_k = h_1 - h_2 \tag{3}$$

c. System Calculations:

Minor Head Loss Coefficient and Equivalent Tube Length As given in equation 5 of the assignment, the minor head loss coefficient can be determined if only the head loss and average fluid velocity at the inlet are known as:

$$K = \frac{2gh_K}{V_1^2} \tag{4}$$

This value can then be used to determine the equivalent tube length as given by equation 6 of the assignment:

$$L_{eq} = \frac{Kd}{f} \tag{5}$$

As the assignment notes, the friction factor used here should be that of a smooth tube; so from equations 7 and 10 of the assignment:

$$f_c = \begin{cases} \frac{64}{Re} & Re \leq 2500 \\ \left[-1.8\ln\left(\frac{6.9}{Re} + \left(\frac{\varepsilon/d}{3.7}\right)^{1.11}\right)\right]^{-2} & Re > 2500 \end{cases} \tag{6}$$

Where $\varepsilon_{smooth,ideal} = 0m$.

Uncertainties: Since all values were sampled 5 times, uncertainty in any given parameter can be calculated using $\delta X = 2\sigma_X$, where σ_X is the standard deviation in X, given by:

$$\sigma_X = \sqrt{\frac{1}{N_X - 1}\sum_i (X_i - \mu_X)^2} \quad | \quad \mu_x = \frac{1}{N_X}\sum_i X_i \tag{7}$$

Note: In plots, this process is applied to the Y *and* X values around certain target values to create X and Y error bars.
For example in the plot of h_e vs Q, this is used to create error bars for each set of $\{Q, h_e\}$ where the flow rate was within $0.03^L/_s$ of the desired test values $0.75^L/_s, 0.65^L/_s,$ *etc.*