A manufacturing facility design office would like to assess the characteristics of a piping material they would like to adopt in the most recent plant design contract that they have signed. As their experienced process engineer, you have been tasked to carry out this evaluation. To do that you need to evaluate the friction factor (f) and the Reynolds number (Re) of water flowing through a segment of this pipe material of known length (L). The standardised test set-up (Figure 1) that has been approved consists of a known section (L) of tubing, a flowmeter, a variable speed pump and a pressure monitor

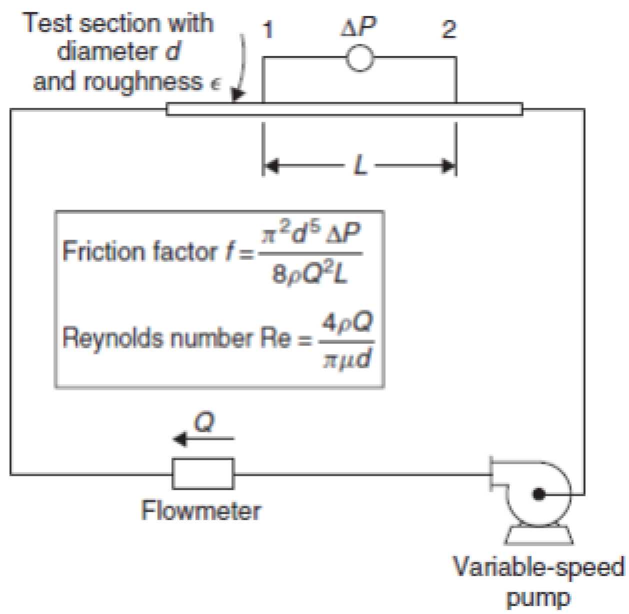

Figure 1 Experimental determination of resistance characteristics

Table 1 Summary of random and standard systematic errors

Variable	Units	Nominal Value	Distribution of random errors	Random Uncertainty (s_r) % value	Distribution of systematic errors	Systematic Uncertainty (b_r) % value
d	m	0.05	Uniform	10	Normal	2.5
ΔP	Pa	80	Triangular	5	Half-Normal	2
ρ	kg/m^3	1000	Uniform	2	Triangular	1
Q	m^3/s	0.003	Normal	3	Half-Normal	3
L	m	0.2	Uniform	8	Half-Normal	2
μ	Pa·s	$8.9 \cdot 10^{-4}$	Normal	8	Triangular	2

1. Using the Taylor Series Method (TSM) for uncertainty propagation, determine the expanded uncertainty of the result both for the calculation of the friction factor (f) and the calculation of the Reynolds number (Re). Discuss and justify your assumptions.

2. Using the Monte Carlo Method (MCM) for uncertainty propagation, determine the expanded uncertainty of the result both for the calculation of the friction factor (f) and the calculation of the Reynolds number (Re). Discuss and justify your assumptions. Using appropriate graphs, prove that your calculation of the expanded uncertainty has converged

3. Did the values for the expanded uncertainties calculated in (Q1) differ from those calculated in (Q2)? If so, explain why this may be the case. Prove your hypothesis/justification by presenting an appropriate MCM simulation

4. You are now looking to identify which among those measured variables have the largest impact on the determination of the friction factor (f) and the Reynolds number (Re). For this question only (i.e. all of question 4), assume that all variables follow a uniform distribution. Perform a Sensitivity Analysis using the Elementary Effects Method for each of the two equations, assuming a range of variation of 50% around the nominal value.

a. Apply the Elementary Effects Method using the original sampling strategy proposed by Morris and justify/prove convergence

b. Apply the Elementary Effects Method using a latin hypercube sampling strategy and justify/prove convergence

c. Apply the Elementary Effects Method using a low discrepancy sequence for sampling and justify/prove convergence

d. Discuss any limitations of the Elementary Effects method you have discovered during its implementation and what steps you have taken to alleviate those limitations

e. You are asked to make a recommendation to prioritise improvements in the measurement of these variables to improve on sensitivity and you would thus like to identify the variables with the most impact on the outcome of your analysis. Justify your answer based on your results from steps (3a, 3b and 3c) and discuss the most appropriate choice of sampling strategy in the context of the present example

Write **“Python Developer”** at the start of the proposal so i can see trhat you read out all questions