Reynolds Experiment – the nature of turbulence

Try several different values of flow rate (from low to high) and visualize the dye behavior for laminar, transitional and turbulent pipe flow.

Turbulent Flow

Turbulent flow is highly unsteady, irregular (3D flow field with many scales), seemingly random and unpredictable (Pope 2000). Turbulent flow is due to flow instability occurs at high Reynolds number.

Water density: $\rho = [M \, L^{-3}]$

Water viscosity: $\mu = [ML^{-1}T^{-1}]$

Averaged flow velocity: $U = [LT^{-1}]$

Pipe diameter: $D = [L]$

4 physical parameters; 3 dimensions $\Rightarrow$ 1 nondimensional group
\[ \Pi_1 = U^\alpha D^\beta \rho^\gamma \mu^\delta = [L T^{-1}]^\alpha [L]^\beta [M L^{-3}]^\gamma [ML^{-1} T^{-1}]^\delta \]

For L: \( \alpha + \beta - 3\gamma - \delta = 0 \)
For T: \( -\alpha - \delta = 0 \)
For M: \( \gamma + \delta = 0 \)
\( \delta = -\alpha, \gamma = \alpha, \beta = \alpha \)

\[ \Pi_1 = U^\alpha D^\alpha \rho^\alpha \mu^{-\alpha} \]

\[ \Pi_1 = \frac{\rho V D}{\mu} = \frac{\text{inertia force}}{\text{viscous force}} = \text{Re} \quad \text{(Reynolds Number)} \]

- When \( \text{Re} \) is large, nonlinear convection terms in Navier-Stokes equations become more important and tends to trigger flow instability and results in turbulent flow.
- During the experiment, you will determine the “critical” Reynolds number for laminar to transitional turbulent flow (\( \text{Re}_i \)) and transitional to fully turbulent flow (\( \text{Re}_t \)).