Calculation of Viscosity of a Newtonian Liquid in a Circular Tube — CHE 324: PhD Problem
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Problem 6 Statement

A Newtonian liquid with density $\rho = 955\,\mathrm{kg/m^3}$ flows through a circular tube of length $L = 0.5\,\mathrm{m}$ and radius $R = 0.75\,\mathrm{mm}$. The pressure drop across the tube is $\Delta P = 490\,\mathrm{kPa}$, and the mass flow rate through the tube is $\dot{m} = 3 \times 10^{-3}\,\mathrm{kg/s}$.

Find the dynamic viscosity μ of the liquid.

Solution

For laminar flow of a Newtonian fluid through a circular tube, the Hagen–Poiseuille equation relates the mass flow rate and pressure drop as follows:

$$\dot{m} = \frac{\pi R^4 \Delta P \rho}{8 \mu L}$$

Rearranging for viscosity μ:

$$\mu = \frac{\pi R^4 \Delta P \rho}{8 \dot{m} L}$$

Given Data:

$$\begin{aligned} \dot{m} &= 3 \times 10^{-3}\,\mathrm{kg/s} \\ R &= 0.75\,\mathrm{mm} = 0.00075\,\mathrm{m} \\ L &= 50\,\mathrm{cm} = 0.5\,\mathrm{m} \\ \Delta P &= 490\,\mathrm{kPa} = 490 \times 10^3\,\mathrm{Pa} \\ \rho &= 955\,\mathrm{kg/m^3} \end{aligned}$$

Calculation:

Calculate R^4:

$$R^4 = (0.00075)^4 = 3.16 \times 10^{-13}\,\mathrm{m}^4$$

Calculate numerator:

$$\pi \times R^4 \times \Delta P \times \rho = \pi \times 3.16 \times 10^{-13} \times 490 \times 10^3 \times 955 \approx 4.638 \times 10^{-4}$$

Calculate denominator:

$$8 \times \dot{m} \times L = 8 \times 3 \times 10^{-3} \times 0.5 = 0.012$$

Finally, compute viscosity:

$$\mu = \frac{4.638 \times 10^{-4}}{0.012} = 0.03865\,\mathrm{Pa} \cdot \mathrm{s}$$

Answer:

$$\boxed{\mu \approx 0.0387\,\mathrm{Pa} \cdot \mathrm{s}}$$