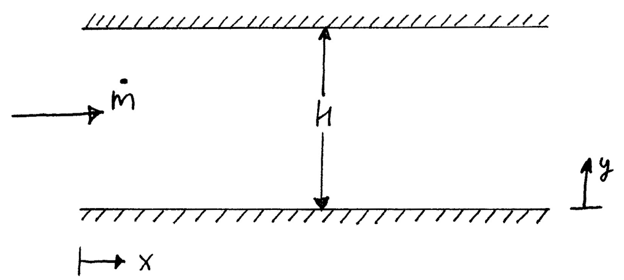
Fundamentals of Fluid Mechanics B
Assignment 3 — Couette and Poiseuille Flow

Question #1

Consider two planes located at $y = 0$ and $y = H$ as follows:



The two planes are rigid and the problem is at steady-state. Focus on the flow for $x \gg H$ and do the following:

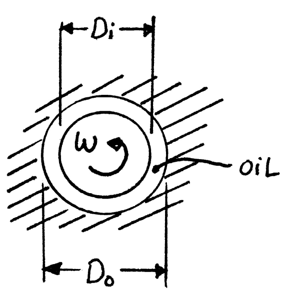
(a) Use the momentum equations in viscous form and the mass conservation equation to determine the velocity distribution in the duct.

(b) Use the velocity distribution found in (a) to find the mass flow rate per unit depth.

(c) Explain why the mass flow rate found in (b) scales with H^3.

Question #2

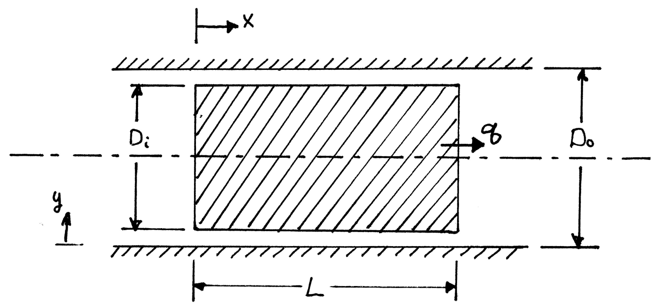
A crankshaft journal bearing in an automobile engine is lubricated by oil with a kinematic viscosity of 10^{-4} m^2/s and a density of 885 kg/m^3:



The bearing inner diameter D_i is of 10 cm, the bearing outer diameter D_o is of 11 cm, and the bearing rotates at 7200 rpm. The bearing is under no load so the clearance is symmetric. Determine the torque per unit depth and the power dissipated per unit depth.

Question #3

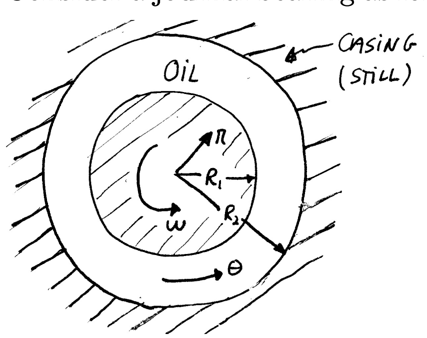
A piston with a diameter of $D_\mathrm{i} = 100$ mm and a length $L = 150$ mm is moving concentrically in a cylinder with a diameter $D_\mathrm{o} = 100.1$ mm. The gap between the cylinder and the piston is filled with oil:



The kinematic viscosity of the oil is 65 cSt and the density is 885 $\mathrm{kg/m^3}$. How big is the force that has to be applied to move the piston in the axial direction with a speed $q = 3$ m/s if only the viscous resistance is considered? Note: 1 cSt$=10^{-6}$ m ^{2}/s.

Question #4

Consider a journal bearing as follows:



Starting from the Navier-Stokes equations in cylindrical coordinates, derive an expression for v_θ as a function of r. It is known that $R_2 - R_1 = \frac{1}{4}R_1$. Indicate clearly the assumptions (including terms dropped) and explain why this is valid in this case.

Answers

2. 10.48 Nm/m, 7903 W/m.
4. $\omega R_1 \ln(r/R_2)/\ln(R_1/R_2)$ or $\omega R_1^2(R_1^2 - R_2^2)^{-1}(r - R_2^2/r)$.

Due on Thursday Feb. 15 at 11:00 am. Do Questions #1, #3 and #4 only.