

**International Master's Programs of Chemical Engineering in the Graduate School of Engineering,  
Kyushu University (Academic Year from October, 2025)**

Subject : Fluid Dynamics (1 sheet)

1. (30 points)

Answer the following questions regarding to the steady-state laminar flow of an incompressible liquid in an annular region between two coaxial cylinders of radii  $\kappa R$  and  $R$  as shown in Fig. 1. Define the required physical properties and parameters.

- (1.1) Write the equation of motion.
- (1.2) Give the radial distribution of axial velocity  $u_z$  using the above answer.
- (1.3) Give the mass flow rate  $w$ .
- (1.4) Give and explain the mass flow rate when the lower limit of  $\kappa \rightarrow 0$  is considered.

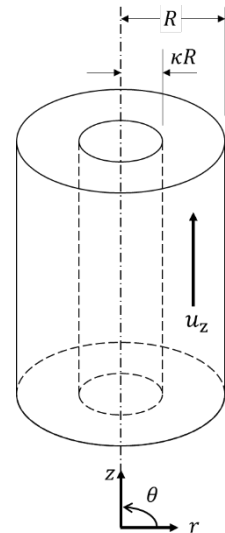


Fig. 1

2. (20 points)

Answer the following questions about the turbulent flow in a pipe.

- (2.1) Explain the friction velocity.
- (2.2) Explain the Prandtl's mixing length hypothesis.
- (2.3) Explain the von Kármán-Prandtl universal logarithmic velocity distribution.