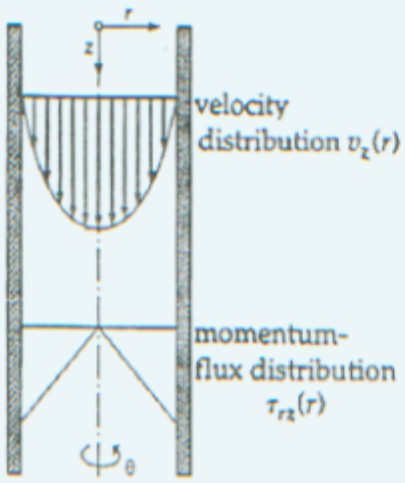
1. **Explain the following terms. (20%)** (1) Reynolds number and creeping flow, (2) Newton's law of viscosity and Newtonian fluid, and (3) rotameter, thermocouple and Bourdon gauge.

2. Flow through a circular tube. (20%) A steady-state, laminar flow of a fluid of constant density ρ and viscosity μ in a vertical tube of length L and radius R. The liquid flow downward under the influence of a pressure difference and gravity; the coordinate system is shown below. Assuming velocity $v_z = v_z(r)$, $v_r = 0$, $v_\theta = 0$, and pressure $p = p(z)$, the momentum-flux distribution τ_{rz} and velocity distribution v_z for the downward flow in a circular tube can be obtained as:

$$\tau_{rz} = -\left(\frac{\mathcal{P}_0 - \mathcal{P}_L}{2L}\right) r$$

$$v_z = \frac{(\mathcal{P}_0 - \mathcal{P}_L)R^2}{4\mu L}\left[1 - \left(\frac{r}{R}\right)^2\right]$$



$\mathcal{P}_0$ and $\mathcal{P}_L$ are "modified pressure" defined as $\mathcal{P} = p + \rho g h$, where h is the distance upward (direction opposed to gravity, $h = -z$). (1) Briefly explain the velocity distribution and momentum-flux distribution according to the equations. Calculate (2) maximum velocity, (3) average velocity, (4) mass rate of flow (Hagen-Poiseuille equation), and (5) force of the fluid in z direction on the wetted surface of the pipe.

3. Mechanical separations of particulate solids. (10%) (1) List three types of the mechanical separations for particulate solids and briefly explain the principles, and (2) sketch a cyclone separator and briefly explain it.

4. **Heat transfer in a circular tube. (25%)** For the same flow geometry considered in Problem 2, using **shell balance** to derive the steady-state temperature equation under the condition of constant wall heat flux q_0. How the resultant equation and boundary conditions may be made dimensionless to facilitate the subsequent solution scheme?

5. **Dimensionless groups in heat or mass transfer. (15%)** Provide the physical significance of the following dimensionless groups: (a) Prandtl number, (b) Grashof number, (c) Schmidt number, (d) Peclet number, (e) Biot number

6. **Terminology in transport phenomena. (10%)** Explain the following terminologies: (a) film temperature, (b) Operating line vs. Equilibrium line, (c) diffusion-controlled process.