Viscous fluid flowing through two infinite parallel plates is shown in the following figure (Fig. (a)). The distance between the plates is \( a \). The bottom plate is stationary and the upper plate moves with constant velocity \( U \). The flow is considered as fully developed laminar flow. Derive the velocity distribution \( u(y) \) as the following equation.

\[
    u(y) = \frac{U y}{a} + \frac{a^2}{2\mu} \left( \frac{\partial P}{\partial x} \right) \left( \frac{y}{a} \right)^2 - \left( \frac{y}{a} \right)
\]

where \( \mu \) is viscosity of fluid, \( \frac{\partial P}{\partial x} \) is pressure drop in the flow direction.

(12%)

(b) Plot the separated velocity profile of (i) \( \frac{\partial P}{\partial x} = 0 \) and (ii) \( \frac{\partial P}{\partial x} < 0 \) qualitatively in the following coordinate (Fig. (b)) in your answer sheet. (8%)

(注：將Fig. (b)之座標繪在答案卷上，並將(i)和(ii)之速度分佈圖繪在答案卷上之座標內)

2. Viscous fluid flows through a circular rough pipe of which the length is \( L \). Consider suitable parameters to determine a set of dimensionless groups that can be used to correlate data of pressure lose. (13%)
3. A horizontal circular jet of water strikes a flat plate as shown in the figure. The velocity magnitude remains constant as the water flows over the plate. Determine (a) the magnitude of the force $F_A$ to hold the plate stationary; (b) the fraction of mass flow along the plate in each of the two directions; (c) the magnitude of $F_A$ to allow the plate to move to the right at a constant speed of 2 m/s. (17%)

4. Water enters a rotating lawn sprinkler through its base at a rate of 2 liter/s as seen in the following sketch. The exit area of each of the nozzles is 50 mm$^2$ and the flow leaving each nozzle is in the tangential direction. The radius of the sprinkler is 300 mm. Determine (a) the resisting torque required to hold the sprinkler stationary; (b) the resisting torque when the sprinkler rotating at 100 rev/min; (c) the speed of the sprinkler if no resisting torque is applied. (17%)
5. An aluminum sphere \( (\rho = 2735\,\text{kg/m}^3) \), \( c_p = 837.3\,\text{W/s/kg} \cdot \text{°C} \), \( k = 207.6\,\text{W/m} \cdot \text{°C} \) of diameter \( d = 2.5\,\text{cm} \) at uniform temperature \( T_0 = 95\,\text{°C} \) is suddenly immersed at time \( t = 0 \) in a well-stirred fluid which is kept at a constant temperature \( T_\infty = 5\,\text{°C} \). The sphere loses heat by convection from its surface to the fluid with a heat transfer coefficient \( h = 100\,\text{W/m}^2 \cdot \text{°C} \). Use a simple lump-system analysis to estimate the time required for the average temperature of the sphere to reach 30\,\text{°C} \). (17%) 

6. Consider a laminar flow inside a long circular tube subjected to uniform heat flux at the wall.
(a). Plot the average fluid and tube wall temperature distributions in the axial direction. (5%)
(b). Specify the condition for the fully developed heat transfer and explain its physical meaning. (5%)
(c). Define the convection heat transfer coefficient in the flow. (6%)