NOTE: In multiple-choice questions, choose **ONLY** one answer.

Questions

Q1. In steady and incompressible fluid flows with the uniform velocity distribution, the momentum flux in a given *x*-direction past a given section is expressed as $M_x =$

(a) ρQV

(b) $\rho V^2/2$

(c) ρQV_x

(d) Q^2/A

Q2. We all intuitively know that the water jet pushes the fire fighter, shown below, towards the left direction. Use the momentum equation to justify that.

Q3. In a duct (rectangular pipe) flow, air flows in the bottom half of the duct with a uniform velocity and there is no flow in the upper half. The value of the kinetic energy correction factor α for this flow is:

(a) 2.0

(b) 2.25

(c) 4.0

(d) 3.0

Q4. In a pipe flow of a **<u>real</u>** fluid with no additional source of energy:

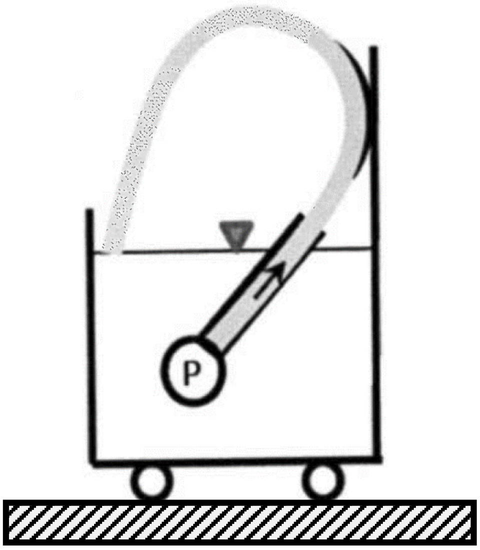
(a) The energy line will be horizontal or slipping upward in the direction of flow.

(b) The energy line can never be horizontal or slopping upward in the direction of the flow.

(c) The Piezometric line can never be horizontal or slopping upward in the direction of the flow.

(d) The center line of the pipe can never be above the Piezometric line.

Q5. A pump is installed in a reservoir on wheels, and the flow is diverted back into the reservoir, as shown. Neglect the friction between the wheels and the ground. Does the cart move or not? Why or why not? **Explain briefly your reasoning.**

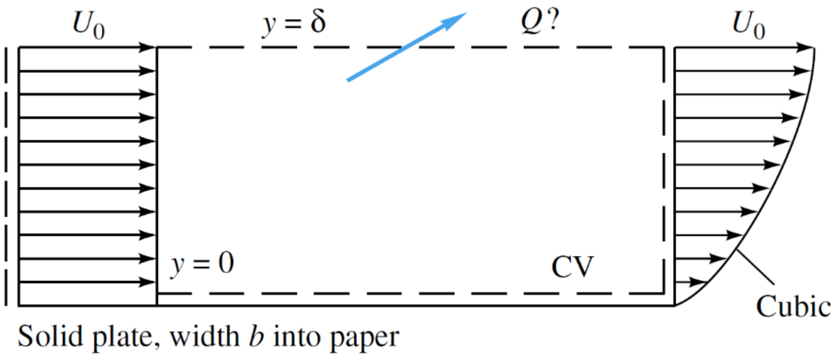


Problems

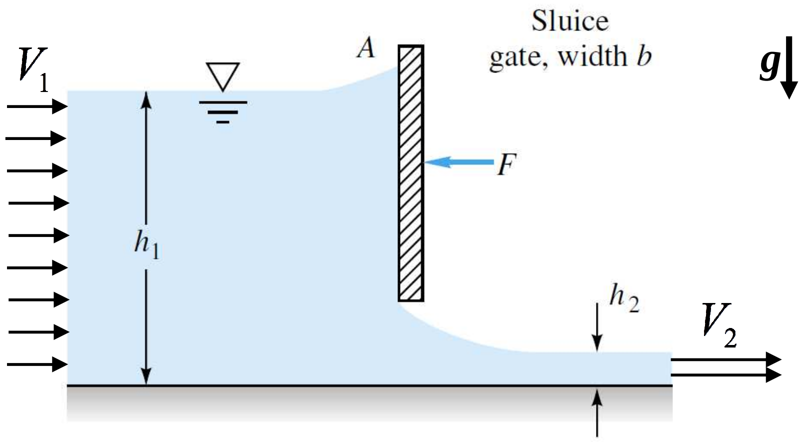
P1. An incompressible fluid flows past an impermeable flat plate, as shown below, with a uniform inlet profile $u = U_0$ and a cubic polynomial exit profile:

$$u \approx U_0 \left(\frac{3\eta - \eta^3}{2} \right) \text{ where } \eta = \frac{y}{\delta}$$

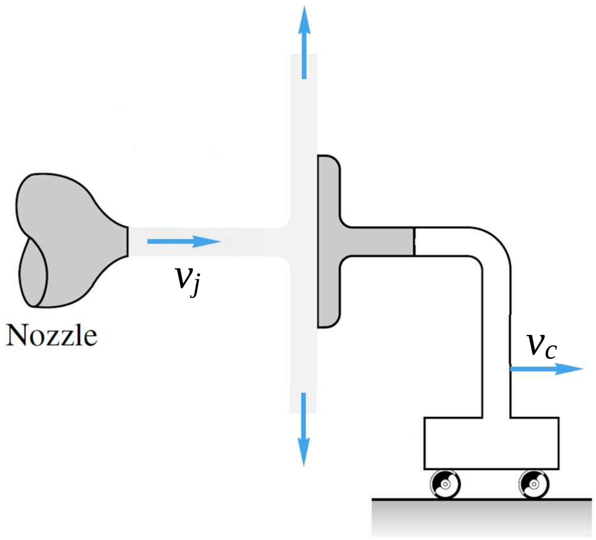
Compute the volume flow rate Q across the top surface of the control volume.



P2. The sluice gate, shown below, controls flow in open channels. The channel is rectangular with a width (and gate width), b=3 m, into the paper. Assume that the flow is uniformly distributed in sections 1 and 2, and neglect friction on the bottom. If $\rho = 1000\ \text{kg/m}^3$, $h_1 = 7\ \text{m}$, $h_2 = 2\ \text{m}$ and $V_1 = 2.5\ \text{m/s}$, what is the required force F to hold the gate? (NOTE: the gravitational effects are **NOT** negligible.)



P3. A water jet of velocity v_j impinges normal to a flat plate that moves to the right at velocity v_c as shown below. Find the force required to keep the plate moving at constant velocity if the jet density is 1000 kg/m^3, the jet area is 3 cm^2, and v_j and v_c are 20 and 15 m/s, respectively. Neglect the weight of the jet and plate, and assume steady flow with respect to the moving plate with the jet splitting into an equal upward and downward jets whose cross-section areas are half of the area of incoming jet.



P4. The *pump-turbine* system shown below draws water from the upper reservoir in the daytime to produce power for a city. At night, it pumps water from lower to upper reservoirs to restore the situation. For a design mass flow rate of 1000 kg/s in either direction, the friction head loss is 5 m. Assume that the efficiency of the *pump-turbine* system in both conditions is 80% and the kinetic energy correction factor $\alpha \approx 1$. ($\rho = 1000$ kg/m^3)

(a) Estimate the power in kW extracted by the turbine.

(b) Calculate the power in kW generated by the turbine.

(c) Sketch the EGL and the HGL for the system in daytime.

(d) Estimate the power in kW delivered to the fluid by the pump.

(e) Calculate the power in kW consumed by the pump.

(f) Sketch the EGL and the HGL for the system at night.