# FLUIDS I
## Example sheet 4: Control Volume Analysis

**1** A 10 cm fire hose with a 3 cm nozzle discharges water at a rate of 1.5 $m^3$/min to the atmosphere. Assuming frictionless flow, find the force exerted by the flange bolts to hold the nozzle on the hose.

(Answer 4069 N)

(**Note**: This problem might give you a theoretical feeling for why it takes more than one fire-fighter to hold a fire hose at full discharge!)

**2** A water jet (diameter 10 cm, velocity 8 m/s) strikes normal to a fixed plate. Neglecting gravity and friction compute the force required to hold the plate fixed.

(Answer 503 N)

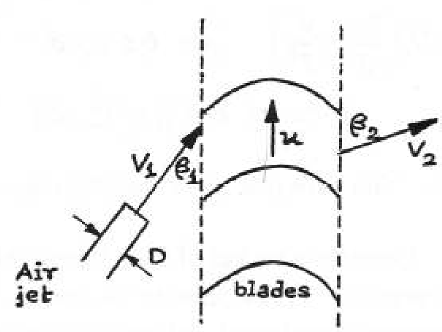
**3** The diameter of a pipe-bend is 300 mm at inlet and 150 mm at outlet and the flow is turned through 120° in a vertical plane. The axis at inlet is horizontal and the centre of the outlet section is 1.4 m below the centre of the inlet section. The total volume of fluid contained in the bend is 0.085 $m^3$. Neglecting friction, calculate the magnitude and direction of the net force exerted on the bend by water flowing through it at 0.23 $m^3$/s when the inlet gauge pressure is 140 kPa.

(Answer 13.12 kN at 12.75° upwards from inlet axis)

**4** A thin-plate orifice inserted inside a pipe causes a large pressure drop. For 20°C water flow at 500 gal/min, with 10 cm pipe diameter and 6 cm orifice diameter, the pressure drop is 145 kPa. If the wall friction is negligible, estimate the force of the water on the orifice plate.

(Answer 1139 N in the flow direction)

**5** A fluid jet of diameter $D_1$ enters a cascade of moving blades at absolute velocity $V_1$ and angle $\beta_1$, and it leaves at absolute velocity $V_2$ and angle $\beta_2$. The blades move at velocity $u$. Find the force acting on the blades and derive a formula for the power delivered to the blades as a function of these parameters.



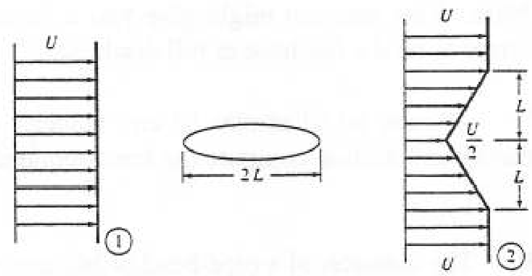

(Answer Force = $\dot{m}(V_1 \cos\beta_1 - V_2 \cos\beta_2)$

Power = $\frac{1}{2}\dot{m}\left(V_1^2 - V_2^2\right)$, where, $\dot{m} = \frac{\pi}{4} D_1^2 \rho_1 V_1$

**6** To propel a light aircraft at an absolute velocity of 240 km/h against a head wind of 48 km/h a thrust of 10.3 kN is required. Assuming a theoretical efficiency of 90% and a constant air density of 1.2 kg/$m^3$ determine the diameter of ideal propeller required and the power needed to drive it.

(Answer 2.63 m, 915.6 kW)

**7** When a uniform stream flows past an immersed thick cylinder, a broad low-velocity wake is created downstream, idealised as a V shape in the adjoining figure. Pressures $p_1$ and $p_2$ are approximately equal. If the flow is two-dimensional and incompressible, with width $b$ into the paper, derive a formula for the drag force $D$ on the cylinder. Rewrite your result in the form of a dimensionless drag coefficient based on body length $C_D = D/(\rho U^2 bL)$.



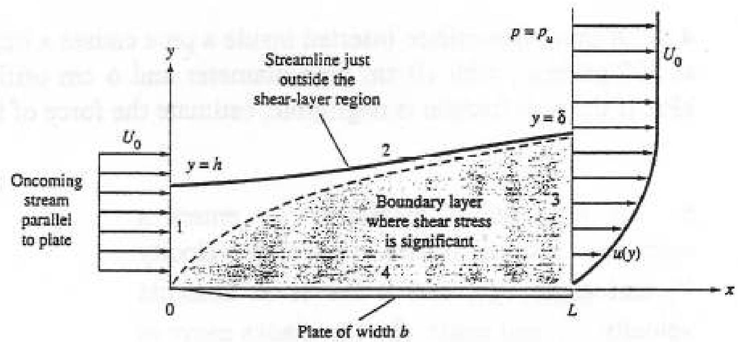

**Hint** : Using the conservation of mass, determine the co-ordinates $\pm H$ of the streamlines at section 1 which pass through the co-ordinates $\pm L$ at section 2. Then use the momentum equation to find the drag force.

(Answer $C_D = 1/3$)

**8** Using a control-volume analysis determine the drag force $D$ on the plate shown in the figure. Assume the pressure is uniform everywhere and the velocity profile at $x = L$ within the boundary layer is given by

$$u = U_o\left(\frac{2y}{\delta} - \frac{y^2}{\delta^2}\right) \qquad for \quad 0 \le y \le \delta .$$

(Answer $D = \frac{2}{15}\rho U_o^2 \, b\delta$)




**Note** : You have just learnt von Karman's integral analysis of a boundary layer.