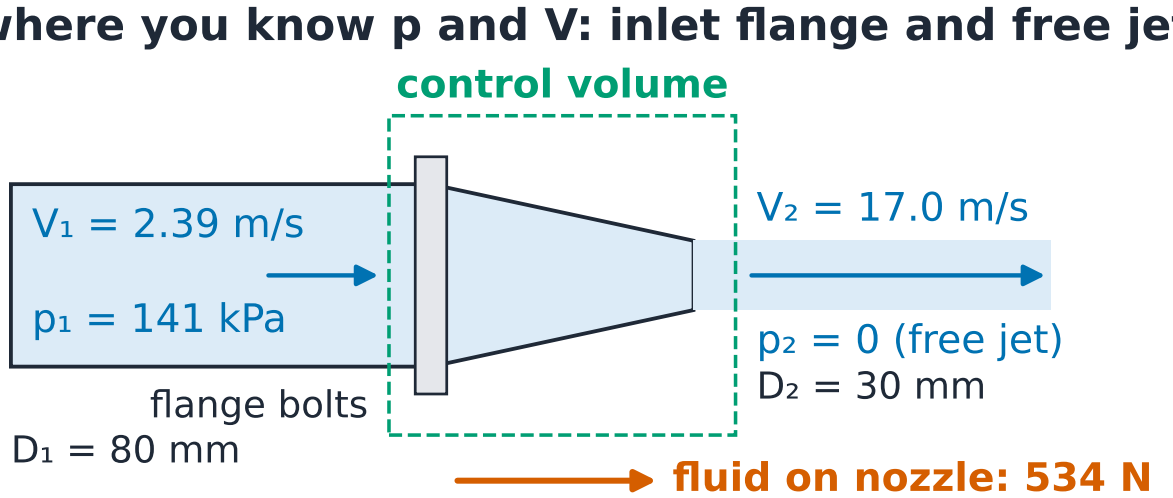
Exercise walk-through

7.2 Conservation and control volumes

University Mechanical Engineering

Control volume: the nozzle bolts



12 L/s from 80 mm into a 30 mm jet: $V_1 = \mathbf{2.39}$, $V_2 = \mathbf{17.0}$ m/s, $p_1 = \mathbf{141}$ kPa. $p_1 A_1 + F = \rho Q(V_2 - V_1)$: the fluid pushes the nozzle downstream with $\mathbf{534}$ N.

The bend and its thrust block

1. **Each direction** 90° bend, 80 mm, 150 kPa gauge, 12 L/s: $pA + \rho QV = 754.0 + 28.6 = \mathbf{782.6}$ N.
2. **Resultant** $\sqrt{2} \times 782.6 = \mathbf{1107}$ N at 45° - the thrust block's load.
3. **Lesson** At low speed pressure dominates momentum, so high-pressure lines need anchors even when the flow is slow.

Exercises 2.1·2.2

2.1 $Q = 8$ L/s flows in a 60 mm pipe and leaves through a 25 mm nozzle. Find the speed in the pipe and in the jet (one decimal and two decimals, m/s). [3]

2.2 The jet of 2.1 hits a flat plate square on and leaves sideways. Find the force on the plate (nearest newton). [3]

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2.1

- $A_1 = \pi(0.030)^2 = 2.827 \times 10^{-3}$ m^2; $V_1 = Q/A_1 = 0.008/(2.827 \times 10^{-3}) = \mathbf{2.8}$ m/s.
- $A_2 = \pi(0.0125)^2 = 4.909 \times 10^{-4}$ m^2; $V_2 = Q/A_2 = \mathbf{16.30}$ m/s.

2.2 The jet of 2.1 hits a flat plate square on and leaves sideways. Find the force on the plate (nearest newton). [3]

2.2

- All the jet's momentum normal to the plate is destroyed: $F = \rho Q V_2 = 998 \times 0.008 \times 16.30 = \mathbf{130}$ N.

Exercise 2.3

2.3 For the nozzle of 2.1, find the inlet gauge pressure (one decimal, kPa) and the force in the flange bolts (nearest newton), and say whether they are in tension or compression. [5]

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- Bernoulli, $p_2 = 0$ gauge: $p_1 = \tfrac{1}{2}\rho(V_2^2 - V_1^2) = 0.5 \times 998 \times (16.30^2 - 2.83^2) = \mathbf{128.5}$ kPa.
- Momentum: $p_1 A_1 + F = \rho Q(V_2 - V_1)$, with $p_1 A_1 = 363.4$ N and $\rho Q(V_2 - V_1) = 107.5$ N.
- $F = 107.5 - 363.4 = -255.9$ N on the fluid, so the fluid pushes the nozzle downstream: the bolts carry **256** N in **tension**.

Exercise 3.1

3.1 The same 8 L/s turns through 90° in the 60 mm pipe at 200 kPa gauge. Find the force from each end (pressure plus momentum, one decimal, N), the resultant anchor force (nearest newton) and its direction. Which term dominates, and what does that mean for thrust blocks? [5]

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3.1

- Each end: $pA+\rho QV = 200\,000\times2.827\times10^{-3}+998\times0.008\times2.83 = 565.5+22.6 = \mathbf{588.1}$ N.
- The two are at right angles: $R = \sqrt{2}\times 588.1 = \mathbf{832}$ N, at 45° into the outside of the bend.
- Pressure is 96% of each term, so even slow, high-pressure lines need thrust blocks at bends.