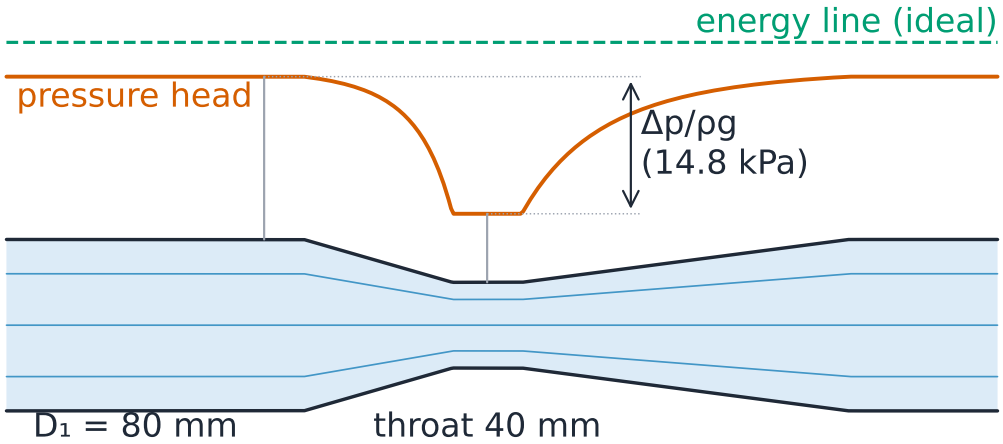
Exercise walk-through

7.3
Bernoulli and flow measurement

University Mechanical Engineering

Bernoulli: speed up, pressure down

Bernoulli along a streamline: speed up, pressure down



Venturi 80 → 40 mm ($\beta = 0.5$), $\Delta p = 14.8$ kPa: $Q_i = A_2\sqrt{2\Delta p/\rho(1-\beta^4)} =$ **7.07** L/s; with $C_d = 0.98$, $Q =$ **6.93** L/s.

The pitot tube and the assumptions

1. **Pitot** Air duct, 450 Pa between ports: $V = \sqrt{2\Delta p/\rho} = \sqrt{2 \times 450/1.204} = \mathbf{27.3}$ m/s.
2. **Validity** Mach 0.08, well under 0.3, so the air is effectively incompressible.
3. **Traps** Never across a pump or a lossy region; never drop $1 - \beta^4$; never $C_d = 1$ for an orifice.

Exercises 2.1·2.2

2.1 An open tank drains through a sharp 20 mm orifice 2.0 m below the surface. Find the ideal jet speed (two decimals, m/s) and the flow with $C_d = 0.61$ (two decimals, L/s). [4]

2.2 A pitot-static tube in an air duct reads 300 Pa. Find the air speed (one decimal, m/s). [3]

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2.1

- Bernoulli from the still surface to the jet, both at atmospheric pressure: $V = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 2.0} = \mathbf{6.26}$ m/s.
- $Q = C_d A V = 0.61 \times \pi (0.010)^2 \times 6.26 = \mathbf{1.20}$ L/s.

2.2 A pitot-static tube in an air duct reads 300 Pa. Find the air speed (one decimal, m/s). [3]

2.2

- Stagnation at the tip: $\Delta p = \tfrac{1}{2}\rho V^2$, so $V = \sqrt{2\Delta p/\rho} = \sqrt{2 \times 300/1.204} = \mathbf{22.3}$ m/s.

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Exercises 2.3·3.1

2.3 A venturi narrows a 100 mm pipe to a 50 mm throat and reads $\Delta p = 20$ kPa. Find the ideal flow and the real flow with $C_d = 0.98$ (two decimals, L/s). [4]

3.1 An orifice plate with the same $\beta = 0.5$ and the same 20 kPa reading replaces the venturi of 2.3. Find its flow with $C_d = 0.61$ (two decimals, L/s). Explain in two sentences why the same reading means less flow, and why the orifice is still often chosen. [5]

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2.3

- $A_2 = \pi(0.025)^2 = 1.963 \times 10^{-3}$ m^2; $1 - \beta^4 = 0.9375$.
- $Q_i = A_2\sqrt{2\Delta p/(\rho(1-\beta^4))} = 1.963 \times 10^{-3}\sqrt{2 \times 20\,000/(998 \times 0.9375)} = \mathbf{12.84}$ L/s.
- $Q = 0.98 \times 12.84 = \mathbf{12.58}$ L/s.

3.1 An orifice plate with the same $\beta = 0.5$ and the same 20 kPa reading replaces the venturi of 2.3. Find its flow with $C_d = 0.61$ (two decimals, L/s). Explain in two sentences why the same reading means less flow, and why the orifice is still often chosen. [5]

3.1

- $Q = C_d Q_i = 0.61 \times 12.84 = \mathbf{7.83}$ L/s.
- The jet contracts after the sharp plate (the vena contracta) and loses energy in eddies, so less flow gives the same pressure drop.
- An orifice is cheap, short and easy to change; the venturi's gentle cone recovers pressure but costs length and money.