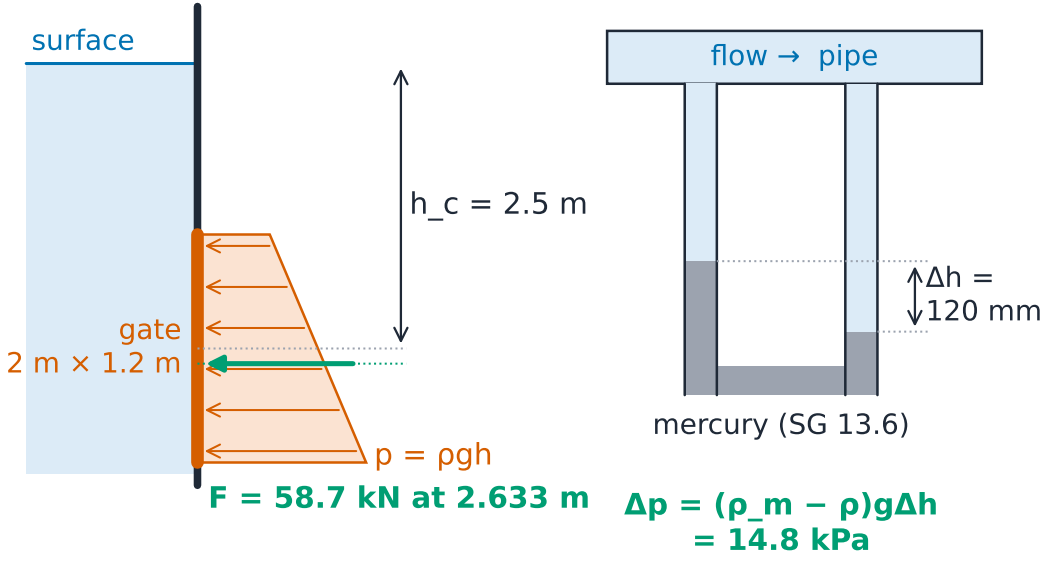
Exercise walk-through

7.1
Fluid properties and statics

University Mechanical Engineering

Statics: pressure grows with depth



Gate 2 m $\times$ 1.2 m, top 1.5 m down: $F = \rho g h_c A = \mathbf{58.7}$ kN, acting at $y_{cp} = y_c + I_c/(y_c A) = \mathbf{2.633}$ m - below the centroid.

Manometers and viscosity

1. **Manometer** Mercury (SG 13.6), $\Delta h = 120$ mm: $\Delta p = (\rho_m - \rho) g \Delta h = \mathbf{14.8}$ kPa. Using ρ_m alone overstates it by 8%.
2. **Viscosity** Plate at 2 m/s on a 0.5 mm oil film, $\mu = 0.29$ Pa · s: $\tau = \mu\, du/dy = \mathbf{1160}$ Pa.
3. **Kinematic** $\nu = \mu/\rho = 1.004 \times 10^{-6}$ m^2/s for water - the **viscosity** that enters every **Reynolds number**.

Exercises 2.1·2.2

2.1 A water tank is 4.0 m deep. Find the gauge pressure at the bottom (one decimal, kPa) and the absolute pressure there (one decimal, kPa). [3]

2.2 A vertical rectangular gate 1.0 m wide and 1.5 m high has its top edge 2.0 m below the surface. Find the resultant force (one decimal, kN) and the depth of the centre of pressure (three decimals, m). [5]

Exercises 2.1·2.2

2.1 A water tank is 4.0 m deep. Find the gauge pressure at the bottom (one decimal, kPa) and the absolute pressure there (one decimal, kPa). [3]

2.1

- Gauge pressure from depth: $p = \rho g h = 998 \times 9.81 \times 4.0 = \mathbf{39.2}$ kPa.
- Absolute adds the atmosphere: $p_{abs} = 101.3 + 39.2 = \mathbf{140.5}$ kPa.

2.2 A vertical rectangular gate 1.0 m wide and 1.5 m high has its top edge 2.0 m below the surface. Find the resultant force (one decimal, kN) and the depth of the centre of pressure (three decimals, m). [5]

2.2

- Centroid depth $h_c = h_{top} + h/2 = 2.0 + 0.75 = 2.75$ m; $A = 1.5$ m^2.
- $F = \rho g h_c A = 998 \times 9.81 \times 2.75 \times 1.5 = \mathbf{40.4}$ kN.
- $I_c = bh^3/12 = 1.0 \times 1.5^3/12 = 0.281$ m^4; $y_{cp} = y_c + I_c/(y_c A) = 2.75 + 0.281/(2.75 \times 1.5) = \mathbf{2.818}$ m.

Exercises 2.3·3.1

2.3 A mercury U-tube across a water pipe fitting reads $\Delta h = 80$ mm. Find the pressure difference (two decimals, kPa). [3]

3.1 A plate of area 0.4 m^2 slides at 1.5 m/s on an oil film 0.8 mm thick with $\mu = 0.29$ Pa · s. Assume a linear velocity profile. Find (a) the shear stress, (b) the force needed to drag the plate and (c) the power dissipated in the film. [5]

Exercises 2.3·3.1

2.3 A mercury U-tube across a water pipe fitting reads $\Delta h = 80$ mm. Find the pressure difference (two decimals, kPa). [3]

2.3

- The water columns cancel except over Δh: $\Delta p = (\rho_m - \rho) g \Delta h = (13.6 - 1) \times 998 \times 9.81 \times 0.08 = \mathbf{9.87}$ kPa.

3.1 A plate of area 0.4 m^2 slides at 1.5 m/s on an oil film 0.8 mm thick with $\mu = 0.29$ Pa · s. Assume a linear velocity profile. Find (a) the shear stress, (b) the force needed to drag the plate and (c) the power dissipated in the film. [5]

3.1

- (a) Linear profile, so $du/dy = V/h$: $\tau = \mu V/h = 0.29 \times 1.5/0.0008 = \mathbf{544}$ Pa.
- (b) $F = \tau A = 543.75 \times 0.4 = \mathbf{218}$ N.
- (c) $P = FV = 217.5 \times 1.5 = \mathbf{326}$ W, all turned to heat in the oil.