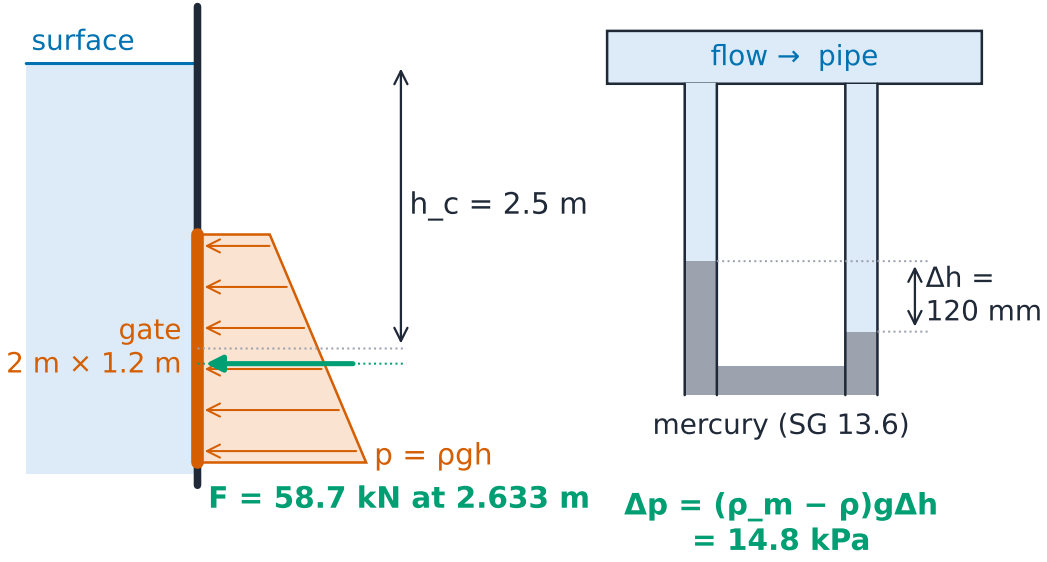
Exercise walk-through

7.1
Fluid properties and statics

University Mechanical Engineering

Statics: pressure grows with depth



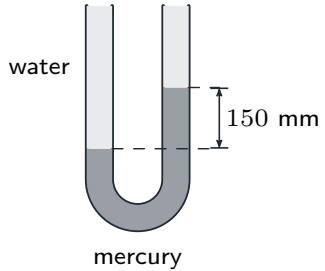
Gate 2 m $\times$ 1.2 m, top 1.5 m down: $F = \rho g h_c A = \mathbf{58.7}$ kN, acting at $y_{cp} = y_c + I_c/(y_c A) = \mathbf{2.633}$ m - below the centroid.

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**.

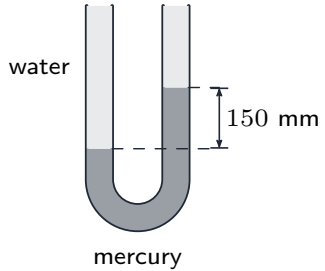
Exercise 2.1

2.1 A U-tube manometer with mercury under water shows a level difference of 150 mm. Find the pressure difference between its two connections (at the same height). [2]



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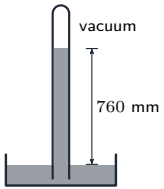


2.1

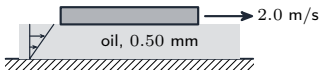
$$\Delta p = (\rho_{Hg} - \rho_w) g \Delta h = 12\,600 \times 9.81 \times 0.150 = \mathbf{18.5\ kPa}$$

Exercises 2.2·2.3

2.2 A mercury barometer reads 760 mm. Find the atmospheric pressure, and the height a water barometer would need. [2]

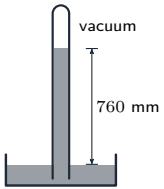


2.3 A plate of area 0.50 m^2 slides at 2.0 m/s on a 0.50 mm oil film with $\mu = 0.10$ Pa s. Find the shear stress, the force and the power lost. [3]



Exercises 2.2·2.3

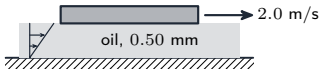
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2.2

$p = 13\,600 \times 9.81 \times 0.760 = \mathbf{101.4\ kPa}$; water: $h = \dfrac{101.4 \times 10^3}{1000 \times 9.81} = \mathbf{10.3\ m}$, far too tall to be practical

2.3 A plate of area 0.50 m^2 slides at 2.0 m/s on a 0.50 mm oil film with $\mu = 0.10$ Pa s. Find the shear stress, the force and the power lost. [3]



2.3

$\tau = \mu \dfrac{U}{h} = 0.10 \times \dfrac{2.0}{0.0005} = \mathbf{400\ Pa}$; $F = 400 \times 0.50 = \mathbf{200\ N}$; $P = FU = \mathbf{400\ W}$

Exercise 2.4

2.4 Give the SI units of dynamic viscosity μ and kinematic viscosity ν, and find ν for an oil with $\mu = 0.10$ Pa s and $\rho = 880$ kg/m^3. [2]



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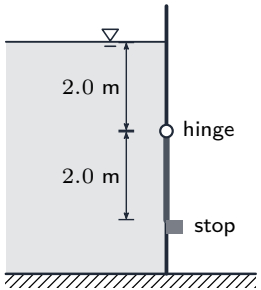
2.4

μ in Pa s $=$ kg/(m s); ν in m^2/s; $\nu = \dfrac{0.10}{880} = \mathbf{1.14 \times 10^{-4}\ m^2/s}$

Exercise 3.1

3.1 A vertical rectangular gate 1.5 m wide and 2.0 m tall is hinged along its top edge, which is 2.0 m below the water surface. A stop at the bottom edge holds it shut.

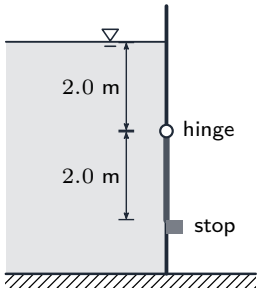
Find the water force, the depth of the centre of pressure, and the force on the stop. [5]



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Find the water force, the depth of the centre of pressure, and the force on the stop. [5]



3.1

$h_c = 3.0$ m, $A = 3.0$ m^2: $F = 1000 \times 9.81 \times 3.0 \times 3.0 = \mathbf{88.3\ kN}$

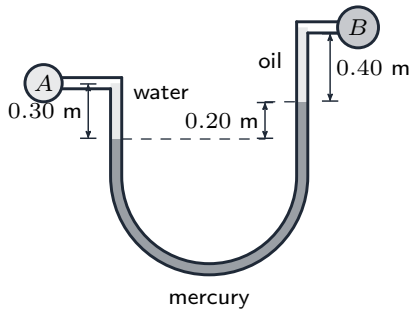
$y_{cp} = 3.0 + \dfrac{1.5 \times 2.0^3/12}{3.0 \times 3.0} = \mathbf{3.11\ m}$, so 1.11 m below the hinge

moments about the hinge: $2.0F_{stop} = 88.3 \times 1.11$, $F_{stop} = \mathbf{49.1\ kN}$

Exercise 3.2

3.2 A manometer joins pipe A (water) to pipe B (oil, $\rho = 850\ \text{kg/m}^3$). From A the water goes down 0.30 m to the mercury. The mercury on the B side stands 0.20 m higher, and the oil above it rises 0.40 m to B.

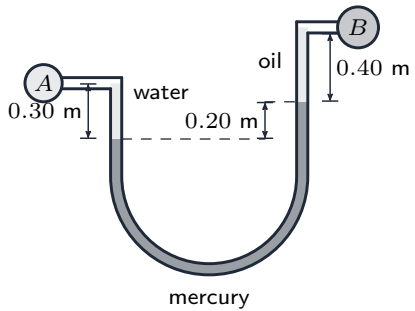
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Find $p_A - p_B$. [4]



3.2

walk from A: $p_A + \rho_w g(0.30) - \rho_{Hg} g(0.20) - \rho_o g(0.40) = p_B$

$p_A - p_B = -2.94 + 26.68 + 3.34 = \mathbf{27.1\ kPa}$

Exercise 3.3 (a)

3.3 A steel pontoon is a box 6.0 m long, 2.5 m wide and 1.2 m deep. With its deck load its mass is 8000 kg, and its centre of gravity is $KG = 0.90$ m above the keel. It floats in fresh water.

(a) Find the draft and the freeboard. [2]

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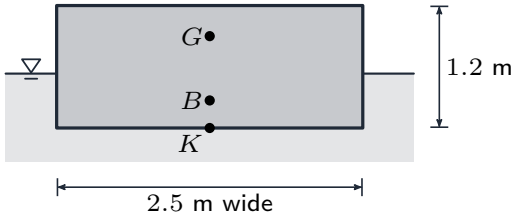
(a) Find the draft and the freeboard. [2]

(a) draft $= \dfrac{8000}{1000 \times 6.0 \times 2.5} = \mathbf{0.533\ m}$; freeboard $= 1.2 - 0.533 = \mathbf{0.67\ m}$

Exercise 3.3 (b)

3.3 A steel pontoon is a box 6.0 m long, 2.5 m wide and 1.2 m deep. With its deck load its mass is 8000 kg, and its centre of gravity is $KG = 0.90$ m above the keel. It floats in fresh water.

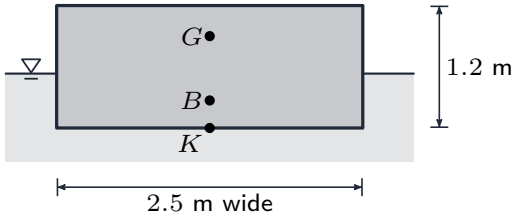
(b) Find KB, BM and the metacentric height GM. Decide whether the pontoon is stable. [4]



Exercise 3.3 (b)

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(b) Find KB, BM and the metacentric height GM. Decide whether the pontoon is stable. [4]



(b) $KB = \dfrac{0.533}{2} = 0.267$ m; $BM = \dfrac{6.0 \times 2.5^3/12}{8.0} = 0.977$ m

$GM = 0.267 + 0.977 - 0.90 = \mathbf{0.34\ m}$; $GM > 0$: **stable**

Exercise 3.3 (c)

3.3 A steel pontoon is a box 6.0 m long, 2.5 m wide and 1.2 m deep. With its deck load its mass is 8000 kg, and its centre of gravity is $KG = 0.90$ m above the keel. It floats in fresh water.

(c) A crane is to be mounted on the deck without changing the mass much. Find the highest KG allowed for a margin of $GM \geq 0.15$ m. [2]

Exercise 3.3 (c)

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(c) $KG \leq 0.267 + 0.977 - 0.15 = \mathbf{1.09\ m}$