

4 Forces, density and pressure – Part 2

Name: _____ Class: _____ Date: _____

Vocabulary

Write each word three times.

English	Write it 3 times (English)		
couple	_____	_____	_____
torque	_____	_____	_____
equilibrium	_____	_____	_____
vector triangle	_____	_____	_____
upthrust	_____	_____	_____
Archimedes' principle	_____	_____	_____
displaced	_____	_____	_____
floats	_____	_____	_____

Recall

In **Part 1** you found the moment of a force ($M = F \times d$), used the principle of moments to balance a beam, and met density, pressure and hydrostatic pressure ($p = \rho gh$). Part 2 adds a special pair of forces, the full rules for balance, and why things float.

New ideas

Read these first. Each idea has a short worked example. Then do the Practice.

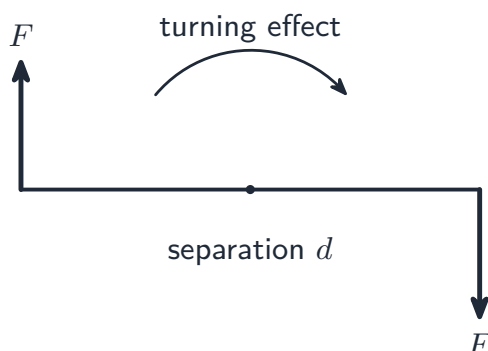
■ 1 Couples and torque

A **couple** is a pair of forces that are equal in size, opposite in direction, and have their lines of action a distance apart. A couple makes an object **turn only** – it gives no straight-line push.

Its turning effect is the **torque** :

$$\tau = F \times d,$$

where d is the perpendicular distance between the two forces. (Two equal forces in the *same* direction are **not** a couple.)

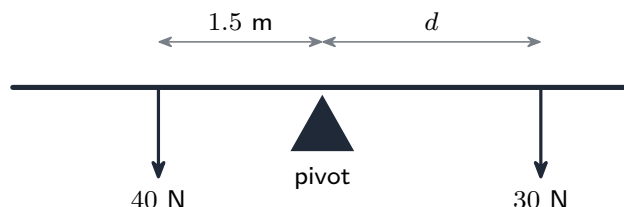


Worked example. Two hands turn a steering wheel with 10 N each in opposite directions, their lines 0.30 m apart: torque $\tau = 10 \times 0.30 = 3.0 \text{ N m}$ – a pure turn, no push.

■ 2 The two conditions for equilibrium

A body is in **equilibrium** only when **both** of these hold:

1. the resultant force is zero (no straight-line acceleration), **and**
2. the resultant moment about any point is zero (no turning).



Three forces in equilibrium can be drawn tip-to-tail as a closed **vector triangle** (the arrows return to the start) – a neat way to find an unknown force.

Worked example. A ladder resting against a wall is in equilibrium: the upward forces balance its weight (force condition), *and* the moments about its foot balance (moment condition) – both must be true at once.

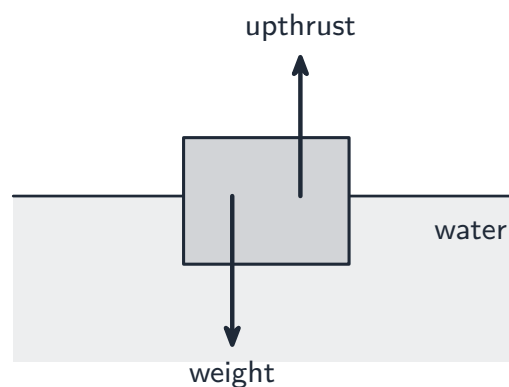
Watch out: a body can have zero resultant *force* yet still spin – equilibrium also needs the resultant *moment* to be zero. Both conditions must hold.

■ 3 Floating and upthrust

A submerged object feels an upward **upthrust** because the water pressure is greater on its bottom than its top. By **Archimedes' principle**, the upthrust equals the weight of fluid **displaced** :

$$F = \rho_{\text{fluid}} g V.$$

An object **floats** when the upthrust equals its weight (only the volume below the surface counts).



Worked example. A block of volume $2.0 \times 10^{-3} \text{ m}^3$ is fully under water ($\rho = 1000 \text{ kg m}^{-3}$): $F = 1000 \times 9.8 \times 2.0 \times 10^{-3} = 20 \text{ N}$.

Practice

4.1 State the two features that make a pair of forces a couple. [2]

4.2 A spanner is turned by a couple of two 6.0 N forces whose lines are 0.40 m apart. Find the torque. [2]

4.3 State the two conditions for a body to be in equilibrium. [2]

4.4 A stone of volume $5.0 \times 10^{-4} \text{ m}^3$ is fully submerged in water ($\rho = 1000 \text{ kg m}^{-3}$, $g = 9.8 \text{ m s}^{-2}$). Find the upthrust on it. [2]

4.5 A steel ship floats on water even though steel is denser than water. Explain why. [2]

4.6 Explain *why* a ship sits *lower* in the water when it is loaded with heavy cargo. [2]
