A-LEVEL PHYSICS • HOLIDAY HOMEWORK 假期作业

# 4 Forces, density and pressure – Part 2

Name: _____ Class: _____ Date: _____

## Vocabulary 词汇

*Write each word three times.* 把每个单词抄写三遍。

| English | 中文 | Write it 3 times (English) | | |
|---|---|---|---|---|
| couple | 力偶 | | | |
| torque | 力偶矩 | | | |
| equilibrium | 平衡 | | | |
| vector triangle | 矢量三角形 | | | |
| upthrust | 浮力 | | | |
| Archimedes' principle | 阿基米德原理 | | | |
| displaced | 排开 | | | |
| floats | 漂浮 | | | |

## 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 ($p = \rho g h$). 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.



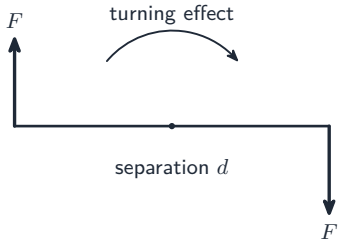
### 1 Couples and torque

A **couple** 力偶 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** 力偶矩:

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

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

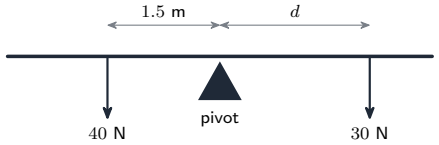



*Worked example.* Two hands turn a steering wheel with 10 N each in opposite directions, their lines 0.30 m apart: torque $\tau = 10 \times 0.30 = 3.0$ N m — a pure turn, no push.

### 2 The two conditions for equilibrium

A body is in **equilibrium** 平衡 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** 矢量三角形 (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.

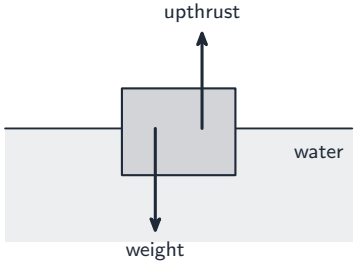
**Watch out:** a body can have zero resultant *force* yet still spin — equilibrium also needs the resultant *moment* to be zero. Both conditions must hold.

### ■ 3 Floating and upthrust

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

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

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




*Worked example.* A block of volume $2.0 \times 10^{-3}$ m$^3$ is fully under water ($\rho = 1000$ kg m$^{-3}$): $F = 1000 \times 9.8 \times 2.0 \times 10^{-3} = 20$ 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 $5.0 \times 10^{-4}$ m$^3$ is fully submerged in water ($\rho = 1000$ kg m$^{-3}$, $g = 9.8$ 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]