A-LEVEL PHYSICS • EXERCISE SHEET

1.2 SI units

Name: ____________ Class: ________ Date: __________ **Total: 27 marks**

KEY WORDS current 电流 • temperature 温度 • derived unit 导出单位 • prefix 词头 • si units 国际单位制

Objective

Build the skills to answer exam questions on **SI units 国际单位制** — base units, derived units, homogeneity and prefixes.

You must be able to:

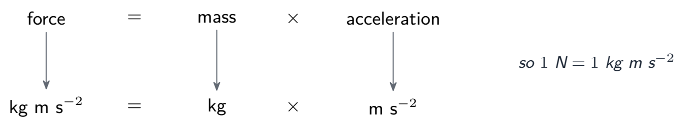
- recall the **five SI base units** (kg, m, s, A, K) and complete an exam table of them
- express a **derived unit** in SI base units, and find the units of an unknown constant
- check the **homogeneity** of an equation, and use it to find an unknown **power**
- convert a **compound unit** that carries **prefixes**

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

Base and derived units

The **base quantities**: mass (kg), length (m), time (s), current (A), temperature (K). Build a **derived unit** from the equation that defines it:



So 1 N = 1 kg m s^{-2}; the **joule** = kg m^2 s^{-2}; the **watt** = kg m^2 s^{-3}; the **pascal** = kg m^{-1} s^{-2}.

Units of an unknown constant

Rearrange for the constant, then substitute base units. For $F = kAv$, where A is an area and v a speed:

$$k = \frac{F}{Av} = \frac{\text{kg m s}^{-2}}{\text{m}^2 \times \text{m s}^{-1}} = \text{kg m}^{-2}\,\text{s}^{-1}$$

Write the fraction first, then cancel one line at a time — that first line is the method mark.

Checking homogeneity

An equation is **homogeneous** when **every term** has the **same base units**. Check $v^2 = u^2 + 2as$:

- LHS: (m s^{-1})^2 = m^2 s^{-2}
- u^2: m^2 s^{-2}; $2as$: (m s^{-2})(m) = m^2 s^{-2}

All three are m^2 s^{-2} — homogeneous. Matching units do **not** prove an equation fully correct (a wrong number, like the 2, would still match), but **mismatched** units prove it wrong. Two terms that are **added** must have the same units, so $F = kv^2 + m$ can never be right.

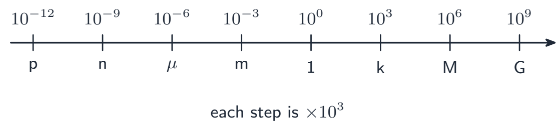
Finding an unknown power

If the equation is homogeneous, the powers must balance. In $T = 2\pi\left(\frac{L}{g}\right)^n$, with T a time, L a length and g an acceleration:

$$\left[\frac{L}{g}\right] = \frac{\text{m}}{\text{m s}^{-2}} = \text{s}^2 \quad\Rightarrow\quad (\text{s}^2)^n = \text{s}^1 \quad\Rightarrow\quad 2n = 1 \quad\Rightarrow\quad n = \tfrac{1}{2}$$

The 2π has no units, so it never enters the check.

Prefixes, and compound units



p	n	μ	m	c	d	k	M	G	T
10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{3}	10^{6}	10^{9}	10^{12}

To convert a **compound** unit, replace **each** prefix by its power of ten — and remember a prefix inside a power is raised to that power too:

$$0.25\ \text{kN mm}^{-2} = 0.25 \times \frac{10^3\ \text{N}}{(10^{-3}\ \text{m})^2} = 0.25 \times \frac{10^3}{10^{-6}}\ \text{N m}^{-2} = 2.5 \times 10^8\ \text{N m}^{-2}$$

$(10^{-3})^2 = 10^{-6}$, not 10^{-3} — that squaring is where most marks are lost.

2 Practice

Now apply the methods above.

2.1 Name the **five** SI base quantities and give each unit. [2]

2.2 Write the SI **base units** of **force**, and of **pressure**. [2]

2.3 Write 5 mA in **amperes** and 2.0 GHz in **hertz**, both in standard form. [2]

2.4 Use $W = Fs$ to express the **joule** in SI base units. [2]

2.5 A density is 3.0 g cm^{-3}. Express it in kg m^{-3}. [2]

2.6 In the equation $P = k\rho v^3$, P is a power, ρ a density and v a speed. **Determine** the SI base units of k. [2]

3 Exam-style questions

3.1 Which of these is **not** an SI base unit? [1]

- **A** ampere
- **B** coulomb
- **C** kelvin
- **D** kilogram

3.2 Which quantity has the same SI base units as **force**? [1]

- **A** $\frac{\text{energy}}{\text{distance}}$
- **B** $\frac{\text{energy}}{\text{time}}$
- **C** momentum × distance
- **D** momentum × time

3.3 What is 6.0 kN cm^{-2} expressed in N m^{-2}? [1]

- **A** 6.0×10^1
- **B** 6.0×10^5
- **C** 6.0×10^7
- **D** 6.0×10^9

3.4 The speed v of a wave on the surface of a liquid is given by $v = k\left(\frac{p}{\rho}\right)^n$, where p is a pressure, ρ is a density and k has no units. The equation is homogeneous. What is the value of n? [1]

- **A** -2
- **B** $-\frac{1}{2}$
- **C** $\frac{1}{2}$
- **D** 2

3.5 An engineering team releases an unmanned **submersible** (an underwater craft) from rest at the surface of a lake. Its volume is 0.25 m^3 and its weight is 2.1 kN. The density of the lake water is 1030 kg m^{-3}.

(a) The team records three quantities during the dive. **Complete** the table by writing the SI base units of each quantity, and ticking whether it is a scalar or a vector. [3]

quantity	SI base units	scalar	vector
water temperature	____________	☐	☐
water pressure	____________	☐	☐
drag force on the submersible	____________	☐	☐

(b) **Show that** the upthrust on the fully submerged submersible is about 2.5 kN. (Upthrust = weight of the water displaced.) [2]

(c) **Determine** the magnitude and the direction of the initial acceleration of the submersible when it is released. [3]

(d) The drag force F on the submersible is modelled as $F = kv^2$, where v is its speed. **Determine** the SI base units of k. [2]

(e) A student writes the drag equation as $F = kv^2 + m$, where m is the mass of the submersible. Use **units** to explain why this equation cannot be correct. [1]

Solutions

Each answer shows the steps, then the **result**.

2.1

- the five SI **base quantities** and their units:
- mass — kg; length — m; time — s; current — A; temperature — K

2.2

- force from $F = ma$: kg × m s^{-2} = $\mathbf{kg\ m\ s^{-2}}$
- pressure from $p = F/A$: kg m s^{-2}/m^2 = $\mathbf{kg\ m^{-1}\ s^{-2}}$

2.3

- m = 10^{-3}, so 5 mA = 5×10^{-3} A = $\mathbf{5 \times 10^{-3}}$ A
- G = 10^9, so 2.0 GHz = $\mathbf{2.0 \times 10^9}$ Hz

2.4

- $W = Fs$ and 1 N = 1 kg m s^{-2}

$$1\ \text{J} = 1\ \text{N m} = (\text{kg m s}^{-2})(\text{m}) = \mathbf{kg\ m^2\ s^{-2}}$$

2.5

- replace each prefix, and raise a prefix inside a power

$$3.0\ \text{g cm}^{-3} = 3.0 \times \frac{10^{-3}\ \text{kg}}{(10^{-2}\ \text{m})^3} = 3.0 \times \frac{10^{-3}}{10^{-6}}\ \text{kg m}^{-3} = \mathbf{3.0 \times 10^3}\ \text{kg m}^{-3}$$

2.6

- rearrange: $k = P/(\rho v^3)$; P is a power so $[P]$ = kg $m^2\,s^{-3}$

$$k = \frac{\text{kg m}^2\,\text{s}^{-3}}{(\text{kg m}^{-3})(\text{m s}^{-1})^3} = \frac{\text{kg m}^2\,\text{s}^{-3}}{\text{kg s}^{-3}} = \mathbf{m^2}$$

3.1 B

- kg, m, s, A, K are the SI **base** units
- the **coulomb** is derived: 1 C = 1 A s
- **A**, **C**, **D** are base units

3.2 A

- force has base units kg m s^{-2}
- energy / distance:

$$\frac{\text{kg m}^2\,\text{s}^{-2}}{\text{m}} = \mathbf{kg\ m\ s^{-2}}$$

- **B** is power (kg $m^2\,s^{-3}$); **C** is kg $m^2\,s^{-1}$; **D** is kg m

3.3 C

- $\mathrm{k} = 10^3$, $\mathrm{c} = 10^{-2}$; square the prefix on cm

$$6.0\ \mathrm{kN\ cm^{-2}} = 6.0 \times \frac{10^3\ \mathrm{N}}{(10^{-2}\ \mathrm{m})^2} = 6.0 \times \frac{10^3}{10^{-4}}\ \mathrm{N\ m^{-2}} = \mathbf{6.0 \times 10^7}\ \mathrm{N\ m^{-2}}$$

3.4 C

- $[p] = \mathrm{kg\ m^{-1}\,s^{-2}}$, $[\rho] = \mathrm{kg\ m^{-3}}$

$$\left[\frac{p}{\rho}\right] = \frac{\mathrm{kg\ m^{-1}\,s^{-2}}}{\mathrm{kg\ m^{-3}}} = \mathrm{m^2\,s^{-2}}$$

- v is a speed, so $(\mathrm{m^2\,s^{-2}})^n = \mathrm{m\ s^{-1}}$
- $2n = 1 \Rightarrow n = \frac{\mathbf{1}}{\mathbf{2}}$

3.5

(a) complete the table

- water temperature: K, **scalar**
- water pressure: $\mathrm{kg\ m^{-1}\,s^{-2}}$, **scalar**
- drag force: $\mathrm{kg\ m\ s^{-2}}$, **vector**

(b) upthrust = weight of water displaced = $\rho V g$

$$U = (1030\ \mathrm{kg\ m^{-3}})(0.25\ \mathrm{m^3})(9.81\ \mathrm{m\ s^{-2}}) = 2526\ \mathrm{N} \approx \mathbf{2.5}\ \mathrm{kN}$$

(c) weight $W = 2.1\ \mathrm{kN} = 2100\ \mathrm{N}$

- resultant $F = U - W = 2526\ \mathrm{N} - 2100\ \mathrm{N} = 426\ \mathrm{N}$ **upwards**

$$m = \frac{W}{g} = \frac{2100\ \mathrm{N}}{9.81\ \mathrm{m\ s^{-2}}} = 214\ \mathrm{kg}$$

$$a = \frac{F}{m} = \frac{426\ \mathrm{N}}{214\ \mathrm{kg}} = \mathbf{2.0}\ \mathrm{m\ s^{-2}}$$

upwards

(d) rearrange $F = kv^2$

$$k = \frac{F}{v^2} = \frac{\mathrm{kg\ m\ s^{-2}}}{(\mathrm{m\ s^{-1}})^2} = \mathbf{kg\ m^{-1}}$$

(e) kv^2 has the units of force, $\mathrm{kg\ m\ s^{-2}}$; m has the unit kg

- terms that are **added** must have the same units, so the equation is not homogeneous