Week 1

A-Level Physics

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

1. Physical quantities and units

A-Level Physics   Name: ____________   Score: ______

1. Every physical quantity has two parts: a number (its ______) and a unit.

   ____

2. Select **all** the SI **base** units.

   ☐ metre (m)

   ☐ newton (N)

   ☐ kilogram (kg)

   ☐ joule (J)

   ☐ second (s)

   ☐ ampere (A)

   ☐ kelvin (K)

   Tick every correct option.

3. A careful enough measurement can be exactly correct, with zero uncertainty.

   ☐ True   ☐ False

4. You walk 4 km east, then 4 km back west. What is your displacement, in km?

   ____________ km

5. Saying "the speed is 90" — with no unit — gives a complete physical quantity.

   ☐ True   ☐ False

6. Which of these are SI base units? Select **all** that apply.

   ☐ the kilogram

   ☐ the ampere

   ☐ the kelvin

   ☐ the newton

   Tick every correct option.

7. Which of these is a **systematic** error?

   ☐ A scale that reads 0.2 mm when nothing is being measured

   ☐ Readings that scatter randomly above and below

   ☐ Pressing the timer button slightly late, sometimes early

☐ A gust of wind that briefly changes a reading

8. Select **all** the quantities that are **vectors**.

   ☐ displacement

   ☐ velocity

   ☐ mass

   ☐ force

   ☐ energy

   ☐ momentum

   ☐ speed

   Tick every correct option.

9. An answer of ”5” to a question asking for a length is complete as long as the working is shown.

   ☐ True ☐ False

10. Is the equation $v = u + at$ homogeneous?

    ☐ True ☐ False

1. Physical quantities and units

A-Level Physics

1. **magnitude**

   The two parts are the **magnitude** (the number) and the **unit**.

2. **metre (m); kilogram (kg); second (s); ampere (A); kelvin (K)**

   The five SI base units are the kilogram, metre, second, ampere and kelvin. The newton and joule are **derived** units, built from the base units.

3. **False**

   No real measurement is exact — every reading has some **uncertainty**. The skill is estimating how big it is.

4. **0 km**

   Displacement is a **vector** — start to finish. You end where you began, so it is 0. The distance travelled is 8 km.

5. **False**

   Without a unit the number is ambiguous. ”90 $\frac{\text{km}}{\text{h}}$” is complete; ”90” is not.

6. **the kilogram; the ampere; the kelvin**

   The newton is derived: kg m s^-2, straight from F = ma. The five you need are the metre, kilogram, second, ampere and kelvin.

7. **A scale that reads 0.2 mm when nothing is being measured**

   A **zero error** shifts every reading by the same amount in the same direction — that is systematic. The others vary randomly from reading to reading.

8. **displacement; velocity; force; momentum**

   Vectors have a direction: displacement, velocity, force and momentum. Mass, energy and speed are scalars (speed is the size of velocity, with no direction).

9. **False**

   A physical quantity is a magnitude AND a unit. 5 metres, 5 centimetres and 5 kilometres are three different lengths, and the mark scheme asks for the unit.

10. **True**

    Yes — every term is a speed. v and u are $\frac{\text{m}}{\text{s}}$, and $at = \frac{\text{m}}{\text{s}^2} \times \text{s} = \frac{\text{m}}{\text{s}}$.

A-LEVEL PHYSICS • EXERCISE SHEET

1.1 Physical quantities

Name: ____________ Class: ________ Date: __________ **Total: 11 marks**

KEY WORDS physical quantities 物理量 • magnitude 大小 • unit 单位 • order of magnitude 数量级 • derived quantity 导出量

Objective

Build the skills to answer exam questions on **physical quantities 物理量** — magnitude and unit, and making sensible estimates.

You must be able to:

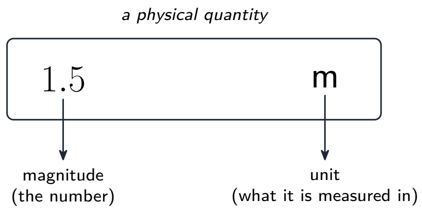
- state that every physical quantity has a **magnitude 大小** and a **unit 单位**
- make reasonable **estimates 估算** of common quantities
- give an answer to the right **order of magnitude 数量级** (power of ten)

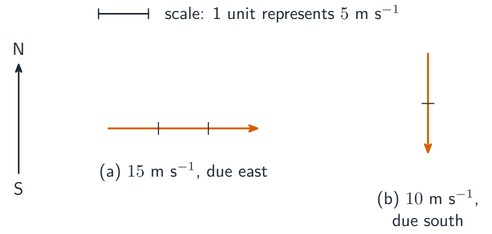
1 Worked examples

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.

Magnitude and unit

A physical quantity needs **both** a number and a unit. "The length is 1.5" means nothing; "the length is 1.5 m" is complete:





Quantities are scalars or vectors

Making estimates

Learn these rough values so you can check whether an answer is sensible:

quantity	estimate
mass of an adult	~ 70 kg
height of an adult	~ 1.7 m
mass of an apple	~ 0.1 kg (weight ≈ 1 N)
speed of sound in air	~ 340 m s^{-1}
speed of light (vacuum)	3.0×10^8 m s^{-1}
free-fall acceleration	$g \approx 9.81$ m s^{-2}

Order of magnitude

The **order of magnitude** is the nearest power of ten. A good estimate has the right power of ten: an adult's mass is $\sim 10^2$ kg (70 kg), **not** 10^1 kg (7 kg). To estimate the seconds in a day, keep the units so they cancel:

$$24\text{ h} \times \frac{60\text{ min}}{1\text{ h}} \times \frac{60\text{ s}}{1\text{ min}} = 86\,400\text{ s} \approx 9 \times 10^4\text{ s},$$

so the order of magnitude is 10^5 s.

Estimating a derived quantity

Combine sensible estimates. The **pressure** a standing person exerts on the floor: weight ≈ 700 N, area of two feet ≈ 0.02 m^2. Substitute with the units still attached:

$$p = \frac{F}{A} \approx \frac{700\text{ N}}{0.02\text{ m}^2} = 3.5 \times 10^4\text{ N m}^{-2} = 3.5 \times 10^4\text{ Pa}.$$

2 Practice

Now apply the methods above.

2.1 A student writes "the mass is 60". State what is **missing** to make it a physical quantity. [1]

2.2 Estimate the **mass of an apple**, giving a unit. [1]

2.3 State the **order of magnitude** of the speed of light in a vacuum, in m s^{-1}. [1]

2.4 Estimate the **height of a typical room** (floor to ceiling), giving a unit. [1]

3 Exam-style questions

3.1 What must all physical quantities have? [1]

- **A** a direction and a magnitude
- **B** a direction and a unit
- **C** a magnitude and a prefix
- **D** a magnitude and a unit

3.2 Which is the best estimate of the **mass of an adult human**? [1]

- **A** 7 kg
- **B** 70 kg
- **C** 700 kg
- **D** 7000 kg

3.3 Estimate the number of **seconds in one day**. Give your answer to an **order of magnitude**. [2]

3.4 A car travels at about 30 m s^{-1}. Estimate the time it takes to travel 1 km, and state the **order of magnitude** of that time in seconds. [2]

3.5 A person of weight 700 N stands on both feet, total contact area about 0.02 m^2. Which is the best estimate of the pressure on the floor? [1]

- **A** 1.4×10^4 Pa
- **B** 3.5×10^4 Pa
- **C** 3.5×10^6 Pa
- **D** 1.4×10^7 Pa

Solutions

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

2.1

- "the mass is 60" gives a magnitude only
- a physical quantity also needs a **unit** — e.g. 60 kg

2.2

- an apple is about 100 g (from the estimate table)
- $1\text{ g} = 10^{-3}\text{ kg}$, so $100\text{ g} = 100 \times 10^{-3}\text{ kg} = \mathbf{0.1}\text{ kg}$
- any value ~ 0.05–0.2 kg with a unit is accepted

2.3

- speed of light $= 3.0 \times 10^{8}\text{ m s}^{-1}$
- write as $a \times 10^{n}$ with $1 \le a < 10$: here $3.0 \times 10^{8}\text{ m s}^{-1}$
- coefficient 3.0 is nearer 1 than 10, so the order of magnitude is $\mathbf{10^{8}}$ m s^{-1}

2.4

- an adult is about 1.7 m tall, so a room is a little taller: **2.5** m
- any value ~ 2–3 m with a unit is accepted

3.1 D

- every physical quantity has a **magnitude** and a **unit**
- "1.5" is not a length; "1.5 m" is
- **A** and **B** add a direction — that describes a *vector*, not every quantity
- **C** a prefix (k, m, µ) is not a unit

3.2 B

- the estimate table gives an adult's mass ~ 70 kg
- **A** 7 kg is a cat; **C** 700 kg a horse; **D** 7000 kg a truck

3.3

- 1 day = 24 h; keep the units so they cancel

$$24\text{ h} \times \frac{60\text{ min}}{1\text{ h}} \times \frac{60\text{ s}}{1\text{ min}} = 86\,400\text{ s}$$

- $86\,400\text{ s} = 8.64 \times 10^{4}\text{ s} \approx 9 \times 10^{4}\text{ s}$ (1 s.f.)
- leading digit $9 \ge 5$, so round up: order of magnitude $\mathbf{10^{5}}$ s

3.4

- $s = 1\text{ km} = 1000\text{ m}$, $v = 30\text{ m s}^{-1}$

$$t = \frac{s}{v} = \frac{1000\text{ m}}{30\text{ m s}^{-1}} \approx 33\text{ s}$$

- $33\text{ s} = 3.3 \times 10^{1}\text{ s} \approx 3 \times 10^{1}\text{ s}$ (1 s.f.)
- leading digit $3 < 5$, so order of magnitude $\mathbf{10^{1}}$ s

3.5 B

$$p = \frac{F}{A} = \frac{700\text{ N}}{0.02\text{ m}^2} = 3.5 \times 10^{4}\text{ N m}^{-2} = \mathbf{3.5 \times 10^{4}}\text{ Pa}$$

- **A** is too small (wrong A, or $F \times A$)
- **C** and **D** are far too large (area probably left in cm^2)

Name: A-Level Physics: **w25 11**

15 A man of weight 600 N stands with both feet flat on the ground.

What is a reasonable estimate of the pressure exerted on the ground by the weight of the man?

A 1×10^0 Pa **B** 1×10^2 Pa **C** 1×10^4 Pa **D** 1×10^6 Pa

A-Level Physics: **w25 12**

1 What is a reasonable estimate of the weight of an adult human?

A 7×10^0 N **B** 7×10^2 N **C** 7×10^4 N **D** 7×10^6 N

A-Level Physics: **w25 14**

1 What is essential to accurately represent all physical quantities?

A a base unit and a number

B a unit and a number expressed in standard form (scientific notation)

C a unit and a numerical magnitude

D an SI unit and a numerical magnitude

A-Level Physics: **s25 12**

1 What must all physical quantities have?

A a direction and a magnitude

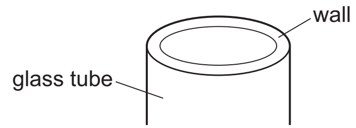
B a direction and a unit

C a magnitude and a prefix

D a magnitude and a unit

Name: A-Level Physics: **s25 14**

3 Calipers are used to determine the thickness of the wall of a glass tube.



The following measurements are made.

internal diameter of the tube = (10.0 ± 0.1) mm

external diameter of the tube = (12.0 ± 0.1) mm

What is the thickness of the wall of the tube?

A (1.0 ± 0.1) mm

B (1.0 ± 0.2) mm

C (2.0 ± 0.1) mm

D (2.0 ± 0.2) mm

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:

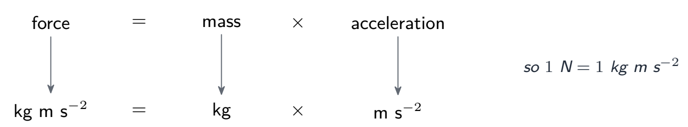
- recall the **five SI base units** (kg, m, s, A, K) and complete an exam table of them
- express a **derived unit** in SI base units, and find the units of an unknown constant
- check the **homogeneity** of an equation, and use it to find an unknown **power**
- convert a **compound unit** that carries **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: $(\text{m s}^{-1})^2 = \text{m}^2\,\text{s}^{-2}$
- u^2: $\text{m}^2\,\text{s}^{-2}$; $2as$: $(\text{m s}^{-2})(\text{m}) = \text{m}^2\,\text{s}^{-2}$

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.

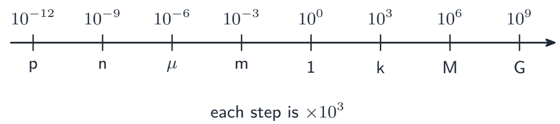
■ Finding an unknown power

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} = **kg m s^{-2}**
- pressure from $p = F/A$: kg m s^{-2}/m^2 = **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}

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

2.5

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

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

2.6

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

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

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:

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

- **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

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

3.4 C

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

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

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

3.5

(a) complete the table

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

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

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

(c) weight $W = 2.1$ kN $= 2100$ N

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

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

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

upwards

(d) rearrange $F = kv^2$

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

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

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

3 What are the SI base units of the watt?

A J s^{-1} **B** $\text{kg m}^2\,\text{s}^{-3}$ **C** $\text{kg m}^2\,\text{s}^{-1}$ **D** N m s^{-1}

22 What are the SI base units of stress?

A kg m s^{-2} **B** $\text{kg m}^{-1}\,\text{s}^{-2}$ **C** $\text{kg m}^{-2}\,\text{s}^{-2}$ **D** $\text{kg m}^{-3}\,\text{s}^{-2}$

A-Level Physics: **w25 12**

3 Which physical quantity could have units of $\text{N s}^2\,\text{m}^{-1}$?

A acceleration

B force

C mass

D momentum

1 Scientists are investigating the variation in air pressure at different locations on a mountain.

(a) The scientists take measurements of several physical quantities at each location.

Complete Table 1.1 by stating the SI base unit for each quantity and identifying with a tick (✓) whether each quantity is a scalar or a vector. Use the space for any working.

Table 1.1

quantity measured	SI base unit	scalar	vector
air temperature			
air pressure			

[2]

(b) **(i)** At one location, the density of the air is 1.1 kg m^{-3}. A spherical weather balloon is filled with a gas and released from rest. The balloon has radius 0.90 m.

Calculate the upthrust acting on the balloon when it is released.

upthrust = ... N [2]

(ii) Explain why an upthrust acts on the balloon.

....

....

....

.... [2]

(iii) The balloon has weight 19 N.

Calculate the magnitude of the initial acceleration of the balloon.

acceleration = ... m s^{-2} [3]

(c) A quantity c relating to the motion of the balloon is calculated from three measured quantities k, F and v using the formula

$$c = \frac{2kF}{v^2}.$$

The percentage uncertainties in the measured quantities are given in Table 1.2.

Table 1.2

measured quantity	percentage uncertainty
k	5%
F	3%
v	4%

The calculated value of c is 1.8.

Determine the absolute uncertainty in c.

absolute uncertainty = ... [2]

[Total: 11]

2 What is $0.25\,\text{kN}\,\text{mm}^{-2}$ expressed in $\text{N}\,\text{m}^{-2}$?

A $0.00025\,\text{N}\,\text{m}^{-2}$

B $0.25\,\text{N}\,\text{m}^{-2}$

C $250\,000\,\text{N}\,\text{m}^{-2}$

D $250\,000\,000\,\text{N}\,\text{m}^{-2}$

4 The time period T of a pendulum is given by

$$T = 2\pi\left(\frac{L}{g}\right)^n$$

where L is the length of the pendulum and g is the acceleration of free fall.

The equation is homogeneous.

What is the value of n?

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

A-LEVEL PHYSICS • EXERCISE SHEET

1.3 Errors and uncertainties

Name: ________ Class: ________ Date: ________ **Total: 36 marks**

KEY WORDS uncertainty 不确定度 • percentage uncertainty 百分比不确定度 • absolute uncertainty 绝对不确定度 • accuracy 准确度 • systematic error 系统误差

Objective

Build the skills to answer exam questions on **errors and uncertainties** — error types, precision vs accuracy, and combining uncertainties.

You must be able to:

- explain **systematic** (incl. **zero**) and **random** errors
- distinguish **precision** 精密度 from **accuracy** 准确度
- combine **absolute** and **percentage** uncertainties in a derived quantity
- **justify** the number of significant figures in a calculated result
- decide, from the uncertainties, whether two results **agree**

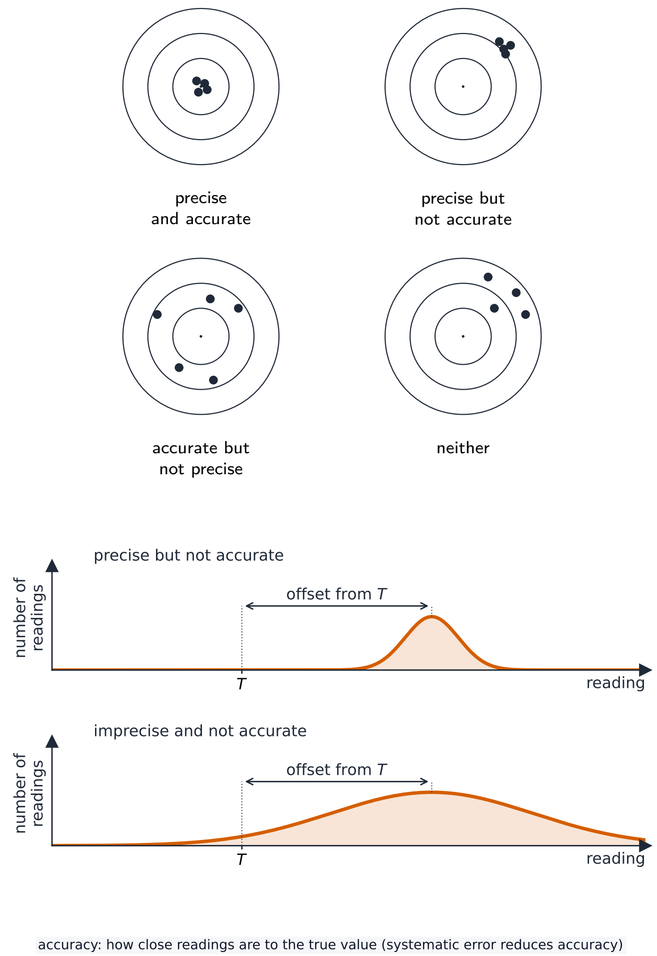
1 Worked examples

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.

■ **Errors, precision and accuracy**

- A **systematic error** shifts every reading the **same way** (a **zero error**, a wrong calibration). Repeating does not reveal it; it harms **accuracy**.
- A **random error** scatters readings **both ways**. Taking the **mean** of many repeats reduces it; it harms **precision**.

Precision = how close repeats are to each other; **accuracy** = how close they are to the true value:



Precision contrasted with accuracy

■ Uncertainty in one quantity

Write a measurement as $x \pm \Delta x$. The **percentage uncertainty** is $\dfrac{\Delta x}{|x|} \times 100\%$. E.g. (2.50 ± 0.05) m $\rightarrow \dfrac{0.05}{2.50} \times 100 = 2\%$.

■ Combining uncertainties

- **Add / subtract** $\rightarrow$ add the **absolute** uncertainties: $y = a \pm b \Rightarrow \Delta y = \Delta a + \Delta b$.
- **Multiply / divide** $\rightarrow$ add the **percentage** uncertainties.
- **Power** $y = a^n \rightarrow$ **multiply** the percentage by $|n|$.

Worked example. $R = V/I$ with $V = (6.0 \pm 0.1)$ V, $I = (2.0 \pm 0.1)$ A: $R = 3.0\ \Omega$; $\%V = 1.7\%$, $\%I = 5.0\%$, so $\%R = 6.7\%$, i.e. $R = (3.0 \pm 0.2)\ \Omega$.

■ Significant figures in a calculated answer

Give a calculated result to the **same number of significant figures as the least precise measurement** it came from — no more. $\rho = \dfrac{m}{V}$ from a mass of 31.3 g (3 s.f.) and a side of 1.53 cm (3 s.f.) is quoted to **3 s.f.**; writing 8.7194×10^3 claims a precision the measurements do not have. When a question says **justify**, say which measurement set the limit.

■ Do two results agree?

An answer with an uncertainty is a **range**, not a point. Two results **agree** when their ranges **overlap**:

$$\rho_A = 8.7 \times 10^3 \text{ kg m}^{-3} \pm 4\% \Rightarrow 8.35 \times 10^3 \text{ to } 9.05 \times 10^3$$

$$\rho_B = 9.2 \times 10^3 \text{ kg m}^{-3} \pm 6\% \Rightarrow 8.65 \times 10^3 \text{ to } 9.75 \times 10^3$$

The two ranges share the band 8.65–9.05 $\times 10^3$, so the samples **could** be the same material. Write both ranges down — that comparison is where the marks are, not the verdict on its own.

2 Practice

Now apply the methods above.

2.1 State the difference between a **systematic** error and a **random** error. [2]

2.2 A balance reads 0.3 g with **nothing** on it. Name this error and state how to correct a reading. [2]

2.3 A length is (2.50 ± 0.05) m. Find its **percentage uncertainty**. [1]

2.4 State the difference between **precision** and **accuracy**. [2]

2.5 A student measures a length with a metre rule as 84.2 cm. **Estimate** the absolute uncertainty in this reading, and explain your choice. [2]

2.6 A speed is calculated as 3.472 m s^{-1} from a distance of 12.5 m and a time of 3.6 s. State how many significant figures the answer should be given to, and **justify** your answer. [2]

3 Exam-style questions

3.1 Repeated readings are **close together** but **far from** the true value. They are: [1]

- **A** accurate but not precise
- **B** precise but not accurate
- **C** both accurate and precise
- **D** neither

3.2 Two lengths are $a = (40 \pm 1)$ mm and $b = (25 \pm 1)$ mm. **Determine** $a - b$ with its **absolute uncertainty**. [2]

3.3 A resistance is found from $R = V/I$, with $V = (6.0 \pm 0.1)$ V and $I = (2.0 \pm 0.1)$ A. Find R and its **absolute uncertainty**. [4]

3.4 A cube has side $L = (2.00 \pm 0.02)$ cm. Its volume is $V = L^3$. Find the **percentage uncertainty** in V. [2]

3.5 Two samples of metal, A and B, are tested to find the density of the material each is made from.

(a) **Explain** what is meant by the **accuracy** of a measured value. [1]

(b) Sample A is a sphere. Its diameter is $d = (2.40 \pm 0.02)$ cm and its mass is $m = (68.5 \pm 0.5)$ g. The volume of a sphere of diameter d is $V = \dfrac{\pi d^3}{6}$.

Show that the density of the material of sample A is about 9.5×10^3 kg m^{-3}. [3]

(c) **Justify** the number of significant figures you have given for the density in **(b)**. [1]

(d) **Calculate** the percentage uncertainty in the density of the material of sample A. [3]

(e) **Determine** the absolute uncertainty in the density of sample A, and write the density as $\rho \pm \Delta\rho$. [2]

(f) The density of the material of sample B is measured as 9.0×10^3 kg m$^{-3} \pm 3\%$. **State and explain** whether A and B could be made from the same material. [2]

3.6 A student times **20** complete swings of a pendulum with a stopwatch and records 31.4 s. Her reaction time makes each timing uncertain by about 0.2 s.

(a) **Estimate** the percentage uncertainty in her value for the **period** of one swing. [2]

(b) Explain why timing 20 swings gives a smaller percentage uncertainty than timing one. [2]

Solutions

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

2.1

- a **systematic** error shifts every reading the **same way**; repeating does not remove it
- a **random** error scatters readings **both ways**; the **mean** of repeats reduces it

2.2

- the balance reads a mass with nothing on it, so this is a **zero error** (systematic)
- **subtract** 0.3 g from every reading

2.3

- percentage uncertainty = $(\Delta x/|x|) \times 100\%$

$$\frac{0.05\text{ m}}{2.50\text{ m}} \times 100\% = \mathbf{2}\%$$

2.4

- **precision**: how close repeats are to **each other**
- **accuracy**: how close a reading (or the mean) is to the **true value**

2.5

- a metre rule is marked in millimetres, so one end is ± 0.05 cm
- a length uses **two** ends, so $\Delta L = \pm 0.1$ cm is also accepted if that is explained

2.6

- 3.6 s is given to **2 s.f.**; 12.5 m is 3 s.f.
- a calculated answer cannot be more precise than the least precise input, so quote **2 s.f.**: 3.5 m s^{-1}

3.1 B

- repeats that are **close together** are **precise**
- they sit **far from** the true value, so they are **not accurate**
- that pattern is a **systematic** error (e.g. a zero error)
- **A** swaps the two words

3.2

- subtract the lengths: $a - b = 40\text{ mm} - 25\text{ mm} = 15\text{ mm}$
- for a difference, add the **absolute** uncertainties: $\Delta = 1\text{ mm} + 1\text{ mm} = 2\text{ mm}$
- $(\mathbf{15} \pm \mathbf{2})$ mm

3.3

- $R = V/I$

$$R = \frac{6.0\text{ V}}{2.0\text{ A}} = 3.0\ \Omega$$

- for a quotient, add the **percentage** uncertainties

$$\%V = \frac{0.1\ \text{V}}{6.0\ \text{V}} \times 100\% = 1.7\%, \qquad \%I = \frac{0.1\ \text{A}}{2.0\ \text{A}} \times 100\% = 5.0\%$$

- $\%R = 1.7\% + 5.0\% = 6.7\%$

$$\Delta R = 0.067 \times 3.0\ \Omega = 0.2\ \Omega \Rightarrow R = (\mathbf{3.0 \pm 0.2})$$

3.4

$$\%L = \frac{0.02\ \text{cm}}{2.00\ \text{cm}} \times 100\% = 1\%$$

- $V = L^3$, so multiply the percentage by 3: $\%V = 3 \times 1\% = \mathbf{3}\%$

3.5

(a) **accuracy** is how close the measured value is to the **true value**

(b) convert **both** quantities to SI first: $d = 2.40\ \text{cm} = 2.40 \times 10^{-2}\ \text{m}$, $m = 68.5\ \text{g} = 68.5 \times 10^{-3}\ \text{kg}$

$$V = \frac{\pi d^3}{6} = \frac{\pi(2.40 \times 10^{-2}\ \text{m})^3}{6} = 7.24 \times 10^{-6}\ \text{m}^3$$

$$\rho = \frac{m}{V} = \frac{68.5 \times 10^{-3}\ \text{kg}}{7.24 \times 10^{-6}\ \text{m}^3} = 9.46 \times 10^3\ \text{kg m}^{-3} \approx \mathbf{9.5 \times 10^3\ kg\ m^{-3}}$$

(c) both d and m are given to **3 s.f.**, so ρ cannot be quoted more precisely than **3 s.f.**

(d)

$$\%m = \frac{0.5\ \text{g}}{68.5\ \text{g}} \times 100\% = 0.73\%$$

$$\%d = \frac{0.02\ \text{cm}}{2.40\ \text{cm}} \times 100\% = 0.83\%$$

- $V \propto d^3$, so $\%V = 3 \times 0.83\% = 2.5\%$
- $\%\rho = \%m + \%V = 0.73\% + 2.5\% = \mathbf{3.2}\%$

(e)

$$\Delta\rho = 0.032 \times 9.46 \times 10^3\ \text{kg m}^{-3} = 0.30 \times 10^3\ \text{kg m}^{-3}$$

- $\rho = (\mathbf{9.5 \pm 0.3}) \times \mathbf{10^3}\ \text{kg m}^{\mathbf{-3}}$

(f) write both as ranges

- A: $9.46 \times 10^3 \pm 3.2\% \Rightarrow 9.16 \times 10^3$ to $9.76 \times 10^3\ \text{kg m}^{-3}$
- B: $9.0 \times 10^3 \pm 3\% \Rightarrow 8.73 \times 10^3$ to $9.27 \times 10^3\ \text{kg m}^{-3}$
- the ranges **overlap**, so A and B **could** be the same material

3.6

(a) the 0.2 s is the uncertainty in the **total** time, not in one swing

$$\%T = \frac{0.2\ \text{s}}{31.4\ \text{s}} \times 100\% = \mathbf{0.6}\%$$

(b) the absolute uncertainty stays ≈ 0.2 s (reaction time) however many swings you time

- 20 swings make the **measured time 20 times larger**, so the same Δt is a much smaller **fraction** of it

2 Two quantities are measured.

$$L = 6.8 \pm 0.1\,\text{cm}$$

$$T = 2.42 \pm 0.08\,\text{s}$$

L and T are related to X by the equation shown.

$$X = \frac{4\pi^2 L}{T^2}$$

What is the calculated value and uncertainty of X?

A $45.8 \pm 0.2\,\text{cm}\,\text{s}^{-2}$

B $45.8 \pm 0.3\,\text{cm}\,\text{s}^{-2}$

C $46 \pm 2\,\text{cm}\,\text{s}^{-2}$

D $46 \pm 4\,\text{cm}\,\text{s}^{-2}$

2 What describes a set of data with a high precision?

A data measured using equipment with small scale divisions

B data that is close to the accepted value

C data with each value having a low uncertainty

D data with repeats that are close to each other

4 A ball is released from rest. The distance the ball falls and the time the ball takes to fall that distance are both measured.

The percentage uncertainty in the measured distance is negligible. The percentage uncertainty in the measured time is 4%.

The distance and the time are then used to calculate the acceleration of free fall.

Air resistance is negligible.

What is the percentage uncertainty in the calculated value of the acceleration of free fall?

A 2% **B** 4% **C** 8% **D** 16%

2 A steel rule can be read to the nearest millimetre. It is used to measure the length of a bar whose true length is 895 mm. Repeated measurements give the following readings.

length / mm 892, 891, 892, 891, 891, 892

Are the readings accurate and precise to within 1 mm?

	results are accurate to within 1 mm	results are precise to within 1 mm
A	no	no
B	no	yes
C	yes	no
D	yes	yes

3 A stone is released from rest and falls vertically to the ground.

The time taken to fall to the ground and the distance travelled are measured. The measurements are used to determine the acceleration of free fall.

The percentage uncertainty in the measured time is 0.05%. The percentage uncertainty in the measured distance fallen is 0.6%.

What is the percentage uncertainty in the calculated value of the acceleration of free fall?

A 0.5% **B** 0.7% **C** 1.1% **D** 1.3%

2 In this experiment, you will investigate the rolling of a plastic bottle.

(a) (i) You are provided with a plastic bottle with a cap, as shown in Fig. 2.1.

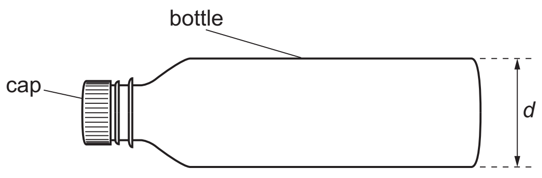


Fig. 2.1

The diameter of the base of the bottle is *d*.

Measure and record *d*.

d = ... [1]

(ii) Estimate the percentage uncertainty in your value of *d*. Show your working.

percentage uncertainty = ... % [1]

(b) • Set up the apparatus as shown in Fig. 2.2.

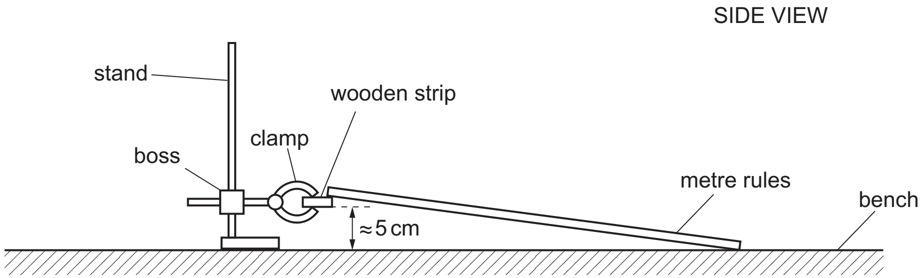


Fig. 2.2

- Adjust the two metre rules so that the rules are approximately parallel to each other, as shown in Fig. 2.3.

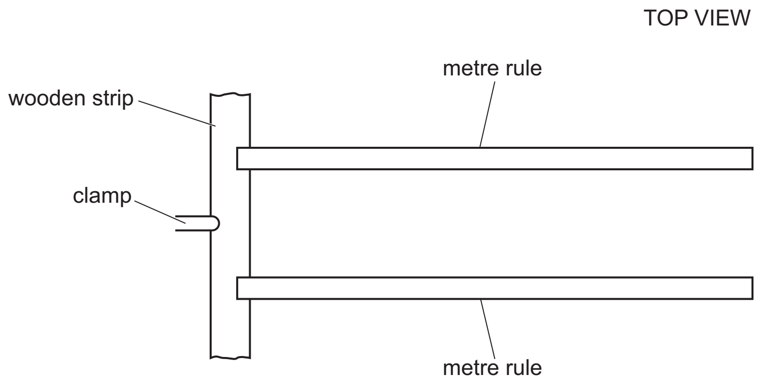


Fig. 2.3

- Pour all the water from the beaker into the bottle.
- Place the bottle on the two rules as shown in Fig. 2.4.

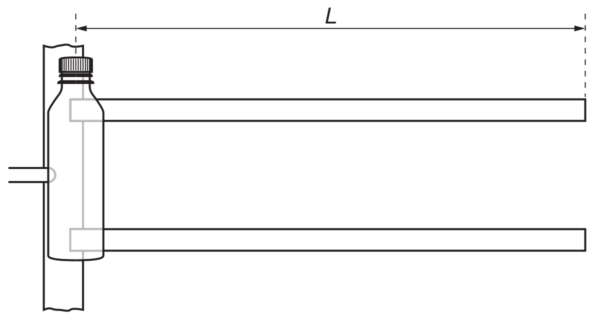


Fig. 2.4 (not to scale)

- Release the bottle. Adjust the rules so that the bottle rolls to the end of the rules.
- The distance that the bottle rolls on the rules is *L*, as shown in Fig. 2.4.

Measure and record *L*.

L = ... [1]

(c) **(i)** • Stand the bottle upright on the bench.

• The height of the water in the bottle is h, as shown in Fig. 2.5.

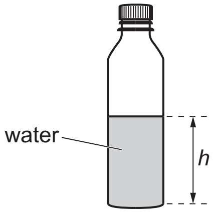


Fig. 2.5

Measure and record h.

h = ...

• The time for the bottle to roll distance L on the rules is t.

Take measurements to determine t.

t = ...
[3]

(ii) A value for the acceleration a of the bottle is given by

$$a = \frac{2L}{t^2}.$$

Calculate a.

a = ... [1]

(iii) Justify the number of significant figures that you have given for your value of a.

....

....

.... [1]

Name: A-Level Physics: **w25 35**

(d) • Pour approximately half the water from the bottle into the beaker.

• Repeat **(c)(i)** and **(c)(ii)**.

h = ...

t = ...

a = ...
[2]

(e) It is suggested that the relationship between a and h is

$$a = \frac{kd\sqrt{\pi h}}{2}$$

where k is a constant.

Using your data, calculate **two** values of k.

first value of k = ...

second value of k = ...
[1]

(f) It is suggested that the percentage uncertainty in the values of k is 15%.

Using this uncertainty, explain whether your results support the relationship in **(e)**.

....

....

....

.... [1]

(g) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

1 ....

....

2 ....

....

3 ....

....

4 ....

....

[4]

(ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1 ....

....

2 ....

....

3 ....

....

4 ....

....

[4]

[Total: 20]

2 Four students, **A**, **B**, **C** and **D**, have completed an experiment to determine the acceleration of free fall, g. Each student repeated the experiment three times. The determined values of g are shown in the table.

Which set of results has a high precision and a low accuracy?

	acceleration of free fall / $m\,s^{-2}$		
	experiment 1	experiment 2	experiment 3
A	7.2	9.4	8.3
B	9.5	9.8	10.2
C	9.8	9.8	9.9
D	10.1	10.2	10.1

3 The diameter of a ball is measured as $(5.26 \pm 0.02)\,cm$.

What is the absolute uncertainty in the volume of the ball?

A $0.29\,cm^3$ **B** $0.87\,cm^3$ **C** $1.1\,cm^3$ **D** $7.0\,cm^3$

A-Level Physics: **s25 12**

3 A student calculates the density of a solid steel cube in an experiment.

The measured mass is $975\,g \pm 10\,g$ and the measured length of side is $50\,mm \pm 1\,mm$.

What is the density of the steel?

A $7.8\,g\,cm^{-3} \pm 3.0\%$

B $7.8\,g\,cm^{-3} \pm 7.0\%$

C $7.8\,g\,cm^{-3} \pm 11\%$

D $7.8\,g\,cm^{-3} \pm 13\%$

A-Level Physics: **m25 12**

12 A student takes measurements to calculate the density of a liquid in a beaker.

The height of the liquid in the beaker is $0.20\,m \pm 2\%$.

The internal diameter of the beaker is $0.05\,m \pm 3\%$.

The mass of the liquid is $0.36\,kg \pm 10\%$.

What is the percentage uncertainty in the calculated density of the liquid?

A 2% **B** 5% **C** 15% **D** 18%

1 **(a)** Explain what is meant by the accuracy of a measured value.

....

.... [1]

(b) Two solid cubes, A and B, are measured to determine the density of their materials.

Table 1.1 shows the measurements for cube A.

Table 1.1

quantity	measurement
length of side	$(1.53 \pm 0.01)\,cm$
mass	$(31.3 \pm 0.5)\,g$

(i) Show that the calculated density of the material of cube A is $8.7 \times 10^3\,kg\,m^{-3}$.

[2]

(ii) Calculate the percentage uncertainty in the density of the material of cube A.

percentage uncertainty = ... % [2]

(iii) The density of the material of cube B is determined to be $9.2 \times 10^3\,kg\,m^{-3} \pm 6\%$.

State and explain whether cube A and cube B could be made from the same material.

....

....

....

.... [2]

[Total: 7]

A-LEVEL PHYSICS • EXERCISE SHEET

1.4 Scalars and vectors

Name: ____________ Class: ________ Date: __________ **Total: 34 marks**

KEY WORDS vector 矢量 • scalar 标量 • component 分量 • perpendicular 垂直 • magnitude 大小

Objective

Build the skills to answer the real exam questions on **scalars and vectors**. In the exam, 1.4 is tested by **multiple-choice** questions and by short parts inside longer questions: classify a quantity, find a **resultant**, or **resolve** a vector into components.

You must be able to:

- tell a **scalar 标量** from a **vector 矢量** and complete a classification table
- find the **resultant 合矢量** of two **perpendicular 垂直** vectors (size and direction)
- give the direction of $\vec{X}+\vec{Y}$ and $\vec{X}-\vec{Y}$
- find the resultant of **two equal forces** at an angle
- **resolve 分解** any vector (a force *or* a velocity) into two perpendicular **components 分量**
- add three or more **coplanar 共面** vectors by components
- **sketch** each component of a projectile's velocity against time

1 Worked examples

Study these first. Each one shows the method for an exam question type used below — read them and you can do the Practice and Exam-style questions yourself.

A — Scalar or vector?

A scalar has size only; a vector has size **and** direction. **Quick test:** if "in which direction?" makes sense, it is a vector. In the exam you often tick a table:

Quantity	Scalar	Vector
speed	✓	
acceleration		✓
energy	✓	
momentum		✓

(Common scalars: mass, time, temperature, energy, distance, speed. Common vectors: displacement, velocity, acceleration, force, momentum.)

B — Add two perpendicular vectors

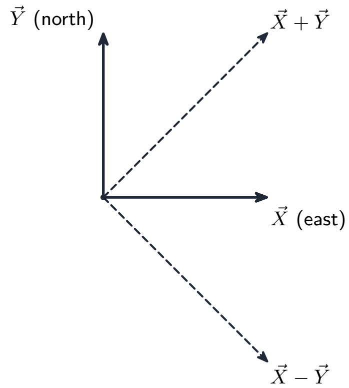
Draw them **tip to tail**; the resultant closes the triangle. For two vectors at 90° the size is $|\vec{R}| = \sqrt{X^2+Y^2}$ and the direction is $\tan\theta = Y/X$.

Worked example. A swimmer heads north at 1.2 m s^{-1}; the river flows east at 0.5 m s^{-1}:

$$|\vec{R}| = \sqrt{1.2^2+0.5^2} = 1.3 \text{ m s}^{-1}, \qquad \tan\theta = \tfrac{0.5}{1.2} \Rightarrow \theta \approx 23° \text{ east of north.}$$

C — Direction of $\vec{X}+\vec{Y}$ and $\vec{X}-\vec{Y}$

To **add**, place the arrows tip to tail. To **subtract**, reverse the second arrow first: $\vec{X}-\vec{Y} = \vec{X}+(-\vec{Y})$, where $-\vec{Y}$ is the same size as $\vec{Y}$ but points the opposite way.



With $\vec{X}$ east and $\vec{Y}$ north: $\vec{X}+\vec{Y}$ points **north-east**, and $\vec{X}-\vec{Y}$ points **south-east**.

C2 — Adding three or more coplanar vectors

Coplanar 共面 vectors all lie in the same flat plane — every vector in this course is coplanar. For three or more, drawing triangles gets messy, so **use components**: add all the x-parts, add all the y-parts, then recombine.

Worked example. Three coplanar forces act at a point: 2.0 N east, 3.0 N north, 4.0 N west.

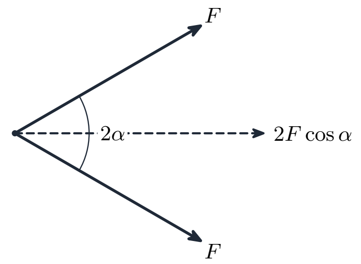
$$\sum x = 2.0 - 4.0 = -2.0 \text{ N}, \qquad \sum y = +3.0 \text{ N}$$

$$R = \sqrt{2.0^2+3.0^2} = 3.6 \text{ N}, \qquad \tan\theta = \tfrac{3.0}{2.0} \Rightarrow \theta = 56° \text{ north of west}$$

Take one direction as positive and stay with it — a lost minus sign is the usual error.

■ D — Two equal forces at an angle

Two equal forces of size F with an angle 2α between them have a resultant of size $2F\cos\alpha$, along the line that **cuts the angle in half**.

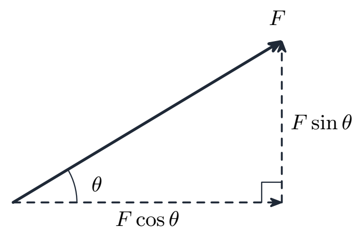


Worked example. Two 6.0 N forces act with 60° between them. Here $2\alpha = 60°$, so $\alpha = 30°$:

$$R = 2F\cos\alpha = 2(6.0)\cos 30° = 10.4 \text{ N}.$$

■ E — Resolve a vector into components

Any vector $\vec{v}$ at angle θ to the horizontal splits into a horizontal part $v\cos\theta$ and a vertical part $v\sin\theta$ — this works for a force **or** a velocity 速度.



Force example. A 50 N force at 30°: horizontal $= 50\cos 30° = 43$ N, vertical $= 50\sin 30° = 25$ N.

Velocity example. A ball kicked at 28 m s^{-1}, 34° above the horizontal: $v_\text{H} = 28\cos 34° = 23$ m s^{-1}, $v_\text{V} = 28\sin 34° = 16$ m s^{-1}.

On a slope of angle θ, the weight splits into $W\sin\theta$ **along** the slope and $W\cos\theta$ **into** the slope.

■ F — The two components of a projectile, against time

Once the components are found, each one has its own simple graph — and the exam asks you to sketch both on one grid:

- **horizontal** v_H: a **horizontal straight line** (no horizontal force, so it never changes).
- **vertical** v_V: a **straight line sloping down**, starting at $+v\sin\theta$, crossing zero at the top of the flight, and reaching $-v\sin\theta$ on landing (taking up as positive).

The gradient of that second line is $-g$, and the time to the top is v_V/g. Label each line, and use the whole time axis you are given.

2 Practice

Now apply the methods above.

2.1 Complete the table by ticking **scalar** or **vector** for each quantity. [3]

Quantity	Scalar	Vector
distance		
force		
temperature		
velocity		
power		
acceleration		

2.2 Forces of 3.0 N east and 4.0 N north act at a point. Find the **magnitude** 大小 of the resultant. [2]

2.3 Resolve a 50 N force acting at 30° to the horizontal into its horizontal and vertical components. [2]

2.4 A ball leaves the ground at 20 m s^{-1} at 60° above the horizontal. Find the **horizontal** and **vertical** components of its velocity. [2]

2.5 Two forces, each 5.0 N, act at a point with 90° between them. Find the **magnitude** of the resultant. [2]

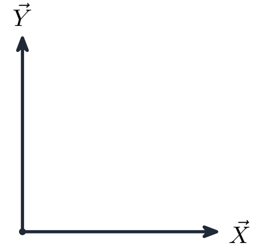
2.6 Three **coplanar** forces act at a point: 6.0 N east, 2.0 N west and 5.0 N north. Find the **magnitude** and the **direction** of the resultant. [3]

3 Exam-style questions

3.1 Which of these is a **vector** quantity? [1]

- **A** energy
- **B** power
- **C** displacement
- **D** temperature

3.2 Two vectors $\vec{X}$ and $\vec{Y}$ are shown: $\vec{X}$ points east and $\vec{Y}$ points north. What are the directions of $\vec{X}+\vec{Y}$ and $\vec{X}-\vec{Y}$? [1]



- **A** $\vec{X}+\vec{Y}$ north-east; $\vec{X}-\vec{Y}$ south-east
- **B** $\vec{X}+\vec{Y}$ north-east; $\vec{X}-\vec{Y}$ north-west
- **C** $\vec{X}+\vec{Y}$ south-west; $\vec{X}-\vec{Y}$ south-east
- **D** $\vec{X}+\vec{Y}$ south-east; $\vec{X}-\vec{Y}$ north-east

3.3 Two forces of 6.0 N and 8.0 N act at a point at right angles to each other. What is the magnitude of the resultant force? [1]

- **A** 2.0 N
- **B** 10 N
- **C** 14 N
- **D** 48 N

3.4 A stone is thrown with a velocity of 15 m s^{-1} at 40° above the horizontal.

(a) Find the **horizontal** and **vertical** components of this velocity. [2]

(b) Air resistance is negligible. State which component stays **constant** during the flight, and why. [2]

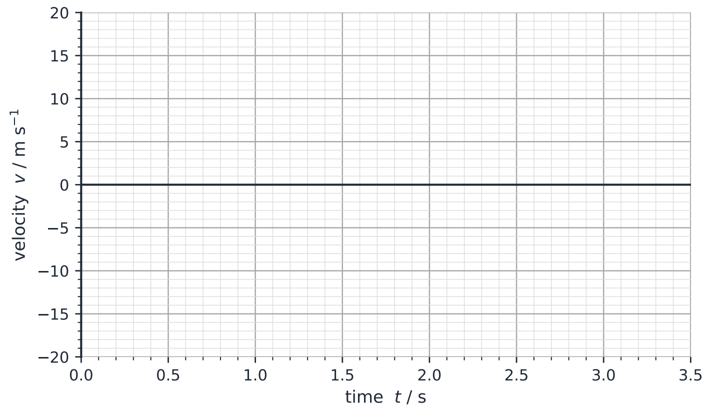
3.5 Two forces, each 7.0 N, act at a point with 80° between them. Find the **magnitude** of the resultant. [2]

3.6 A player kicks a ball from level ground with a velocity of 21 m s^{-1} at 55° to the horizontal. Air resistance is negligible.

(a) **Calculate** the horizontal component v_H and the vertical component v_V of the velocity of the ball as it leaves the ground. [2]

(b) **Show that** the ball reaches its maximum height at time $t = 1.75$ s. [1]

(c) The ball lands at time $t = 3.5$ s. On the grid below, **sketch** the variation with time t of v_H and of v_V, from $t = 0$ to $t = 3.5$ s. Take the upward direction as positive. **Label** your lines H and V. [4]



(d) **Determine** the magnitude and the direction of the velocity of the ball just before it lands. [3]

(e) State why the horizontal component of the velocity does not change during the flight. [1]

Solutions

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

2.1

- scalar: size only; vector: size **and** direction
- distance **scalar**; force **vector**; temperature **scalar**; velocity **vector**; power **scalar**; acceleration **vector**

2.2

- the forces are perpendicular, so use Pythagoras

$$R = \sqrt{(3.0\ \text{N})^2 + (4.0\ \text{N})^2} = \sqrt{25\ \text{N}^2} = \mathbf{5.0}\ \text{N}$$

2.3

- horizontal is the adjacent side: $F\cos\theta$; vertical is the opposite side: $F\sin\theta$
- horizontal: $50\ \text{N} \times \cos 30° = \mathbf{43}\ \text{N}$
- vertical: $50\ \text{N} \times \sin 30° = \mathbf{25}\ \text{N}$

2.4

- $v_\text{H} = v\cos\theta$, $v_\text{V} = v\sin\theta$
- $v_\text{H} = 20\ \text{m s}^{-1} \times \cos 60° = \mathbf{10}\ \text{m s}^{-1}$
- $v_\text{V} = 20\ \text{m s}^{-1} \times \sin 60° = \mathbf{17}\ \text{m s}^{-1}$

2.5

- equal forces at 90°: Pythagoras, or $R = 2F\cos 45°$

$$R = \sqrt{(5.0\ \text{N})^2 + (5.0\ \text{N})^2} = \mathbf{7.1}\ \text{N}$$

2.6

- take east and north as positive
- $\sum x = 6.0\ \text{N} - 2.0\ \text{N} = 4.0\ \text{N}$ east; $\sum y = 5.0\ \text{N}$ north

$$R = \sqrt{(4.0\ \text{N})^2 + (5.0\ \text{N})^2} = \mathbf{6.4}\ \text{N}$$

$$\tan\theta = \frac{5.0\ \text{N}}{4.0\ \text{N}} \Rightarrow \theta = \mathbf{51}°\ \text{north of east}$$

3.1 C

- a vector needs a **direction** as well as a size
- **displacement** is "how far, and which way"
- **A**, **B**, **D** (energy, power, temperature) are scalars — *distance* is the scalar trap against displacement

3.2 A

- $\vec{X}$ east and $\vec{Y}$ north: tip-to-tail sum points **north-east**

- $\vec{X} - \vec{Y} = \vec{X} + (-\vec{Y})$: reverse $\vec{Y}$ to south, so the result points **south-east**
- **B** keeps $\vec{Y}$ pointing north when subtracting

3.3 B

- perpendicular forces: Pythagoras

$$R = \sqrt{(6.0\ \text{N})^2 + (8.0\ \text{N})^2} = \sqrt{100\ \text{N}^2} = \mathbf{10}\ \text{N}$$

- **A** is the difference; **C** is the sum; **D** is the product

3.4

(a) resolve at 40° to the horizontal

- $v_\text{H} = 15\ \text{m s}^{-1} \times \cos 40° = \mathbf{11}\ \text{m s}^{-1}$
- $v_\text{V} = 15\ \text{m s}^{-1} \times \sin 40° = \mathbf{9.6}\ \text{m s}^{-1}$

(b) the **horizontal** component stays constant

- no air resistance ⇒ no horizontal force ⇒ no horizontal acceleration

3.5

- two equal forces: $2\alpha = 80°$ so $\alpha = 40°$

$$R = 2F\cos\alpha = 2 \times 7.0\ \text{N} \times \cos 40° = \mathbf{10.7}\ \text{N}$$

3.6

(a)

- $v_\text{H} = 21\ \text{m s}^{-1} \times \cos 55° = \mathbf{12}\ \text{m s}^{-1}$
- $v_\text{V} = 21\ \text{m s}^{-1} \times \sin 55° = \mathbf{17}\ \text{m s}^{-1}$

(b) at the top, $v_\text{V} = 0$, so $t = v_\text{V}/g$

$$t = \frac{17.2\ \text{m s}^{-1}}{9.81\ \text{m s}^{-2}} = \mathbf{1.75}\ \text{s}$$

(c)

- **H**: horizontal straight line at $v = 12\ \text{m s}^{-1}$ across the whole grid, labelled H
- **V**: straight line of negative gradient, labelled V
- starts at $+17\ \text{m s}^{-1}$ and ends at $-17\ \text{m s}^{-1}$
- crosses $v = 0$ at $t = 1.75$ s

(d) just before landing, $v_\text{H} = 12\ \text{m s}^{-1}$ and $v_\text{V} = -17\ \text{m s}^{-1}$

$$v = \sqrt{(12\ \text{m s}^{-1})^2 + (17\ \text{m s}^{-1})^2} = \mathbf{21}\ \text{m s}^{-1}$$

$$\tan\theta = \frac{17\ \text{m s}^{-1}}{12\ \text{m s}^{-1}} \Rightarrow \theta = \mathbf{55}°\ \text{below the horizontal}$$

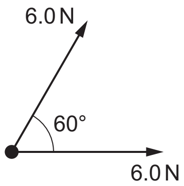
(e) air resistance is negligible, so there is **no horizontal force** and therefore no horizontal acceleration

1 The table shows some physical quantities.

Which row correctly identifies the quantities as scalars or vectors?

	acceleration	charge	kinetic energy	wavelength
A	scalar	vector	vector	scalar
B	vector	vector	scalar	scalar
C	scalar	scalar	scalar	vector
D	vector	scalar	scalar	scalar

4 The diagram shows two forces of 6.0 N acting on an object. The angle between the lines of action of the two forces is 60°.



What is the magnitude of the resultant force?

A 6.0 N **B** 7.9 N **C** 10 N **D** 12 N

1 A child kicks a ball so that it leaves horizontal ground with a velocity of $28\,\mathrm{m\,s^{-1}}$ at an angle of 34° to the horizontal, as shown in Fig. 1.1.

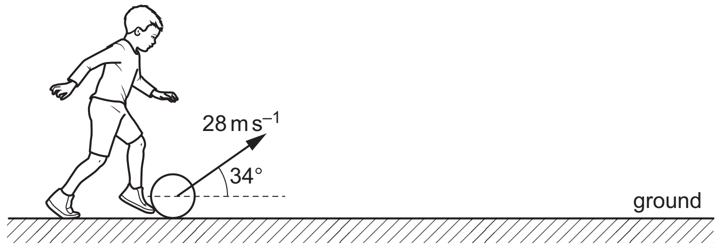


Fig. 1.1

Air resistance is negligible. The ball leaves the ground at time $t = 0$.

(a) **(i)** Calculate the horizontal component v_H and the vertical component v_V of the velocity of the ball immediately after it has left the ground.

v_H = ... $\mathrm{m\,s^{-1}}$

v_V = ... $\mathrm{m\,s^{-1}}$
[2]

(ii) Show that the ball reaches its maximum height at time $t = 1.6\,\mathrm{s}$.

[1]

(iii) On Fig. 1.2, sketch the variation of v_H with time t between $t = 0$ and $t = 3.2\,s$. Label your line H.

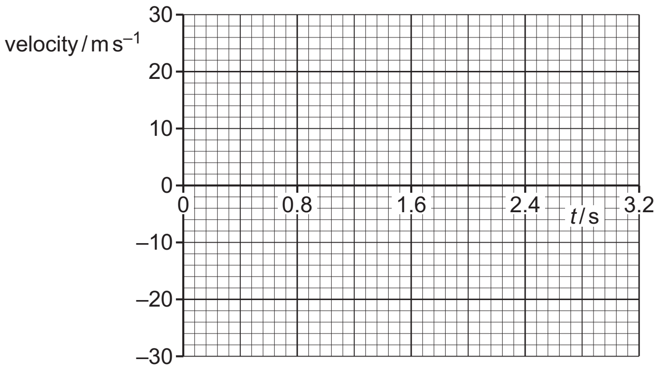


Fig. 1.2

[1]

(iv) On Fig. 1.2, sketch the variation of v_V with time t between $t = 0$ and $t = 3.2\,s$. Assume that velocity in the upward direction is positive. Label your line V. [3]

(b) The total change in momentum of the ball between leaving the ground at $t = 0$ and landing on the ground at $t = 3.2\,s$ is $13\,kg\,m\,s^{-1}$.

(i) Define momentum.

....

.... [1]

(ii) Calculate the force that acts on the ball while it is in the air.

force = ... N [2]

(iii) Determine the mass of the ball.

mass = ... kg [1]

[Total: 11]

1 Which quantity is a vector?

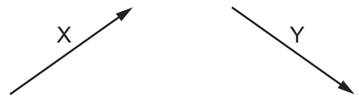
A pressure

B temperature

C weight

D work

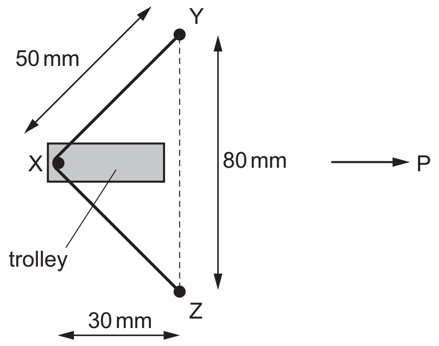
4 Two vectors, X and Y, are shown.



What are the directions of X + Y and X – Y?

	X + Y	X – Y
A	→	↓
B	→	↑
C	←	↓
D	←	↑

4 The diagram shows two fixed pins, Y and Z. A length of elastic is stretched between Y and Z and around pin X, which is attached to a trolley.



X is at the centre of the elastic and the trolley is to be propelled in the direction P at right angles to YZ. The tension in the elastic is 4.0 N.

What is the force accelerating the trolley in the direction P when the trolley is released?

A 2.4 N **B** 3.2 N **C** 4.8 N **D** 6.4 N

1 **(a)** Table 1.1 lists some physical quantities. Identify with ticks (✓) which quantities are vectors and which are scalars.

Table 1.1

quantity	scalar	vector
acceleration		
displacement		
gravitational potential energy		
speed		
temperature		

[2]

(b) A constant resultant force F acts on a car of mass m. The car moves from rest with constant acceleration a along horizontal ground. When the car has displacement s, the speed of the car is v.

(i) Using the concept of work done on the car, show that the kinetic energy E_K of the car is given by the equation

$$E_K = \frac{1}{2}mv^2.$$

[3]

(ii) The mass of the car is 920 kg. At time $t = 0$, the car is at rest. At time $t = 5.8$ s, its velocity is 17 m s^{-1}.

Calculate the kinetic energy of the car at time $t = 5.8$ s.

kinetic energy = ... J [1]

(iii) Between time t = 0 and time t = 5.8 s, the work done against resistive forces is 4.7×10^4 J.

Determine the average output power of the car during this time.

power = ... W [3]

(iv) At time t = 5.8 s, the speed of the car becomes constant.

State and explain whether the output power of the car is greater than, less than or the same as the output power just before t = 5.8 s.

....

.... [1]

[Total: 10]