1.1 Physical quantities

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS physical quantities • magnitude • unit • order of magnitude • derived quantity

Objective

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

You must be able to:

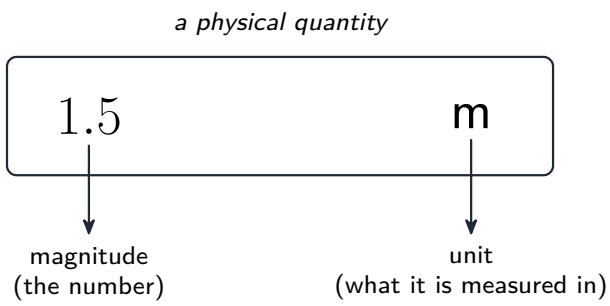
- state that every physical quantity has a **magnitude** and a **unit**
- make reasonable **estimates** of common quantities
- give an answer to the right **order of magnitude** (power of ten)

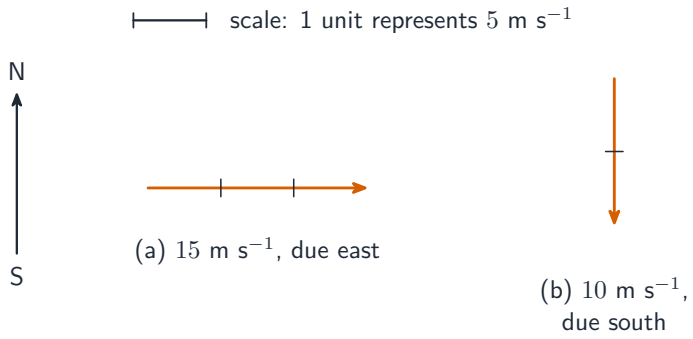
1 Worked examples

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	$\sim 340\ \frac{\text{m}}{\text{s}}$
speed of light (vacuum)	$3.0 \times 10^8\ \frac{\text{m}}{\text{s}}$
free-fall acceleration	$g \approx 9.81\ \text{m s}^{-2}$

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 $\approx 0.02\ \text{m}^2$. Substitute with the units still attached:

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

■ Recognising quantities and estimates

Distinguish the quantity from its unit: temperature is measured in kelvin, time in seconds or minutes, potential difference in volts, and spring constant in N/m. A quantity has a measurable numerical magnitude; a unit name or a category alone does not state a quantity. Values may be fractional and units may be non-SI. Visible light has wavelengths roughly 400–700 nm; green is about 540 nm (1 nm = 10^{-9} m).

2 Practice

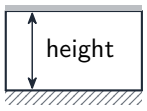
Now apply the methods above.

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 $\frac{\text{m}}{\text{s}}$. [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]

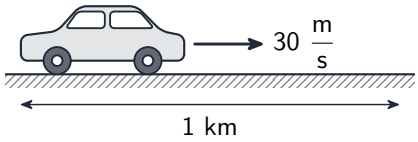
☐ **A** a direction and a magnitude
B a direction and a unit
C a magnitude and a prefix
D a magnitude and a unit

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

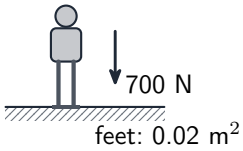
3.3 Estimate the number of **seconds in one day**. Give your answer to an **order of magnitude**. [2]

3.4 A car travels at about 30 $\frac{\text{m}}{\text{s}}$. 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 g = 10^{-3} kg, so 100 g = 100×10^{-3} kg = $\mathbf{0.1}$ kg
- any value $\sim$ 0.05–0.2 kg with a unit is accepted

2.3

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

2.4

- an adult is about 1.7 m tall, so a room is a little taller: $\mathbf{2.5}$ m
- any value $\sim$ 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 $\sim$ 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 $9 \geq 5$, so round up: order of magnitude $\mathbf{10^5}$ s

3.4

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

$$t = \frac{s}{v} = \frac{1000\ \text{m}}{30\ \dfrac{\text{m}}{\text{s}}} \approx 33\ \text{s}$$

- $33\ \text{s} = 3.3 \times 10^1\ \text{s} \approx 3 \times 10^1\ \text{s}$ (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)