

Exercise walk-through

1.1

Physical quantities

A-Level Physics

A number *and* a unit

A **physical quantity** has two parts:

- a **magnitude** – the number
- a **unit** – what the number means

The number alone tells you **nothing**.

1.5 m

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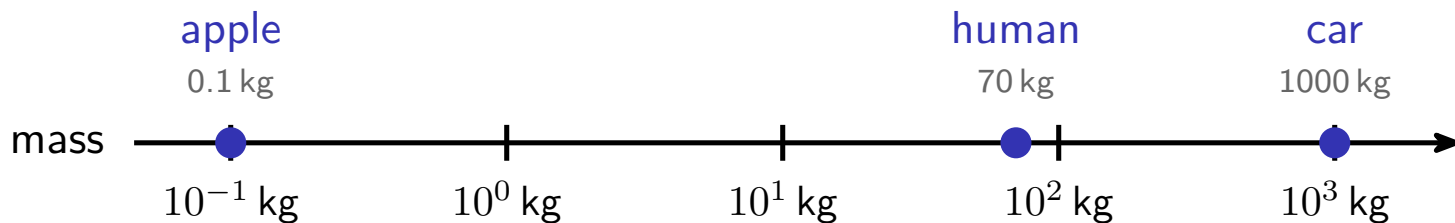
magnitude unit

“1.5” ❌

“1.5 m” ✅

Estimate the everyday

A good estimate has the right **order of magnitude** – the right power of ten.
Paper 1 usually opens with one.



Each step along the line is a **factor of ten**. Pick the answer on the right step: a human is about 10^2 kg, not 10^1 or 10^3 .

Estimates to know by heart

human **mass**

70 kg

human **weight**

700 N

human height

1.7 m

an apple

0.1 kg

speed of sound in air

340 m s^{-1}

speed of light in
a **vacuum**

$3.0 \times 10^8 \text{ m s}^{-1}$

free fall

$g \approx 9.81 \text{ m s}^{-2}$

An apple weighs about 1 N. That one number lets you check every other force estimate.

More values to know

Sizes

- a car: $\sim 1000 \text{ kg}$
- height of a room: $\sim 3 \text{ m}$
- visible light wavelength:
 $\sim 5 \times 10^{-7} \text{ m}$
- **diameter** of an
atom: $\sim 10^{-10} \text{ m}$; a
nucleus: $\sim 10^{-15} \text{ m}$

Speeds and power

- walking: $\sim 1.5 \text{ m s}^{-1}$
- a car on a fast road:
 $\sim 30 \text{ m s}^{-1}$
- a kettle: $\sim 2 \text{ kW}$
- a person climbing
stairs: $\sim 300 \text{ W}$

Materials and the air

- **density** : water
 1000 kg m^{-3} , air
 $\sim 1.2 \text{ kg m}^{-3}$, steel
 $\sim 8000 \text{ kg m}^{-3}$
- **atmospheric
pressure** :
 $\sim 1.0 \times 10^5 \text{ Pa}$
- room temperature:
 $\sim 20^\circ\text{C} \approx 293 \text{ K}$

The right power of ten matters most: for a human, 70 kg is a good estimate; 7 kg is not.

Building an estimate

Not on the list? **Build it** from values that are.

Kinetic energy of a car

$m \approx 1000 \text{ kg}$, $v \approx 30 \text{ m s}^{-1}$:

$$\frac{1}{2}mv^2 \approx \frac{1}{2} \times 1000 \times 30^2 \approx 5 \times 10^5 \text{ J}$$

Pressure under a standing person

weight $\approx 700 \text{ N}$ on about 0.02 m^2 :

$$p \approx \frac{700}{0.02} \approx 4 \times 10^4 \text{ Pa}$$

Always check that the **power of ten** looks sensible before you move on.

Exercises 2.1-2.2

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]

Exercises 2.1-2.2

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

2.1

Worked steps

- “the mass is 60” gives a magnitude only
- a physical quantity also needs a **unit** — e.g. 60 kg **B1**

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

2.2

Worked steps

- an apple is about 100 g (from the estimate table)
- $1 \text{ g} = 10^{-3} \text{ kg}$, so $100 \text{ g} = 100 \times 10^{-3} \text{ kg} = 0.1 \text{ kg}$ **B1**
- any value $\sim 0.05\text{--}0.2 \text{ kg}$ with a unit is accepted

Exercises 2.3-2.4

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]

Exercises 2.3-2.4

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

2.3

Worked steps

- speed of light = $3.0 \times 10^8 \text{ m s}^{-1}$
- write as $a \times 10^n$ with $1 \leq a < 10$: here $3.0 \times 10^8 \text{ m s}^{-1}$
- coefficient 3.0 is nearer 1 than 10, so the order of magnitude is 10^8 m s^{-1} **B1**

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

2.4

Worked steps

- an adult is about 1.7 m tall, so a room is a little taller: **2.5 m** **B1**
- any value $\sim 2\text{--}3 \text{ m}$ with a unit is accepted

Exercise 3.1

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

Exercise 3.1

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[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

3.1

Worked steps

D

- every physical quantity has a **magnitude** and a **unit** **B1**
- “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.

Exercise 3.2

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

Exercise 3.2

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

3.2

Worked steps

B

- the estimate table gives an adult's mass ~ 70 kg **B1**
- A: 7 kg is a cat; C: 700 kg a horse; D: 7000 kg a truck.

Exercise 3.3

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

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3.3

Worked steps

- 1 day = 24 h; keep the units so they cancel **M1**

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

- $86\,400 \text{ s} = 8.64 \times 10^4 \text{ s} \approx 9 \times 10^4 \text{ s}$ (1 s.f.)
- leading digit $9 \geq 5$, so round up: order of magnitude 10^5 s **A1**

Exercise 3.4

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]

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3.4

Worked steps

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

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

M1

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

■ leading digit $3 < 5$, so order of magnitude 10^1 s A1

Exercise 3.5

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 $1.4 \times 10^4 \text{ Pa}$

B $3.5 \times 10^4 \text{ Pa}$

C $3.5 \times 10^6 \text{ Pa}$

D $1.4 \times 10^7 \text{ Pa}$

Exercise 3.5

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☐

A 1.4×10^4 Pa

B 3.5×10^4 Pa

C 3.5×10^6 Pa

D 1.4×10^7 Pa

3.5

Worked steps

B

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

B1

- A is too small (wrong A, or $F \times A$).
- C and D are far too large (area probably left in cm²).