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Answers and Mark Schemes

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Name: _____ Class: _____ Date: _____

SECONDARY 3 · PHYSICS · PHYSICAL QUANTITIES, UNITS AND MEASUREMENT

Physical Quantities, Units and Measurement

Theory and worked examples

Physical quantities, base quantities and SI units

Physics is built on measurement. Anything we can measure, such as the length of an MRT carriage or the mass of a durian, is a physical quantity. A physical quantity consists of a numerical magnitude and a unit: in "the bench is 1.8 m long", 1.8 is the magnitude and m (metre) is the unit. A number without its unit is meaningless, because 1.8 m and 1.8 cm are very different lengths. Scientists everywhere use one agreed set of units, the SI units (Système International). Six of the quantities you need are base quantities; every other quantity, called a derived quantity, is worked out from them.

> KEY IDEA
> **Physical quantity = numerical magnitude + unit. Always write the unit after the number, with a space: 25 kg, 3.0 m, 12 s.**

- Derived quantities and their units come from the base units: area (m^2) = length × length; volume (m^3) = length × length × length; speed (m/s) = distance ÷ time; density (kg/m^3) = mass ÷ volume.
- The symbol for the second is a small s, not S; the kilogram is kg, not Kg. A capital letter changes the meaning (S is the unit siemens, and K is kelvin).
- The kilogram is the only base unit that already contains a prefix (kilo). The gram (g) is not the SI unit of mass.
- Temperature in the laboratory is usually measured in degrees Celsius (°C), but the SI base unit of temperature is the kelvin (K).

WORDS TO KNOW

physical quantity	a quantity that can be measured; it consists of a numerical magnitude and a unit
magnitude	the size of a quantity: the number part, such as 1.8 in 1.8 m
SI unit	a unit of the international system used by all scientists, such as the metre and the kilogram
base quantity	one of the quantities on which all others are built (mass, length, time, current, temperature, amount of substance)
derived quantity	a quantity worked out from base quantities, such as area, volume, speed and density

Base quantity	SI unit	Symbol of the unit
mass	kilogram	kg
length	metre	m
time	second	s
electric current	ampere	A
temperature	kelvin	K
amount of substance	mole	mol

WORKED EXAMPLE

Siti lists these quantities: volume, time, speed, temperature, area, current. (a) Which of them are base quantities? (b) Give the SI unit of each base quantity you named. (c) Explain why speed is a derived quantity.

1. Compare each quantity with the six base quantities: mass, length, time, current, temperature, amount of substance.
2. Time, temperature and current are on the list; volume, speed and area are not.
3. Speed is worked out by dividing a distance (a length) by a time, so it comes from two base quantities.

(a) time, temperature, current. (b) time: second (s); temperature: kelvin (K); current: ampere (A). (c) Speed = distance ÷ time, so it is derived from the base quantities length and time; its unit m/s is made from the metre and the second.

TRY THIS

A pupil writes "the mass of the bag is 4". What is missing, and why does it matter?

Answer: The unit is missing (for example 4 kg). Without a unit the magnitude has no meaning: 4 g and 4 kg are very different masses.

Prefixes and standard form

Physics deals with very large and very small values, from the width of a hair to the distance to the Sun. Instead of writing many zeros, we use standard form (a number between 1 and 10 multiplied by a power of ten) and prefixes. A prefix is placed in front of a unit and multiplies it by a power of ten: the k in km means $\times 10^3$, so 1 km = 10^3 m = 1000 m. Learn the nine prefixes in the table, with their symbols and powers of ten.

KEY IDEA

To change a prefixed unit to the unit without a prefix, replace the prefix by its power of ten: 2.5 mm = 2.5×10^{-3} m; 4.0 MW = 4.0×10^6 W.

- Capital letters for the big prefixes (M, G, T); small letters for k and the small prefixes. M (mega) and m (milli) differ by a factor of 10^9.
- Going from a SMALLER unit to a BIGGER unit, the number gets smaller (e.g. 450 mm = 0.450 m), and the other way round.
- When dividing two powers of ten, subtract the indices: $10^3 \div 10^{-6} = 10^{3-(-6)} = 10^9$.

WORDS TO KNOW

standard form	a number written as $A \times 10^n$, where A is at least 1 and less than 10, and n is a whole number, e.g. 2.5×10^{-3}
prefix	a word or letter in front of a unit that multiplies it by a power of ten, such as kilo (k) = 10^3

Prefix	Symbol	Factor	Example
tera	T	10^{12}	1 TJ = 10^{12} J
giga	G	10^9	1 GW = 10^9 W
mega	M	10^6	1 MJ = 10^6 J
kilo	k	10^3	1 km = 1000 m
deci	d	10^{-1}	1 dm = 0.1 m
centi	c	10^{-2}	1 cm = 0.01 m
milli	m	10^{-3}	1 mm = 0.001 m
micro	μ	10^{-6}	1 μm = 10^{-6} m
nano	n	10^{-9}	1 ns = 10^{-9} s

WORKED EXAMPLE

Write each quantity in its SI unit without a prefix, in standard form: (a) 2.5 mm, (b) 450 nm (the wavelength of blue light), (c) 36 μs, (d) 1.2 GW (the output of a power station).

1. Replace each prefix by its factor: m = 10^{-3}, n = 10^{-9}, μ = 10^{-6}, G = 10^{9}.
2. (a) 2.5 mm = 2.5 × 10^{-3} m.
3. (b) 450 nm = 450 × 10^{-9} m = 4.5 × 10^{2} × 10^{-9} m = 4.5 × 10^{-7} m.
4. (c) 36 μs = 36 × 10^{-6} s = 3.6 × 10^{-5} s.
5. (d) 1.2 GW = 1.2 × 10^{9} W.

(a) 2.5 × 10^{-3} m (b) 4.5 × 10^{-7} m (c) 3.6 × 10^{-5} s (d) 1.2 × 10^{9} W

TRY THIS

How many micrometres are there in 1 mm?

Answer: 1 mm = 10^{-3} m and 1 μm = 10^{-6} m, so 1 mm = 10^{-3} ÷ 10^{-6} = 10^{3} = 1000 μm.

Converting units

Before you put numbers into a formula, change every quantity into SI units. Write the conversion as a multiplication by a factor that equals one, such as (1000 m / 1 km), so the old unit cancels. Speeds are often given in km/h (on road signs and car speedometers), but the SI unit of speed is m/s. Areas and volumes need extra care, because each length in them is converted.

KEY IDEA

km/h → m/s: ÷ 3.6. m/s → km/h: × 3.6. cm^2 → m^2: × 10^{-4}. cm^3 → m^3: × 10^{-6}.

- Speed: 1 km/h = 1000 m ÷ 3600 s, so to change km/h to m/s divide by 3.6; to change m/s to km/h multiply by 3.6.
- Area: 1 cm = 10^{-2} m, so 1 cm^2 = (10^{-2} m)^2 = 10^{-4} m^2; 1 mm^2 = 10^{-6} m^2.
- Volume: 1 cm^3 = (10^{-2} m)^3 = 10^{-6} m^3; 1 m^3 = 10^{6} cm^3. Also 1 litre = 1000 cm^3 = 10^{-3} m^3.
- Mass: 1 kg = 1000 g = 10^{6} mg; 1 g = 10^{-3} kg.
- Time: 1 h = 60 min = 3600 s.

WORKED EXAMPLE

An MRT train travels at 72 km/h. (a) Convert this speed to m/s. (b) The floor area of a hawker stall table top is 3500 cm². Convert this to m². (c) A water tank on an HDB roof holds 2.4 m³. Convert this to cm³ and to litres.

1. (a) 72 km/h = 72 × 1000 m ÷ 3600 s.
2. = 72 000 ÷ 3600 = 20 m/s (or 72 ÷ 3.6 = 20 m/s).
3. (b) 1 $cm^2 = 10^{-4}$ m^2, so 3500 cm^2 = 3500 × 10^{-4} m^2 = 0.35 m^2.
4. (c) 1 $m^3 = 10^6$ cm^3, so 2.4 m^3 = 2.4 × 10^6 cm^3.
5. 1 litre = 1000 cm^3, so 2.4 × 10^6 cm^3 ÷ 1000 = 2400 litres.

(a) 20 m/s (b) 0.35 m^2 (c) 2.4 × 10^6 cm^3 = 2400 litres

TRY THIS

A cyclist at East Coast Park rides at 5.0 m/s. What is this speed in km/h?

Answer: 5.0 × 3.6 = 18 km/h

Orders of magnitude: from an atom to the Earth

The order of magnitude of a quantity is the power of ten closest to its value. It lets us compare sizes that are wildly different without exact figures. A typical atom is about 10^{-10} m across, while the Earth is about 10^7 m across: the Earth is about 10^{17} times wider than an atom. Learn the rough sizes in the table so that you can tell whether an answer is sensible.

- The size of an atom (10^{-10} m) and the size of the Earth (10^7 m) are the two ends of the range you must know.
- To compare two sizes, divide them: subtract the powers of ten. $10^7 \div 10^{-10} = 10^{17}$.
- If an answer comes out as "a person is 10^3 m tall", your working has gone wrong: check against the table.

WORDS TO KNOW

order of magnitude	the power of ten nearest to a value; 0.0002 m (2 × 10^{-4} m) has an order of magnitude of 10^{-4} m

CHAPTER 1

Practice Questions

Part 2: Physical Quantities, Units and Measurement



In the practice questions

23 questions, 70 marks. For each multiple-choice question, write the letter of the correct option (A, B, C or D) in the brackets. Write your other answers on the lines given. The answers are on page 322.

- Section A: Multiple-Choice Questions: 15 questions, 15 marks
- Section B: Structured Questions: 6 questions, 35 marks
- Section C: Free-Response Questions: 2 questions, 20 marks

Name: _____ Class: _____ Date: _____

SECONDARY 3 · PHYSICS · PHYSICAL QUANTITIES, UNITS AND MEASUREMENT

Physical Quantities, Units and Measurement

INSTRUCTIONS

- 23 questions, 70 marks in total.
- Answer all questions in the spaces provided.
- For MCQs, write the letter (A, B, C or D) in the brackets.
- Write your other answers on the lines given, in full sentences.

Section A: Multiple-Choice Questions

1 Which of these is a base quantity? ( ) [1]

(A) force (B) temperature (C) speed (D) volume

2 Which list contains only vector quantities? ( ) [1]

(A) distance, force, mass (B) energy, velocity, weight
(C) acceleration, displacement, force (D) speed, time, velocity

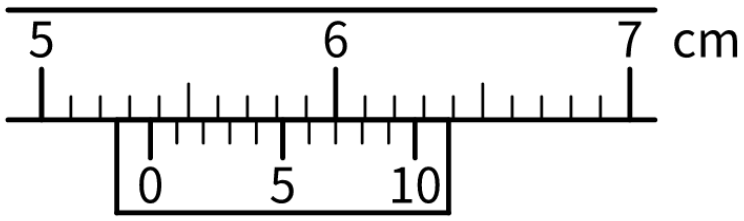
3 A grain of sand has a diameter of 450 μm. What is this diameter in metres? ( ) [1]

(A) 4.5×10^{-4} m (B) 4.5×10^{-5} m (C) 4.5×10^{-7} m (D) 4.5×10^{-3} m

4 Which is closest to the diameter of a typical atom? ( ) [1]

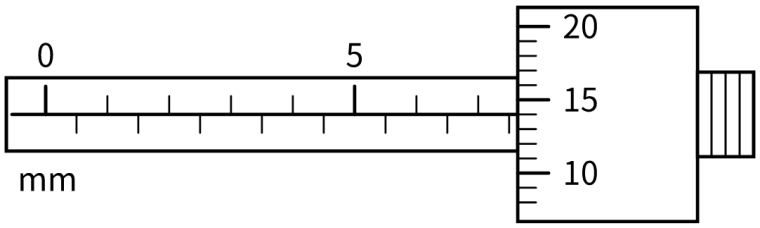
(A) 10^{-4} m (B) 10^{-6} m (C) 10^{-8} m (D) 10^{-10} m

5 The diagram shows the scales of a pair of vernier calipers. There is no zero error. What is the reading? ( ) [1]



Ⓐ 5.30 cm Ⓑ 5.37 cm Ⓒ 5.73 cm Ⓓ 5.07 cm

6 The diagram shows the scales of a micrometer screw gauge. There is no zero error. What is the reading? ( ) [1]

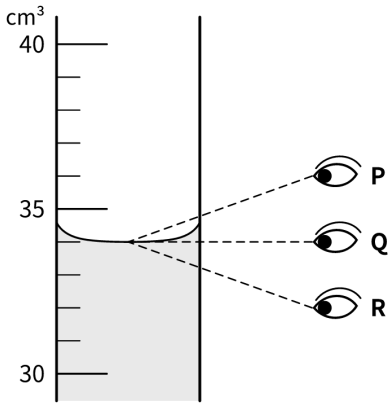


Ⓐ 7.14 mm Ⓑ 7.39 mm Ⓒ 7.64 mm Ⓓ 8.14 mm

7 A micrometer screw gauge reads −0.02 mm when it is fully closed. It reads 4.56 mm when it is closed on a ball bearing. What is the diameter of the ball bearing? ( ) [1]

Ⓐ 4.58 mm Ⓑ 4.54 mm Ⓒ 4.56 mm Ⓓ 4.52 mm

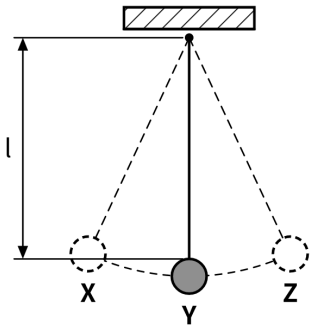
8 The diagram shows water in a measuring cylinder and three eye positions, P, Q and R. Which row gives the correct eye position and the volume of the water? ( ) [1]



	eye position	volume / cm³
A	P	34
B	Q	35
C	R	34
D	Q	34

Ⓐ row A Ⓑ row B Ⓒ row C Ⓓ row D

9 A pendulum bob swings from X, through its lowest point Y, to Z and back. It takes 0.60 s to move from X to Z. What is the period of the pendulum? ( ) [1]



(A) 0.30 s (B) 1.2 s (C) 0.60 s (D) 2.4 s

10 Which instrument is the most suitable for measuring the inside diameter of a test tube, which is about 1.5 cm? ( ) [1]

(A) vernier calipers (B) micrometer screw gauge
(C) metre rule (D) measuring tape

11 A stack of 250 identical cards, pressed flat, is 3.0 cm thick. What is the thickness of one card? ( ) [1]

(A) 0.012 mm (B) 0.75 mm (C) 0.12 mm (D) 1.2 mm

12 Three statements are made about physical quantities.
1 The kelvin is the SI base unit of temperature.
2 The gram is the SI base unit of mass.
3 A physical quantity consists of a numerical magnitude and a unit.
Which statements are correct? ( ) [1]

(A) 1 and 2 only (B) 1 and 3 only (C) 2 and 3 only (D) 1, 2 and 3

13 A bus travels along an expressway at 54 km/h. What is this speed in m/s? ( ) [1]

(A) 15 m/s (B) 54 m/s (C) 150 m/s (D) 194 m/s

14 Which length is the largest? ( ) [1]

(A) 3.0×10^5 mm (B) 0.40 km (C) 2.0×10^4 cm (D) 5.0×10^8 μm