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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

A physical quantity is a property that can be measured. It always consists of a numerical magnitude together with a unit, for example the length of a corridor is 12 m, not just "12". The base quantities are not defined in terms of any other physical quantity. Every other physical quantity is a derived quantity: it is defined from the base quantities by multiplying and/or dividing them (for example, area = length × length).

KEY IDEA

The six base quantities (mass, length, time, electric current, temperature, amount of substance) are not defined from other quantities; every other quantity is derived from them.

- A derived quantity's unit comes from the base quantities in its formula: speed = distance ÷ time, so its unit is m/s.
- Two more derived quantities you will meet often in this book: area (m^2) and volume (m^3), both built only from length.

WORDS TO KNOW

physical quantity	a property that can be measured, consisting of a numerical magnitude and a unit
base quantity	one of the six fundamental SI quantities, not defined in terms of other quantities
derived quantity	a quantity defined from base quantities by multiplying and/or dividing them

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

WORKED EXAMPLE

State whether each of the following is a base quantity or a derived quantity, and give its SI unit: (a) the mass of a durian (b) the speed of an MRT train (c) the volume of a water bottle (d) the temperature of a bowl of soup.

1. (a) Mass is one of the six base quantities, measured directly. SI unit: kilogram (kg).
2. (b) Speed = distance ÷ time, so speed is a derived quantity. SI unit: metre per second (m/s).
3. (c) Volume = length × length × length, so volume is a derived quantity. SI unit: cubic metre (m^3).
4. (d) Temperature is one of the six base quantities, measured directly. SI unit: kelvin (K).

(a) base quantity, kg (b) derived quantity, m/s (c) derived quantity, m^3 (d) base quantity, K.

TRY THIS

Is electric current a base quantity or a derived quantity? Give its SI unit and symbol.

Answer: A base quantity; the ampere (A).

Prefixes and standard form

Some measurements are very large or very small, and writing every digit out in full is awkward. Standard form writes a number as $M \times 10^n$, where $1 \leq M < 10$ and n is an integer. A prefix is an alternative way of showing the same power of ten, written directly in front of the unit instead of as a power of ten. To change a measurement into a prefix, write it in standard form first, then pick the prefix whose factor matches the power of ten.

KEY IDEA

Standard form and prefixes are two ways of writing the same very large or very small measurement.

- A prefix attaches directly to the unit: 1 nm = 1×10^{-9} m, not "1×10^{-9}" on its own.
- Check the size makes sense after converting: a length in millimetres must be a bigger number than the same length in metres.

WORDS TO KNOW

standard form a number written as $M \times 10^{n}$, where $1 \leq M < 10$

prefix a symbol placed in front of a unit to show a power of ten, such as kilo (k) for 10^{3}

Prefix	Symbol	Factor
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

WORKED EXAMPLE

The current in a small torch LED is 0.000 020 A. (a) Write this current in standard form. (b) Write it again using a suitable prefix.

1. (a) Move the decimal point until exactly one non-zero digit remains before it: 0.000 020 A = 2.0×10^{-5} A.
2. (b) 2.0×10^{-5} A = 20×10^{-6} A. The factor 10^{-6} is micro (μ), so the current is 20 μA.

(a) 2.0×10^{-5} A (b) 20 μA.

TRY THIS

A bacterium is about 0.000 002 m long. Write this length using a suitable prefix.

Answer: 2 μm (2×10^{-6} m).

Orders of magnitude: from an atom to the Earth

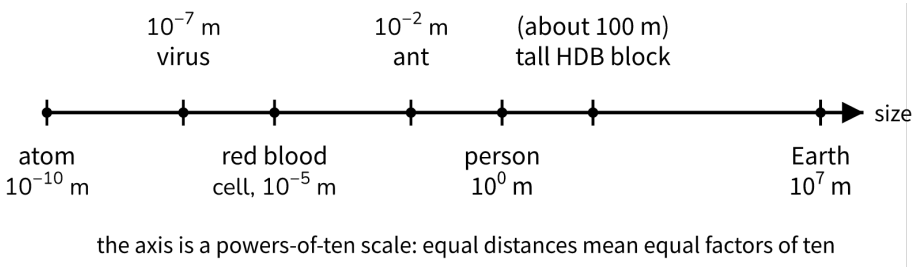
Physical quantities in this syllabus range enormously in size, from a single atom to the whole Earth. The order of magnitude of a quantity is the power of ten, 10^n, when its size is written in standard form as $A \times 10^n$ (with $1 \leq A < 10$). It lets you compare sizes that differ hugely from each other without needing an exact value — for example, saying that the Earth is about 10^{17} times wider than an atom is far more useful for picturing the difference than quoting both measurements out in full.

KEY IDEA

The order of magnitude of a quantity is just the power of ten, 10^n, in its standard form $A \times 10^n$; it lets very different scales be compared quickly.

WORDS TO KNOW

order of magnitude	the power of ten, 10^n, when a quantity's size is written in standard form $A \times 10^n$



the axis is a powers-of-ten scale: equal distances mean equal factors of ten

WORKED EXAMPLE

A virus has a diameter of about 1×10^{-7} m. A football has a diameter of about 2×10^{-1} m. About how many times bigger is the football than the virus? Give your answer as an order of magnitude.

1. Divide the two diameters: $(2 \times 10^{-1}) \div (1 \times 10^{-7}) = 2 \times 10^6$.
2. Written in standard form, 2×10^6 has the power of ten n = 6, so its order of magnitude is 10^6.

About 2×10^6 times bigger; order of magnitude 10^6.

TRY THIS

Put these in order from smallest to largest: a classroom (10^1 m), an ant (10^{-2} m), the Earth (10^7 m), a red blood cell (10^{-5} m).

Answer: red blood cell, ant, classroom, Earth.

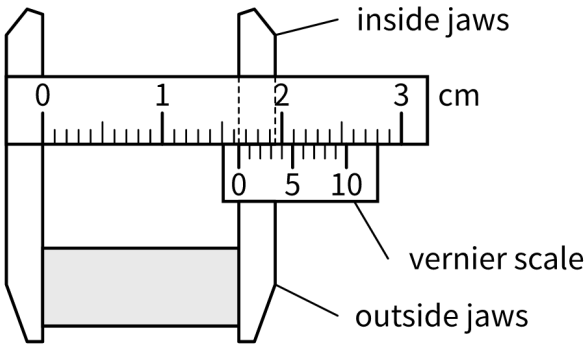
Measuring length: the metre rule and vernier calipers

A metre rule or measuring tape, read to the nearest millimetre, is precise enough for lengths from a few centimetres up to several metres. For a length too short to read precisely this way — such as the diameter of a test tube — vernier calipers are used instead. Vernier calipers have outside jaws (for an external length), inside jaws (for an internal diameter) and a depth rod, together with a main scale (in cm) and a sliding vernier scale with 10 divisions. The reading is the main-scale division just before the vernier's zero, plus the vernier division that lines up exactly with a main-scale line, multiplied by 0.01 cm.

- A metre rule has a precision of about 0.1 cm; always place the object with no gap against the zero mark, or measure between two marks and subtract.
- Read any scale with your eye directly in line with the mark, not from the side — looking at an angle causes a parallax error.

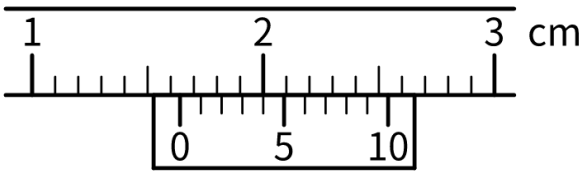
WORDS TO KNOW

parallax error	an error caused by viewing a scale from an angle rather than straight on
vernier calipers	an instrument with a sliding scale that measures length to a precision of 0.01 cm



WORKED EXAMPLE

A pupil uses vernier calipers (with no zero error) to measure the external diameter of a rim, as shown in the figure. State the diameter, and explain why the pupil's eye should look straight at the scale rather than from an angle.



1. Read the main scale: the division just before the vernier's zero is 1.6 cm.
2. Read the vernier scale: the 4th vernier division lines up exactly with a main-scale line, giving 4×0.01 cm = 0.04 cm.
3. Add the two readings: 1.6 cm + 0.04 cm = 1.64 cm.

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 330.

- 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 in the spaces. Show working and units.

Section A: Multiple-Choice Questions

1 A pupil records four properties during an experiment with a toy car: the volume of fuel used, the speed of the car, the amount of substance in the battery's electrolyte, and the weight of the car. Which of these four is a base quantity? ( ) [1]

(A) volume
(B) speed
(C) amount of substance
(D) weight

2 A capacitor stores a charge of 0.000 015 C. Expressed in standard form, this is ( ) [1]

(A) 1.5×10^{-5} C (B) 1.5×10^{-4} C (C) 15×10^{-6} C (D) 1.5×10^{5} C

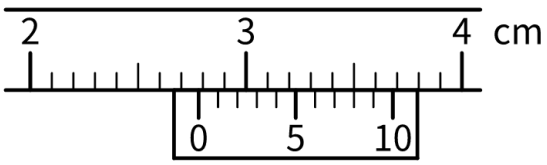
3 A length of 4.7×10^{-9} m is best written, using a prefix, as ( ) [1]

(A) 4.7 μm (B) 4.7 mm (C) 4.7 cm (D) 4.7 nm

4 The Earth has a diameter of order of magnitude 10^7 m. A football field has a length of order of magnitude 10^2 m. The Earth's diameter is about how many times the length of the field? ( ) [1]

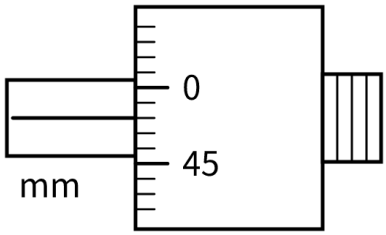
(A) 10^2 (B) 10^5 (C) 10^9 (D) 10^{14}

5 Vernier calipers measure the external diameter of a rod. What is the reading shown? ( ) [1]



(A) 2.68 cm (B) 2.87 cm (C) 2.78 cm (D) 7.82 cm

6 The anvil and spindle of a micrometer screw gauge are closed with nothing between them, and the scale reads as shown. What is the zero error? ( ) [1]



(A) +0.02 mm (B) +0.48 mm (C) −0.48 mm (D) −0.02 mm

7 A pupil repeats a length measurement five times and takes the average, to reduce the effect of ( ) [1]

(A) random error (e.g. due to reaction time)
(B) zero error
(C) parallax error
(D) systematic error

8 A measuring cylinder holds 35 cm^3 of water. A small stone is lowered in, fully covered, and the level rises to 54 cm^3. What is the volume of the stone? ( ) [1]

(A) 35 cm^3 (B) 19 cm^3 (C) 54 cm^3 (D) 89 cm^3

9 A workshop technician needs to check the inside width of a metal sleeve, about 1.5 cm, before fitting a rod into it. Which instrument should be used? ( ) [1]

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

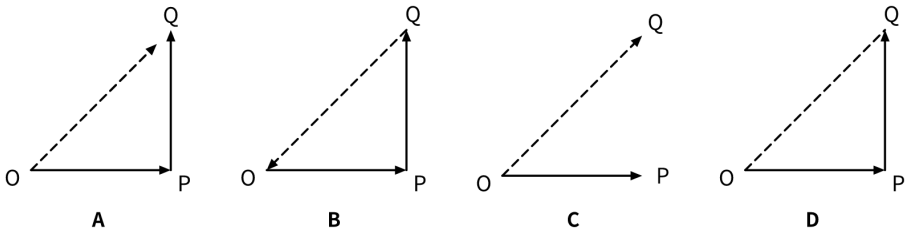
10 The table gives four pairs of a quantity with its type. Which row is correct? ( ) [1]

Row	Quantity	Type
A	mass	vector
B	weight	scalar
C	distance	vector
D	velocity	vector

11 The jaws of a pair of vernier calipers are closed with nothing between them, and the scale does not read exactly zero. Which of these statements about this zero error are correct?
1 It is a systematic error.
2 It can be removed by repeating the reading several times and averaging.
3 The actual reading is found by subtracting the zero error from the observed reading. ( ) [1]

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

12 Each diagram below shows an attempt to add two vectors, OP and PQ, by scale drawing, with the resultant drawn dashed. Which diagram shows the resultant correctly? ( ) [1]



13 A signal box at a level crossing is pulled sideways by two cables: a tension of 8 N due east and a tension of 15 N due north. What is the magnitude of the single force having the same effect as both cables together? ( ) [1]

Ⓐ 7 N Ⓑ 23 N Ⓒ 289 N Ⓓ 17 N