CHAPTER 1

Units and Measurements

CBSE Class 11 · Physics · Chapter 1

CBSE · Physics · Class 11

WHAT THIS CHAPTER DOES

A Name the 7 SI base units and write the dimensional formula of any derived quantity.

B Propagate errors correctly through sums, products, quotients and powers.

Boards prep that builds confidence, not anxiety.

TODAY'S MISSION

Today's mission

1. Name the 7 SI base units and write the dimensional formula of any derived quantity.
2. Propagate errors correctly through sums, products, quotients and powers.
3. Report any result to the correct number of significant figures.
4. Use dimensional analysis to check, derive and convert — and know its three limits.

WHY THIS MATTERS

Why this chapter matters

1. It is the entry-point of the whole Physics course (the old 'Physical World' chapter was removed in the rationalised syllabus).
2. Error handling and significant figures are graded in EVERY Physics practical and numerical for the next two years.
3. Dimensional analysis is a self-check tool you will reach for in every chapter — it catches wrong formulae before you waste time on them.

TOPIC

A

Physical quantities and the SI system

TOPIC

Quantities, units and the SI base set

PHYSICAL QUANTITY

A physical quantity is anything in nature that can be measured and expressed as a number multiplied by a unit — for example a length of 2.5 m means the number 2.5 times the unit metre. Every measurement therefore has two parts, the numerical value and the unit, and neither is meaningful without the

FUNDAMENTAL VS DERIVED UNITS

A fundamental (base) unit is chosen by convention and defined independently of all others — there are exactly seven in the SI. A derived unit is constructed by combining base units according to the defining relation of the quantity: speed is metre per

THE 7 SI BASE UNITS

The Système International fixes seven base units: the metre (m) for length, the kilogram (kg) for mass, the second (s) for time, the ampere (A) for electric current, the kelvin (K) for thermodynamic temperature, the mole (mol) for amount of substance, and the candela (cd) for luminous

HOW THE BASE UNITS ARE DEFINED

Since 2019 the SI base units are defined by fixing the numerical values of seven fundamental constants, not by physical artefacts. The second is defined via the caesium-133 hyperfine transition frequency; the metre via the fixed speed of light $c = 299\,792\,458\ m\ s^{-1}$ (the

TOPIC

B

Measuring length, mass and time

TOPIC

Spanning the scales of nature

LENGTH — LARGE DISTANCES

Ordinary lengths are read with a metre scale (least count 1 mm), vernier callipers (0.1 mm) or a screw gauge (0.01 mm). But planetary and stellar distances are far too large for any scale, so we use the PARALLAX method: the same far object is viewed from two ends of a known

LENGTH — TINY DISTANCES

At the other extreme, the size of a molecule or an atom is far below the least count of any mechanical instrument, so indirect estimation is used — for example spreading a known volume of oleic acid into a monomolecular film on water and dividing volume by area to

MASS

Mass is measured with a common balance for everyday objects and a sensitive physical/chemical balance (least count down to a milligram) in the laboratory. Very large masses — planets and stars — are inferred indirectly through gravitational effects (Newton's law of

TIME

Time is measured by any phenomenon that repeats regularly — historically the swing of a pendulum, today the vibrations of a caesium atom. The atomic (caesium) clock, on which the definition of the second rests, is so stable it drifts by less than a second in millions of years, which is why it

TOPIC

C

Accuracy, precision and errors

THEOREM · LOAD-BEARING RESULT

Accuracy vs Precision

> " Accuracy is how close a measurement is to the TRUE value. Precision is how close repeated measurements are to EACH OTHER, and is limited by the least count (resolution) of the instrument. The two are independent.

STATEMENT

A measurement can be precise but inaccurate (a clock 5 minutes fast gives the same wrong reading every time), or accurate but imprecise (readings scattered around the true value). High

WHY THIS MATTERS

- Confusing the two is the commonest conceptual error in this chapter
- Precision is fixed by the instrument's least count
- accuracy is fixed by calibration and by the absence of systematic error.

WATCH OUT FOR

NOTE Buying a finer instrument improves PRECISION (smaller least count) but does NOT fix a systematic ACCURACY error such as a zero error — that must be corrected, not averaged away.

TOPIC

Two families of error

SYSTEMATIC ERRORS

A systematic error pushes every reading in the SAME direction by a consistent amount, so it cannot be reduced by averaging more readings. Its three usual sources are instrumental (a zero error in a vernier, a wrongly calibrated scale), imperfect experimental technique (not accounting for buoyancy

RANDOM ERRORS

A random error fluctuates unpredictably in size and sign from one reading to the next — caused by tiny uncontrollable changes such as voltage flicker, draughts, or variable human reaction time on a stopwatch. Because they scatter symmetrically about the true value, random errors ARE

ABSOLUTE ERROR

For a set of readings a_1, a_2, ⋯, a_n, the best estimate of the true value is the arithmetic mean a_mean. The absolute error of the i-th reading is $\Delta a_i = |a_{mean} - a_i|$ — note it is always taken as a positive magnitude. The MEAN absolute error is $\Delta a_{mean} = (\Sigma|\Delta a_i|)/n$, and the result is then reported as a mean ±

RELATIVE AND PERCENTAGE ERROR

Absolute error alone does not tell you how serious an error is — 1 cm is trivial on a kilometre but catastrophic on a centimetre. The RELATIVE (fractional) error fixes this by dividing the mean absolute error by the mean value: relative error

TOPIC

D

Combination (propagation) of errors

THEOREM · LOAD-BEARING RESULT

Rules for Propagation of Errors

> " Sum/difference ($Z = A \pm B$): ABSOLUTE errors add → $\Delta Z = \Delta A + \Delta B$. Product/quotient ($Z = AB$ or A/B): RELATIVE errors add → $\Delta Z/Z = \Delta A/A + \Delta B/B$. Power ($Z = A^p B^q / C^r$): $\Delta Z/Z = |p|(\Delta A/A) + |q|(\Delta B/B) + |r|(\Delta C/C)$.

STATEMENT

Errors always combine to give the MAXIMUM possible (worst-case) error, so every contribution is added as a positive quantity — even a term in the denominator and even a difference. The

WHY THIS MATTERS

- These three rules let you predict the reliability of a computed result from the reliabilities of the measured inputs, and they tell you which measurement to make most carefully (the one with the largest exponent).

WATCH OUT FOR

NOTE Do NOT add absolute errors for a product, and do NOT subtract errors for a difference or a denominator. The whole framework assumes worst-case: everything adds.

WORKED EXAMPLE

Maximum percentage error in $Z = A^2B / C^3$

1. Given errors: $\Delta A/A = 1\%$, $\Delta B/B = 2\%$, $\Delta C/C = 3\%$. The exponents are $a = 2$, $b = 1$, $c = 3$.
2. Apply the power rule: %error in $Z = |2|(1\%) + |1|(2\%) + |3|(3\%)$.
3. Compute term by term: $2 \times 1 = 2$; $1 \times 2 = 2$; $3 \times 3 = 9$.
4. Add (worst case): maximum %error in $Z = 2 + 2 + 9 = 13\%$. Note C, raised to the 3rd power, dominates — measure C most carefully.

TRY IT · SOLVE BEFORE YOU PEEK

Two lengths are measured as $L_1 = 5.00 \pm 0.02$ cm and $L_2 = 3.00 \pm 0.01$ cm. What is $L_1 - L_2$ with its absolute error?

SOLUTION

ANSWER $L_1 - L_2 = 2.00$ cm. For a difference, ABSOLUTE errors add: $\Delta L = 0.02 + 0.01 = 0.03$ cm. So the result is 2.00 ± 0.03 cm. (Note the errors add even though the quantities subtract — worst case.)

TOPIC

E

Significant figures

TOPIC

Counting and keeping meaningful digits

WHAT THEY MEAN

Significant figures are the digits in a measurement that are known reliably plus one final estimated (uncertain) digit. Reporting 2.34 cm claims you are sure of the 2 and 3 and are estimating the 4 — so it conveys both the value and, implicitly, the precision of the instrument. Writing extra

THE COUNTING RULES

Count significant figures by four rules: (1) every non-zero digit is significant; (2) zeros BETWEEN non-zero digits are significant (so 2.005 has 4); (3) LEADING zeros are never significant — they only place the decimal (0.00250 has 3 significant figures: 2, 5, 0); (4) TRAILING zeros

RULES FOR CALCULATIONS

When you combine measurements, the result cannot be more precise than the least-precise input. For MULTIPLICATION and DIVISION, the answer keeps as many SIGNIFICANT FIGURES as the input with the fewest: $4.327 \times 2.1 = 9.0867$ is reported as 9.1 (two

ROUNDING RULES

After applying the calculation rule, round the surplus digits using the standard convention: if the digit to be dropped is greater than 5, round up; if less than 5, leave the last kept digit unchanged; if it is exactly 5, the common school rule rounds up (the alternative 'round-to-even' / banker's

WORKED EXAMPLE

Report 2.91 × 3.6 to correct significant figures

1. Count significant figures: 2.91 has 3 s.f.; 3.6 has 2 s.f.
2. For multiplication, the result keeps the FEWEST significant figures of the inputs → 2 s.f. (set by 3.6).
3. Raw product: $2.91 \times 3.6 = 10.476$.
4. Round 10.476 to 2 significant figures → 10. (Written as 1.0×10^1 to show clearly that it is 2 s.f.)

TOPIC

F

Dimensions and dimensional analysis

TOPIC

The M-L-T bookkeeping of physics

WHAT A DIMENSION IS

The dimensions of a physical quantity are the powers to which the base quantities must be raised to represent it — in mechanics we track mass [M], length [L] and time [T]. The dimensional formula packages these powers: velocity is $[M^0 L^1 T^{-1}]$, acceleration is $[M^0 L^1 T^{-2}]$, and force, from F = ma, is $[M^1 L^1 T^{-2}]$. To

BUILDING DERIVED DIMENSIONS

Every mechanical quantity's dimensional formula follows from its definition by simple substitution. Work or energy = force × distance = $[MLT^{-2}][L]$ = $[ML^2T^{-2}]$; power = work/time = $[ML^2T^{-3}]$; pressure = force/area = $[MLT^{-2}]/[L^2]$ = $[ML^{-1}T^{-2}]$; momentum = mass ×

DIMENSIONLESS QUANTITIES

Some quantities have the dimensional formula $[M^0L^0T^0]$ — they are pure numbers with no dimensions. Examples are strain (length/length), relative density and refractive index (a ratio of like quantities), plane angle in radians (arc/radius), and all numerical constants such as 2π

PRINCIPLE OF HOMOGENEITY

The principle of dimensional homogeneity states that every term that is added, subtracted or equated in a physically valid equation must carry identical dimensions — you cannot add a length to a time any more than you can add metres to seconds. This principle is the engine behind every

WORKED EXAMPLE

Dimensionally check $v^2 = u^2 + 2as$

1. Find the dimensions of each whole term. $[v^2] = (LT^{-1})^2 = L^2T^{-2}$; $[u^2] = (LT^{-1})^2 = L^2T^{-2}$.

2. For the last term, $[2as] = [a][s] = (LT^{-2})(L) = L^2T^{-2}$ (the constant 2 is dimensionless).

3. Compare: all three terms have dimensions $M^0L^2T^{-2}$. By the principle of homogeneity, identical dimensions can be added/equated.

4. Conclusion: the equation is dimensionally CORRECT. Caveat: this cannot prove the ½ or 2 are right — dimensionless constants are invisible to this method.

TOPIC

Three uses — and three limits

USE 1 — CHECKING EQUATIONS

The first and commonest use is verifying that a derived or recalled equation is dimensionally consistent: write the dimensions of every term and demand homogeneity. If even one term differs, the equation is certainly wrong and you have caught the slip before substituting

USE 2 — DERIVING RELATIONS

When a quantity is known to depend on a few others, dimensional analysis can recover the FORM of the relation. To find the period T of a simple pendulum, assume $T \propto l^a g^b m^c$, write the dimensions, equate the powers of M, L and T on both sides, and solve to get a = ½, b = –½, c = 0,

USE 3 — CONVERTING UNITS

Dimensional analysis converts a quantity's numerical value between unit systems. Because the physical quantity is fixed, $n_1[u_1] = n_2[u_2]$, so the new numerical value is $n_2 = n_1 (u_1/u_2)$ where the unit ratio is expanded using the dimensional formula $M^aL^bT^c$. For example, converting a

THREE LIMITATIONS

Dimensional analysis fails in three definite situations that CBSE tests directly. First, it cannot determine DIMENSIONLESS CONSTANTS — the ½, the 2π, any pure number — because they have no dimensions to track. Second, it cannot handle equations containing TRIGONOMETRIC

TOPIC

Accuracy vs precision

TRAP → TRUTH

× **MISTAKE** Accuracy and precision mean the same thing — a 'precise' instrument is automatically 'accurate'.

✓ **CORRECT** Accuracy = closeness of a measured value to the TRUE value. Precision = closeness of repeated measurements to EACH OTHER (and is set by the least count / resolution). A clock running 5 min fast is precise (always the same offset) but inaccurate. A balance that gives 4.99, 5.01, 5.00 g for a true 5.00 g object is both accurate and precise. The two are independent.

TOPIC

Error propagation in products and quotients

TRAP → TRUTH

× **MISTAKE** When you multiply or divide quantities, you add their ABSOLUTE errors.

✓ **CORRECT** For a product or quotient you add the RELATIVE (or percentage) errors, not the absolute errors. For $Z = AB$ or A/B, $\Delta Z/Z = \Delta A/A + \Delta B/B$. Absolute errors add only for a SUM or DIFFERENCE ($Z = A \pm B \Rightarrow \Delta Z = \Delta A + \Delta B$). Mixing these two rules is the single biggest error-propagation mistake.

TOPIC

Error in a power

TRAP → TRUTH

× **MISTAKE** If $Z = A^3$, the error is the same as for A — the power does not matter.

✓ **CORRECT** A power MULTIPLIES the relative error by the magnitude of the exponent: if $Z = A^p B^q / C^r$ then $\Delta Z/Z = |p|(\Delta A/A) + |q|(\Delta B/B) + |r|(\Delta C/C)$. So a cube triples the relative error of that quantity. This is why the most error-sensitive quantity is the one raised to the highest power — measure it most carefully.

TOPIC

Significant figures — trailing zeros

TRAP → TRUTH

× **MISTAKE** Trailing zeros never count, so 4500 has only 2 significant figures and 4.500 has only 2.

✓ **CORRECT** Trailing zeros AFTER a decimal point ARE significant: 4.500 has 4 significant figures. For a number like 4500 with no decimal point the trailing zeros are ambiguous — write it in scientific notation (4.5×10^3 = 2 s.f.; 4.500×10^3 = 4 s.f.) to be unambiguous. Leading zeros (0.0025) are NEVER significant; they only fix the decimal place.

TOPIC

Dimensional analysis — what it can do

TRAP → TRUTH

× **MISTAKE** If an equation is dimensionally correct, then it must be physically correct.

✓ **CORRECT** Dimensional correctness is necessary but NOT sufficient. Dimensions cannot detect a missing dimensionless constant (the ½ in $s = ut + \frac{1}{2}at^2$, or the 2π in $T = 2\pi\sqrt{l/g}$), cannot test trigonometric, exponential or logarithmic terms, and cannot derive a relation that is a SUM of several terms. A dimensionally balanced equation can still be wrong by a pure number or a missing term.

TOPIC

Dimensionless quantities

TRAP → TRUTH

× **MISTAKE** Every physical quantity has dimensions of M, L and T.

✓ **CORRECT** Some quantities are dimensionless (their dimensional formula is $M^0 L^0 T^0$): strain, refractive index, relative density, angle (radian), the arguments of sin, cos, e^x and ln, plus all pure numbers like 2π and the ½ in kinematic equations. The angle in 'sin θ' MUST be dimensionless — this is exactly why dimensional analysis cannot handle trigonometric terms.

TOPIC

Least count and zero error

TRAP → TRUTH

× **MISTAKE** Zero error of an instrument is a random error you can average away.

✓ **CORRECT** A zero error (e.g. a vernier whose jaws read 0.02 cm when fully closed) is a SYSTEMATIC error — it shifts every reading in the same direction by the same amount. You cannot average it out; you must CORRECT for it (subtract it). Random errors (small fluctuations in repeated readings) are reduced by averaging; systematic errors are not.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark numerical: 'A physical quantity $Z = A^a B^b / C^c$. Given the percentage errors in A, B

1 — WRITE THE PROPAGATION RULE FOR POWERS (1 m)

State the rule explicitly: for $Z = A^a B^b / C^c$, the maximum relative error is $\Delta Z/Z = |a|(\Delta A/A) + |b|(\Delta B/B) + |c|(\Delta C/C)$. Writing the rule earns the first mark even before substitution.

2 — SUBSTITUTE THE GIVEN PERCENTAGE ERRORS WITH THEIR EXPONENTS (1 m)

Multiply each percentage error by the MAGNITUDE of its exponent (always positive — errors add, never subtract). e.g. for $Z = A^2 B / C^3$ with errors 1%, 2%, 3%: %error in Z = 2(1) + 1(2) + 3(3) = 2 + 2 + 9 = 13%.

3 — QUOTE THE FINAL ANSWER CORRECTLY (1 m)

State: 'Maximum percentage error in Z = 13%.' If the question gives a value of Z, also report Z ± its absolute error rounded to matching precision. Always say 'maximum' — error propagation gives the worst case.

TOPPER TEMPLATE · MARK-BY-MARK

3-mark question: 'Check the dimensional correctness of the equation [e.g. $v^2 = u^2 +$

1. WRITE THE DIMENSIONAL FORMULA OF EACH TERM — 1 m

List dimensions term-by-term. For $v^2 = u^2 + 2as$: $[v^2] = (LT^{-1})^2 = L^2 T^{-2}$; $[u^2] = L^2 T^{-2}$; $[2as] = [a][s] = (LT^{-2})(L) = L^2 T^{-2}$ (the 2 is dimensionless).

2. COMPARE EVERY TERM — THEY MUST MATCH — 1 m

Show that all three terms have identical dimensions $L^2 T^{-2}$. State the principle of homogeneity: only quantities with the SAME dimensions can be added or equated.

3. CONCLUDE WITH THE CORRECT CAVEAT — 1 m

'Since every term has the dimensions $L^2 T^{-2}$, the equation is dimensionally correct (homogeneous).' Add the caveat for full marks: dimensional correctness does not guarantee the equation is physically complete, since dimensionless constants cannot be checked this way.

TOPPER TEMPLATE · MARK-BY-MARK

2-mark question: 'State the number of significant figures in the given measurements … correct number of significant figures.

1 COUNT SIGNIFICANT FIGURES USING THE RULES — 1 m

Apply the rules: all non-zero digits count; zeros between non-zero digits count; leading zeros NEVER count; trailing zeros count only if a decimal point is present. e.g. 0.00520 → 3 s.f.; 4.500 → 4 s.f.; 6.320 × 10^3 → 4 s.f.

2 ROUND THE RESULT TO THE LEAST-PRECISE INPUT — 1 m

For multiplication/division, the result keeps as many significant figures as the input with the FEWEST. For addition/subtraction, keep as many DECIMAL PLACES as the input with the fewest. Round using the standard rule (⩾5 rounds up; the 'round-to-even' convention is acceptable). State the final rounded value with its unit.

PYQ PATTERNS

Top PYQ patterns to drill

#1	If a quantity is measured as $Z = A^a B^b / C^c$, find the maximum percentage error in Z given the percentage errors in A, B, C. (2-3 marks)	Almost every paper (SQP + most school finals)
#2	Check the dimensional correctness of $v^2 = u^2 + 2as$ (or a similar kinematic / SHM relation). (2-3 marks)	Very common — SQP and school finals
#3	State the number of significant figures in given measurements, then round a result to the correct number of significant figures. (1-2 marks)	Common — almost every paper has one such part
#4	Derive / check a formula using dimensions, e.g. the time period of a simple pendulum $T = 2\pi\sqrt{l/g}$. (2-3 marks)	Frequent in school finals
#5	Distinguish accuracy from precision, or systematic from random error, with an example. (2 marks)	Frequent 2-markers

RECAP · MEMORISE THESE

5-line revision

1 Units — 7 SI base units; derived units and dimensional formulae are built from M, L, T by the defining equation. SI is coherent and decimal.

2 Errors — Sum/difference → ABSOLUTE errors add. Product/quotient/power → RELATIVE errors add, each ×|exponent|. Everything adds (worst case).

3 Sig figs & dimensions — Leading zeros never count; trailing zeros count only with a decimal point. Dimensional analysis checks, derives and converts — but cannot find constants, handle sin/exp/log, or build multi-term relations.

WHAT'S NEXT

What's next

→ Chapter 2 — Motion in a Straight Line (uses the $v^2 = u^2 + 2as$ you just dimensionally checked, and the error/sig-fig habits in every numerical).

→ Sit the 15-MCQ Quick Drill (companion PDF) — under 20 minutes, target $\geqslant$ 12/15.

→ Then the full school-pattern paper — 30 marks, 60 minutes.

You've learned the grammar of physics.

Now prove it. Take the drill, sit the paper, beat the chapter.

readyforboards.com

Helpline: +91 70330 05444

Boards prep that builds confidence, not anxiety.