JEE MAIN · PAPER 1 · PHYSICS

01 Units & Measurements

Formula & concept sheet

The language of every physics problem: units, dimensions, significant figures and errors. What each idea means, the tables to remember, how it is used and how questions are framed around it.

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READ ALONGSIDE NCERT XI · Units and Measurements

HOW TO USE THIS SHEET

1. **Skim** — Read the Key ideas, then the formula cards.
2. **Memorise** — Learn the formulas and check every Trap box.
3. **Test** — Do the worked examples, then this chapter's PYQs.
4. **Revise** — Use the last-minute checklist before the exam.

Formula memorise · **Key idea** why it works · **Trap** marks lost here · **PYQ** how it is asked

Practise this chapter with real past-paper questions on Prep Vault. Written for revision, not as a first read.

CHAPTER 01

Units & Measurements

NCERT XI · Units and Measurements

Covers: SI units · dimensions and dimensional analysis · significant figures · errors in measurement · least count.

1 SI units and conversion

A measurement is a number times a unit. The SI system has **seven base quantities**; every other unit (newton, joule, volt …) is a combination of them. The radian and steradian are supplementary units. Conversion questions give a value in CGS or atomic units and ask for SI: the dimension powers are the exponents.

BASE QUANTITIES

QUANTITY	SI UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

HANDY CONVERSIONS

UNIT	IN SI
1 Å	10^{-10} m
1 light year	9.46×10^{15} m
1 astronomical unit	1.5×10^{11} m
1 atomic mass unit	1.66×10^{-27} kg
1 eV	1.6×10^{-19} J
1 dyne · 1 erg	10^{-5} N · 10^{-7} J
1 atm	1.013×10^{5} Pa

PREFIXES

tera T 10^{12} · giga G 10^{9} · mega M 10^{6} · kilo k 10^{3}

centi c 10^{-2} · milli m 10^{-3} · micro μ 10^{-6}

nano n 10^{-9} · pico p 10^{-12} · femto f 10^{-15}

UNIT CONVERSION

$$n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$$

for a quantity of dimensions $[M^a L^b T^c]$; n is its numerical value in each system

2 Dimensions of common quantities

The **dimension** of a quantity shows how it is built from mass $[M]$, length $[L]$, time $[T]$, current $[A]$, temperature $[K]$ and amount $[\mathrm{mol}]$. Powers add when quantities multiply and subtract when they divide.

MECHANICS

QUANTITY	DIMENSIONS
Velocity, acceleration	$[LT^{-1}]$, $[LT^{-2}]$
Momentum, impulse	$[MLT^{-1}]$
Force, weight	$[MLT^{-2}]$
Work, energy, torque	$[ML^2T^{-2}]$
Power	$[ML^2T^{-3}]$
Pressure, stress, modulus	$[ML^{-1}T^{-2}]$
Angular momentum, h	$[ML^2T^{-1}]$
Surface tension, spring const.	$[MT^{-2}]$
Viscosity η	$[ML^{-1}T^{-1}]$
Gravitational constant G	$[M^{-1}L^3T^{-2}]$

ELECTRICITY, MAGNETISM, HEAT

QUANTITY	DIMENSIONS
Potential difference	$[ML^2T^{-3}A^{-1}]$
Resistance	$[ML^2T^{-3}A^{-2}]$
Capacitance	$[M^{-1}L^{-2}T^4A^2]$
Inductance	$[ML^2T^{-2}A^{-2}]$
Magnetic field B	$[MT^{-2}A^{-1}]$
Permittivity ε_0	$[M^{-1}L^{-3}T^4A^2]$
Permeability μ_0	$[MLT^{-2}A^{-2}]$
Specific heat	$[L^2T^{-2}K^{-1}]$
Latent heat	$[L^2T^{-2}]$

KEY IDEA

Do not memorise the table: rebuild each entry from its defining formula. Force $= ma$ gives $[MLT^{-2}]$; work $= F\,d$, pressure $= F/A$ and power $= W/t$ follow in one step each.

3 Dimensional analysis

Only quantities of the **same dimensions** can be added, subtracted or equated: the **principle of homogeneity**. Every correct physical equation obeys it, which makes dimensions a quick check and, in simple cases, a way to find the form of a relation.

USES

check an equation

derive a relation

convert units

checking is the most common use

LIMITATIONS

no numerical constants

no sin, exp, log forms

cannot add terms

also cannot tell a vector from a scalar

DIMENSIONLESS

angle, strain, relative density, refractive index, friction coefficient, Poisson ratio

the argument of sin, exp and log must be dimensionless

DERIVING A RELATION

$T = k\,\ell^a m^b g^c$

$[T] = [L]^a[M]^b[LT^{-2}]^c$

match the powers of M, L, T: $b = 0$, $c = -\frac{1}{2}$, $a = \frac{1}{2}$, so $T = k\sqrt{\ell/g}$. The constant k (here 2π) needs experiment

DIFFERENT QUANTITIES, SAME DIMENSIONS

DIMENSIONS	QUANTITIES
$[ML^2T^{-2}]$	work, energy, torque, heat
$[ML^{-1}T^{-2}]$	pressure, stress, modulus, energy density
$[T^{-1}]$	frequency, angular velocity, $1/RC$
$[T]$	RC, L/R, $\sqrt{LC}$, $\sqrt{\ell/g}$
$[LT^{-1}]$	speed, E/B, $1/\sqrt{\mu_0\varepsilon_0}$

HOW IT IS USED

Questions give an equation with unknown constants (for example $X = 5YZ^2$ with X and Z named) and ask the dimensions of one constant: write each dimension, then solve for the unknown. Or a different set of base units is chosen (say h, c, G) and a quantity is re-expressed in them.

4 Significant figures

Significant figures are the digits that carry information: the certain digits plus the first uncertain one. A result can never be more precise than the measurements it came from.

COUNTING RULES

CASE	EXAMPLE	SIG. FIGS
Non-zero digits	4.27	3
Zeros between digits	1.005	4
Leading zeros	0.0025	2
Trailing zeros after the decimal	2.500	4
Trailing zeros, no decimal	1.20×10^3	3 (use standard form)
Exact counts, defined factors	7 tiles, 100 cm in 1 m	unlimited

OPERATIONS

$\times$ and $\div$: keep the fewest sig. figs

$+$ and $-$: keep the fewest decimal places

round only at the end

ROUNDING

drop digit < 5: leave

drop digit > 5 (or 5 then non-zero): round up

exactly 5: make the kept digit even

for example $2.35 \to 2.4$, $2.45 \to 2.4$

TRAP

Exact numbers do not limit the answer: the area of 7 identical tiles is $7\times$ the area of one, kept to the sig. figs of the area. A trailing zero counts only if it follows a decimal point.

5 Errors in measurement

Every measurement is uncertain. The error is the amount by which a reading can differ from the true value. JEE Main combines errors as the **maximum possible error**, which means the individual errors add (never subtract, never in quadrature).

MEAN ABSOLUTE ERROR

$$\overline{\Delta a} = \frac{1}{n}\sum |a_i - \bar{a}|$$

$\bar{a}$ is the mean of the n readings

RELATIVE AND PERCENTAGE ERROR

$$\delta = \frac{\overline{\Delta a}}{\bar{a}}, \quad \% = \delta \times 100$$

a result is written $\bar{a} \pm \overline{\Delta a}$

SUM AND DIFFERENCE

$$Z = A \pm B$$

$$\Delta Z = \Delta A + \Delta B$$

absolute errors add even for a difference

PRODUCT, QUOTIENT AND POWERS

$$Z = \frac{A^p B^q}{C^r} \Rightarrow \frac{\Delta Z}{Z} = p\frac{\Delta A}{A} + q\frac{\Delta B}{B} + r\frac{\Delta C}{C}$$

powers multiply the fractional error: a cube of side a gives $\frac{\Delta V}{V} = 3\frac{\Delta a}{a}$

LEAST COUNT

vernier: $\frac{1\ \text{MSD}}{N}$ (1 MSD − 1 VSD)

screw gauge: $\frac{\text{pitch}}{\text{circular divisions}}$

the smallest reading an instrument gives, and the error of a single reading

HOW IT IS USED AND ASKED

Typical question: a derived quantity such as $g = 4\pi^2\ell/T^2$ or density m/a^3 is built from measured values with their errors, and the percentage error is asked. List the powers, then add the weighted fractional errors. Other questions ask the least count or round a result to the right number of significant figures.

6 Worked examples

DIMENSIONS OF A CONSTANT

$P = \frac{a - t^2}{b\,x}$, with P pressure, x distance, t time. Find the dimensions of a/b.

$[a] = [T^2]$; $[b] = \frac{[T^2]}{[P][L]} = [M^{-1}T^4]$; so $\left[\frac{a}{b}\right] = [MT^{-2}]$

UNITS TO CGS

$G = 6.67 \times 10^{-11}\ \text{m}^3\,\text{kg}^{-1}\,\text{s}^{-2}$. Express it in cm, g, s.

$G = 6.67 \times 10^{-11} \times 10^{6} \times 10^{-3} = 6.67 \times 10^{-8}$ (cm³ g⁻¹ s⁻²)

ERROR IN DENSITY

A cube: side 10.0 ± 0.1 cm, mass 100 ± 1 g. Percentage error in density?

$$\frac{\Delta\rho}{\rho} = \frac{1}{100} + 3 \cdot \frac{0.1}{10} = 1\% + 3\% = 4\%$$

ERROR IN FREE-FALL ACCELERATION

$g = 4\pi^2\ell/T^2$ with ℓ known to 1% and T to 2%. Percentage error in g?

$$\frac{\Delta g}{g} = 1\% + 2 \times 2\% = 5\%$$

7 Last-minute checklist

- Write every dimension out before you compare; an equation is checked term by term.
- $\sin$, $\cos$, $\log$ and powers of e need a dimensionless argument.
- Errors add for $A + B$ and for $A - B$; for A^pB^q the fractional errors are weighted by the powers.
- Multiplication keeps the fewest sig. figs; addition keeps the fewest decimal places.
- For a cube, volume error is three times the edge error, in per cent.

Now test it. Practise this chapter with past-paper and bank questions on Prep Vault. **Practice this chapter →**