PC01 — Units, Dimensions & Measurements

📖 PC01 · CDS General Science — Physics

🎯 CDS Level : High Priority

Every Physics problem begins here. Units tell us *how much*; dimensions tell us *what kind*. CDS consistently places 1–2 questions from this chapter — they are direct, factual, and completely scoring once you know the key dimensional formulae and conversion rules.

> 📌 **CDS pattern in this chapter:**
> (1) Identify the dimensional formula of a given quantity (Force, Energy, Pressure, etc.);
> (2) Which pair of quantities shares the same dimensional formula;
> (3) Check whether a given equation is dimensionally correct;
> (4) SI unit of a derived quantity;
> (5) Least count of Vernier caliper / Screw gauge.

Topics at a Glance

① SI Units
7 base quantities; derived units

② Dimensional Analysis
Formulae; checking equations; conversion

③ Significant Figures
Rules for counting; rounding off

④ Errors in Measurement
Absolute, relative, percentage error

⑤ Vernier Caliper
Least count; zero error; reading

⑥ Screw Gauge
Pitch; least count; reading

1. International System of Units (SI)

1.1 7 Fundamental Quantities & Their SI Units

All physical measurements trace back to these seven base quantities

#	Fundamental Quantity	SI Unit	Symbol
1	**Length**	Metre	m
2	**Mass**	Kilogram	kg
3	**Time**	Second	s
4	**Electric Current**	Ampere	A
5	**Temperature**	Kelvin	K
6	**Amount of Substance**	Mole	mol
7	**Luminous Intensity**	Candela	cd

💡 **Mnemonic for 7 base quantities:** *My Kind Sister Taught A Little Child* — Mass, K (temperature), Substance (amount), Time, Ampere, Length, Candela.

IMPORTANT DERIVED UNITS (MOST CDS-TESTED)

Force: Newton (N) = $kg\ m\ s^{-2}$

Energy / Work: Joule (J) = $kg\ m^2\ s^{-2}$ = $N \cdot m$

Power: Watt (W) = J/s = $kg\ m^2\ s^{-3}$

Pressure: Pascal (Pa) = N/m^2 = $kg\ m^{-1}\ s^{-2}$

Frequency: Hertz (Hz) = s^{-1}

Electric Charge: Coulomb (C) = $A \cdot s$

Voltage: Volt (V) = J/C = $kg\ m^2\ s^{-3}\ A^{-1}$

Resistance: Ohm (Ω) = V/A = $kg\ m^2\ s^{-3}\ A^{-2}$

Magnetic Field: Tesla (T) = $kg\ s^{-2}\ A^{-1}$

Joule and Newton-metre have the same unit but different physical meanings (energy vs torque). This is a repeated CDS trap.

2. Dimensional Analysis

2.1 Dimensional Formulae & Their Applications

Express every quantity in terms of M (mass), L (length), T (time) — and A (current) when needed

MASTER TABLE OF DIMENSIONAL FORMULAE

Velocity:	$[LT^{-1}]$	**Acceleration:**	$[LT^{-2}]$
Force:	$[MLT^{-2}]$	**Momentum:**	$[MLT^{-1}]$
Work / Energy:	$[ML^2T^{-2}]$	**Power:**	$[ML^2T^{-3}]$
Pressure:	$[ML^{-1}T^{-2}]$	**Torque:**	$[ML^2T^{-2}]$
Angular momentum:	$[ML^2T^{-1}]$	**Planck's const (h):**	$[ML^2T^{-1}]$
Surface tension:	$[MT^{-2}]$	**Viscosity:**	$[ML^{-1}T^{-1}]$
Gravitational G:	$[M^{-1}L^3T^{-2}]$	**Density:**	$[ML^{-3}]$
Frequency:	$[T^{-1}]$	**Latent heat:**	$[L^2T^{-2}]$
Strain:	dimensionless	**Refractive index:**	dimensionless
Specific heat (c):	$[L^2T^{-2}K^{-1}]$		

Same-dimension pairs (key CDS question):

Work and Torque → both $[ML^2T^{-2}]$ (same dimension, different meaning)

Angular momentum and Planck's constant h → both $[ML^2T^{-1}]$

Impulse and Momentum → both $[MLT^{-1}]$

Three Uses of Dimensional Analysis

① Check Equations

Both sides must match.
Example: $v = u + at$
LHS: $[LT^{-1}]$
RHS: $[LT^{-1}] + [LT^{-2}][T]$
$= [LT^{-1}]$ ✓ Correct

② Convert Units

Use dimension to convert between systems (CGS↔SI).
1 N = 10^5 dyne
1 J = 10^7 erg
Systematic conversion

③ Derive Relations

Find how quantities relate by matching dims.
Cannot find:
dimensionless constants
(½, 2π, etc.)

Fig. 1 — Three applications of dimensional analysis. The critical limitation: it cannot determine pure numbers like ½ or 2π that appear in physical equations.

WORKED EXAMPLE — DIMENSIONAL CHECK

Q: Is the equation $s = ut + \frac{1}{2}at^2$ dimensionally correct?

LHS: $[s] = L$

RHS: $[ut] = LT^{-1} \times T = L$ | $[\frac{1}{2}at^2] = LT^{-2} \times T^2 = L$

All three terms = [L]. ✓ **Equation is dimensionally correct.** (Note: ½ is dimensionless — dimensional analysis cannot verify it, but it confirms the structure.)

3. Significant Figures & Rounding Off

3.1

Rules for Counting Significant Figures

Every measured value has a precision — significant figures express it

📌 Rules for Counting Sig. Figs

- All non-zero digits are significant: 1245 → 4 sig figs
- Zeros between non-zero digits are significant: 1005 → 4 sig figs
- Leading zeros are NOT significant: 0.0045 → 2 sig figs
- Trailing zeros after decimal point ARE significant: 2.500 → 4 sig figs
- Trailing zeros without decimal point — ambiguous: 1200 could be 2, 3, or 4

📌 Rounding Off Rules

- If digit to be dropped < 5: round down (leave preceding digit unchanged)
- If digit to be dropped > 5: round up
- If digit = 5 and followed by non-zero: round up
- If digit = exactly 5 with nothing after: round to even (banker's rounding)
- In addition/subtraction: result has fewest decimal places
- In multiplication/division: result has fewest significant figures

4. Errors in Measurement

4.1

Types of Error & Their Expression

⚡ ERROR FORMULAE

Absolute error: $\Delta a = |a\_measured - a\_true|$

Mean absolute error: $\Delta a\_mean = (\Delta a_1 + \Delta a_2 + \ldots + \Delta a_n) / n$

Relative error: $\Delta a / a\_mean$ (dimensionless)

Percentage error: $(\Delta a / a\_mean) \times 100\%$

Error in sum/difference: $\Delta Z = \Delta A + \Delta B$

Error in product/quotient: $\Delta Z/Z = \Delta A/A + \Delta B/B$

Error in power: $\Delta Z/Z = n \times (\Delta A/A)$ (for $Z = A^n$)

Systematic errors: consistent bias in one direction (faulty instrument, wrong technique). Random errors: unpredictable, vary in magnitude and direction — reduced by taking multiple readings.

5. Measuring Instruments — Vernier Caliper & Screw Gauge

5.1 Precision Measuring Tools

Vernier caliper reads to 0.1 mm; screw gauge reads to 0.01 mm

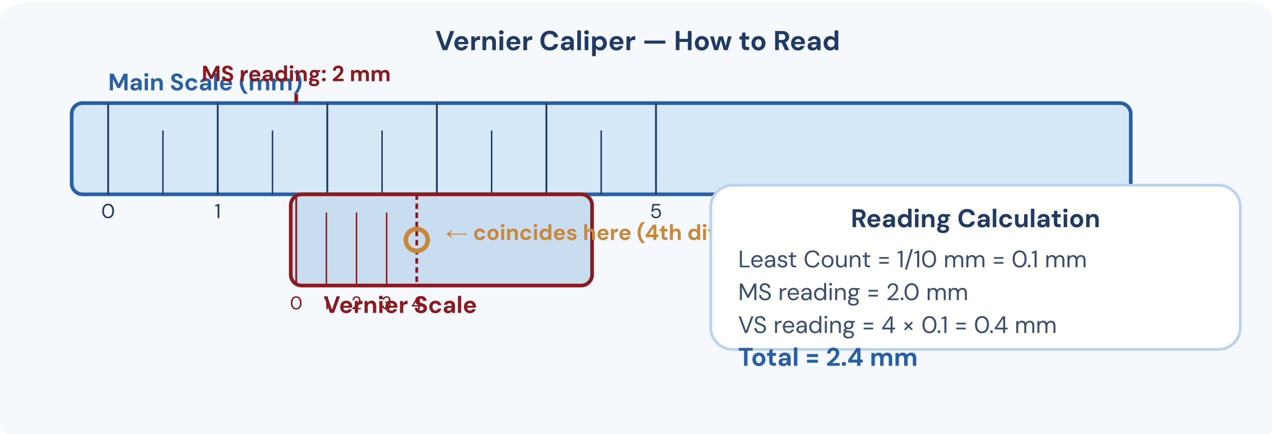

Fig. 2 — Vernier caliper reading. The main scale gives the whole mm reading (2 mm). The Vernier scale division that coincides with a main scale line (4th here) gives the fractional part (0.4 mm). Total = 2.4 mm.

VERNIER CALIPER & SCREW GAUGE — KEY FORMULAE

Vernier Caliper:

Least Count (LC) = 1 MSD - 1 VSD

Standard Vernier: 1 MSD = 1 mm; 10 VSD = 9 MSD → LC = 0.1 mm

Reading = Main Scale Reading + (Vernier Division coinciding × LC)

Zero error: if Vernier zero is ahead of main zero → +ve error (subtract from reading)

Screw Gauge (Micrometer):

Pitch = distance moved per complete rotation of thimble (usually 0.5 mm or 1 mm)

Least Count = Pitch / Number of circular scale divisions

Standard screw gauge: Pitch = 0.5 mm; 50 circular divisions → LC = 0.01 mm

Reading = PSR + (CSR × LC) (PSR = Pitch Scale Reading; CSR = Circular Scale Reading)

Screw gauge has smaller least count (0.01 mm) than Vernier caliper (0.1 mm) — it is more precise. Used to measure thickness of a wire, diameter of a sphere, etc.

CDS PYQ **Units, Dimensions & Measurements**

Q1. The dimensional formula of pressure is:

(a) MLT^{-2}

(b) $ML^{-1}T^{-2}$

(c) $ML^{2}T^{-2}$

(d) $ML^{-2}T^{-2}$

Answer: (b) $ML^{-1}T^{-2}$
Pressure = Force / Area = $[MLT^{-2}] / [L^{2}] = [ML^{-1}T^{-2}]$. SI unit = Pascal (Pa). This is the most directly repeated dimensional formula question in CDS. Pressure has the same dimension as energy density (energy per unit volume) — also $ML^{-1}T^{-2}$.

Q2. Which of the following pairs has the same dimensional formula?

(a) Force and Impulse

(b) Work and Torque

(c) Power and Pressure

(d) Momentum and Force

Answer: (b) Work and Torque — both $[ML^2T^{-2}]$

Work = Force × distance; Torque = Force × arm — both are force times length, giving $[ML^2T^{-2}]$. They have identical dimensions but completely different physical meanings. This distinction is a classic CDS and general science trap. Other option analysis: Impulse = $[MLT^{-1}]$ ≠ Force $[MLT^{-2}]$; Power = $[ML^2T^{-3}]$ ≠ Pressure $[ML^{-1}T^{-2}]$.

Q3. The least count of a screw gauge with pitch 0.5 mm and 50 circular scale divisions is:

(a) 0.5 mm

(b) 0.1 mm

(c) 0.01 mm

(d) 0.001 mm

Answer: (c) 0.01 mm

Least Count = Pitch / Number of circular divisions = 0.5 mm / 50 = **0.01 mm**. This is why a screw gauge is more precise than a Vernier caliper (LC = 0.1 mm). This formula is directly tested — know it cold.

Q4. The unit of Planck's constant h has the same dimension as:

(a) Momentum

(b) Energy

(c) Angular Momentum

(d) Force

Answer: (c) Angular Momentum — both $[ML^2T^{-1}]$

From $E = hf$: $h = E/f = [ML^2T^{-2}] / [T^{-1}] = [ML^2T^{-1}]$. Angular momentum $L = I\omega = [ML^2][T^{-1}] = [ML^2T^{-1}]$. Both have the same dimension. This is a high-value CDS question — the connection between Planck's constant and angular momentum is conceptually deep and frequently tested.

📚 Formula Sheet — PC01

📍 Key Dimensional Formulae

- Force: $[MLT^{-2}]$
- Energy/Work/Torque: $[ML^2T^{-2}]$
- Power: $[ML^2T^{-3}]$
- Momentum/Impulse: $[MLT^{-1}]$
- Pressure: $[ML^{-1}T^{-2}]$

📍 More Key Formulae

- Angular momentum = h (Planck's): $[ML^2T^{-1}]$
- Surface tension: $[MT^{-2}]$
- Viscosity: $[ML^{-1}T^{-1}]$
- G (gravitational): $[M^{-1}L^3T^{-2}]$
- Strain, angle, RIndex: dimensionless

⚥ Measuring Instruments

- Vernier LC = 1 MSD – 1 VSD = 0.1 mm
- Screw gauge LC = Pitch / n = 0.01 mm
- Reading = MS + VS × LC
- +ve zero error → subtract from reading
- -ve zero error → add to reading

📚 SI Derived Units

- 1 N = kg m s^{-2}
- 1 J = N·m = kg m^2 s^{-2}
- 1 W = J/s
- 1 Pa = N/m^2
- 1 Hz = s^{-1}

⚡ Quick Revision — PC01

📍 7 Base SI Units

- m (metre), kg (kilogram), s (second)
- A (ampere), K (kelvin)
- mol (mole), cd (candela)
- Mnemonic: My Kind Sister Taught A Little

📍 Same-Dim Pairs

- Work = Torque: $[ML^2T^{-2}]$
- Ang. momentum = Planck's h: $[ML^2T^{-1}]$
- Impulse = Momentum: $[MLT^{-1}]$

🚨 CDS Traps

- Leading zeros NOT significant (0.005 → 1 sig fig)
- Dimensional analysis cannot find constants (½, π)
- Angle and strain are dimensionless

Child

- Pressure = Energy density: $[ML^{-1}T^{-2}]$

- Screw gauge more precise than Vernier

📝 Practice Exercise

E-01

The dimension of gravitational constant G is:

(a) $M^{-1}L^3T^{-2}$ (b) MLT^{-2}

(c) ML^2T^{-2} (d) $ML^{-1}T^{-2}$

E-02

A Vernier caliper has 10 Vernier divisions equal to 9 main scale divisions of 1 mm each. Its least count is:

(a) 0.01 mm (b) 0.1 mm

(c) 1 mm (d) 0.001 mm

E-03

Which of the following is dimensionless?

(a) Strain (b) Stress

(c) Young's modulus (d) Pressure

E-04

The number of significant figures in 0.00500 is:

(a) 6 (b) 5

(c) 3 (d) 1

Answers: E-01: (a) $M^{-1}L^3T^{-2}$ [from $F = GMm/r^2$; $G = Fr^2/Mm = MLT^{-2} \cdot L^2/(M \cdot M) = M^{-1}L^3T^{-2}$] | E-02: (b) 0.1 mm [LC = 1 MSD − 1 VSD = 1 − 9/10 = 0.1 mm] | E-03: (a) Strain [= change in length

/ original length = L/L = dimensionless; Stress, Young's modulus, and Pressure all have dimensions] | E-04: (c) 3 [Leading zeros not significant; 5, 0, 0 after decimal → 3 sig figs]

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