Unit 1 · Physical Quantities

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Mechanics (Units 1–8 together): 26 of 75 marks
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** an MCQ from this unit: a 20 cm length recorded to the nearest millimeter (significant figures)
- **MCQ (1 mark)**
  - dimensionally incorrect or physically correct equation
  - same dimensions, different units
  - which quantity is dimensionless (strain)
  - dimensions of b in $v = b/t + ct^2$
  - momentum in [F], [L], [T]
  - light year: [L]
  - perimeter with uncertainty
  - fewest significant figures; 0.0050×10^{-12} has 2
  - accurate and precise from a spread of data
- **Short (5 marks, in parts)**
  - define dimensional formula; energy in [F L T]
  - find a power (flow in a pipe, air drag) or relation (string's frequency)
  - dimensions of constants in $a + bt + ct^2$, $c/(d + t)$
  - precision vs accuracy; most accurate of 2, 2.00, 2.000, 2.0000 cm
  - 10 J in a system of 10 cm, 100 g, 30 s; area with uncertainty; 72 km/h, 20 g/cm^3

Key terms

Physical quantity: anything that can be measured; quantity $= nu$ (number × unit).

Fundamental quantities: seven, defined on their own: mass, length, time, temperature, electric current, luminous intensity, amount of substance.

Derived quantities: made from the fundamental ones by multiplying or dividing (area, velocity, force).

Supplementary: plane angle (radian = arc ÷ radius) and solid angle (steradian); since 1995 counted as dimensionless derived units.

Measurement: comparing an unknown quantity with an agreed reference amount of the same kind, the **unit**.

Accuracy: closeness of a measurement to the **true value**.

Precision: closeness of repeated measurements to **one another**.

Significant figures: the certain digits plus the first uncertain one.

Dimensions: the powers to which the fundamental quantities are raised to represent a quantity.

Dimensional formula: $[M^aL^bT^c]$; **dimensional equation**: $[X] = [M^aL^bT^c]$.

Principle of homogeneity: in a correct equation every term on both sides has the same dimensions.

Formulas

$n_1u_1 = n_2u_2$	n number, u unit **Use:** changing units
$n_2 = n_1\left(\frac{M_1}{M_2}\right)^a\left(\frac{L_1}{L_2}\right)^b\left(\frac{T_1}{T_2}\right)^c$	$[M^aL^bT^c]$ the quantity's dimensions **Use:** converting between systems
$Z = A \pm B$: $\Delta Z = \Delta A + \Delta B$	absolute uncertainties add **Use:** sum, difference
$Z = AB$ or A/B: $\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$	relative uncertainties add **Use:** product, quotient
$Z = A^n$: $\frac{\Delta Z}{Z} = n\frac{\Delta A}{A}$	a power **Use:** powers

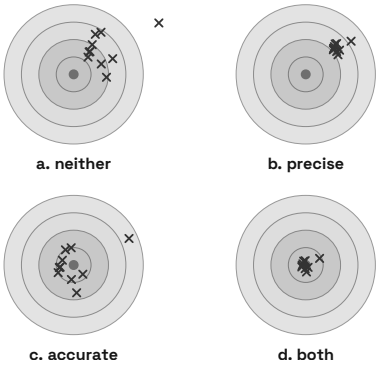
Units

System	Length	Mass	Time
CGS	cm	g	s
MKS	m	kg	s
FPS	foot	pound	s
SI (1960)	m	kg	s, + K, A, cd, mol

- SI base units: m, kg, s, K, A, cd, mol; since **2019** each fixed by a constant of nature
  - second: 9 192 631 770 vibrations of cesium-133's radiation
  - meter: light's path in vacuum in 1/299 792 458 s
  - kilogram: Planck's constant fixed (Kibble balance); before, a platinum–iridium cylinder (1889–2019)
  - kelvin, ampere, mole, candela: Boltzmann constant, electron's charge, Avogadro constant, a green light's brightness

- a good unit: well defined, same everywhere, unchanging, easily copied
- writing units: name in small letters (newton), symbol of a person's unit a capital (N, Pa); symbols never plural (5 kg), no full stop; one slash: kg/(m s^2)
- mN millinewton, nm nanometer, N m newton meter
- prefixes: G 10^9, M 10^6, k 10^3, c 10^{-2}, m 10^{-3}, μ 10^{-6}, n 10^{-9}, p 10^{-12}

Accuracy, precision, significant figures



Darts on a target: accurate and precise, precise not accurate, accurate not precise, neither.

- 9.8, 10.2, 10.4 kg: accurate (average $\approx$ 10), not precise; 12.5, 12.6, 12.4 kg: precise, not accurate (scale off)
- a constant instrument fault spoils **accuracy**, not precision
- more significant figures = more **precise** (ruler 3.5 cm, mm scale 3.56 cm, vernier 3.567 cm)
- a length of 20 cm to the nearest mm is written **20.0 cm**

Counting significant figures

1. non-zero digits count (21.48: 4)
2. zeros **between** count (15.0041: 6)
3. **leading** zeros don't (0.00025: 2)
4. **trailing zeros after a decimal point** do (5.00: 3; 0.200: 3)
5. trailing zeros in a whole number without a point: not (9800: 2)
6. scientific notation: only the digits of N (6.62×10^{-34}: 3)

Rounding off (first digit dropped)

- below 5: keep (123.42 $\rightarrow$ 123.4); above 5, or 5 then non-zero: up (2.4851 $\rightarrow$ 2.49)
- exactly 5: up if odd, stay if even (12.35 $\rightarrow$ 12.4, 12.45 $\rightarrow$ 12.4)

In calculations

- add, subtract: fewest **decimal places** (3.240 + 7.14 = 10.38)
- multiply, divide: fewest **significant figures** ($118.6 \times 16.2 = 1.92 \times 10^3$)
- subtracting still **adds** uncertainties

Dimensions

Quantity	Dimensions	Quantity	Dimensions
velocity	$[LT^{-1}]$	pressure, stress, modulus	$[ML^{-1}T^{-2}]$
acceleration, g	$[LT^{-2}]$	angular velocity, frequency	$[T^{-1}]$
force, weight	$[MLT^{-2}]$	G	$[M^{-1}L^3T^{-2}]$
momentum, impulse	$[MLT^{-1}]$	surface tension	$[MT^{-2}]$
work, energy, torque	$[ML^2T^{-2}]$	viscosity η	$[ML^{-1}T^{-1}]$
power	$[ML^2T^{-3}]$	specific heat	$[L^2T^{-2}K^{-1}]$
gravitational potential, latent heat	$[L^2T^{-2}]$	R	$[ML^2T^{-2}K^{-1}mol^{-1}]$
strain, angle, relative density	$[M^0L^0T^0]$	charge	$[AT]$

- variables and constants, with or without dimensions: velocity / strain; G, h, c / π, ½
- same formula, different quantities: work and torque; pressure, stress, modulus

Uses

1. **check** an equation: $s = ut + \frac{1}{2}at^2 \rightarrow [L] = [L] + [L]$ ✓; $s = ut^2 + \frac{1}{2}at^2$ ✗
2. **derive** a relation: pendulum $T = km^a l^b g^c \rightarrow [T] = [M^a L^{b+c} T^{-2c}] \rightarrow a = 0, c = -\frac{1}{2}, b = \frac{1}{2} \rightarrow T = k\sqrt{l/g}$ ($k = 2\pi$ by experiment)
3. **convert** units: 1 N = (1000)(100) dyne = 10^5 dyne
4. find an **unknown's** dimensions: $v = A + Bt + Ct^2 \rightarrow [LT^{-1}], [LT^{-2}], [LT^{-3}]$

- dimensionally wrong $\rightarrow$ certainly wrong; dimensionally right $\rightarrow$ may still be wrong (a number or a term)
- string: $f = \frac{k}{L}\sqrt{T/\mu}$ ($k = \frac{1}{2}$)

Limitations

- no value for pure numbers (2π, ½)
- no sin, e, log relations
- can't tell scalar from vector, or which of two quantities with one formula
- not for more than three quantities in mechanics, or a sum of terms

COMMON MISTAKES

✗	more significant figures = more accurate
✓	more **precise**.
✗	leading zeros count
✓	never; trailing zeros **after the point** do.
✗	20 cm to the nearest mm written 20 cm
✓	**20.0 cm**.
✗	subtracting subtracts uncertainties
✓	absolute uncertainties always **add**.
✗	dimensionally correct, so correct
✓	may miss a pure number ($s = ut + at^2$).
✗	product's uncertainty: add absolute ones
✓	add **relative** ones.