FREE NOTES · NCERT + JEE/NEET LEVEL

Units & Measurement

Physics ki pehli seedhi: cheezon ko naapna kaise hai, unit kya hoti hai, significant figures, dimensions aur errors. Simple Hinglish me, examples aur solved numericals ke saath.

01 Physical quantity & unit
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01 Physical quantity & unit

Jo cheez **naapi ja sake** aur jise number me likha ja sake, use **physical quantity** kehte hain: length, mass, time, speed, force. "Sundarta" ya "gussa" physical quantity nahi hain, kyunki unhe kisi standard se naap nahi sakte.

Kisi quantity ko naapne ke liye ek **standard reference** chahiye. Isi standard ko **unit** kehte hain.

HAR NAAP KE DO HISSE

$$\text{Physical quantity} = \text{n} \times \text{u}$$

n = numerical value, u = unit. Jaise 5 m me n = 5, u = metre. Unit badi karo toh number chhota ho jaata hai: $n_1u_1 = n_2u_2$ (5 m = 500 cm).

Type	Matlab	Example
Fundamental (base) quantity	Jo kisi aur quantity pe depend nahi karti	Length, mass, time
Derived quantity	Base quantities ko jod/guna karke banti hai	Speed = length/time, force = mass × acceleration

02 SI system: 7 base units

Poori duniya me ek jaise units use ho, isliye 1971 se **SI (Système Internationale)** system chalta hai. Isme 7 base units hain:

Base quantity	SI unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

YAAD KARNE KI TRICK

Order yaad rakho: **L M T I K N J** (Length, Mass, Time, current I, Kelvin, mole N, candela J). Dimensions me bhi yahi letters aate hain.

Supplementary units: plane angle ka radian (rad) aur solid angle ka steradian (sr). Ye dimensionless hain.

PLANE ANGLE

$$d\theta = ds / r$$

Arc length ÷ radius. Poora circle = 2π rad.

SOLID ANGLE

$$d\Omega = dA / r^2$$

Sphere ka area ÷ radius². Poora sphere = 4π sr.

UNIT LIKHNE KE RULES

- Person ke naam wali unit ka naam chhote akshar me, symbol bade me: newton (N), kelvin (K).
- Symbol ka plural nahi hota: 10 kg, "10 kgs" galat.
- Symbol ke baad full stop nahi lagta (beech sentence me).

03 Bade aur chhote naap

Bahut badi doori (taaron tak) ya bahut chhoti (atom) ke liye special units aur tareeke hain.

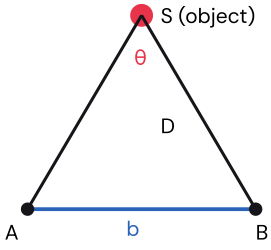
Unit	Value	Kahan use
Fermi (fm)	10^{-15} m	Nucleus ka size
Angstrom (Å)	10^{-10} m	Atom ka size, wavelength
Astronomical unit (AU)	1.496×10^{11} m	Earth–Sun ki average doori
Light year (ly)	9.46×10^{15} m	Light ek saal me jitna chalti hai
Parsec (pc)	3.08×10^{16} m ≈ 3.26 ly	Sabse badi doori ki unit

Parallax method (door ke taare, pahaad)

Do jagah (A aur B) se ek hi object dekho. Dono jagah ke beech ki doori **b (basis)** aur object pe banne wala angle **θ (parallax angle)** naap lo.

$$D = b / \theta$$

θ radian me hona chahiye. Degree ko radian: × π/180.



Basis b chhota, doori D badi ⇒ θ bahut chhota

Mass: chhote particles ke liye **unified atomic mass unit**: 1 u = 1/12 × (carbon-12 atom ka mass) = 1.66×10^{-27} kg.

04 Significant figures

Naap me jitne digits **pakke (reliable)** hain, plus pehla **andaaze wala (uncertain)** digit, wo sab significant figures hain. Jitne zyada significant figures, utna precise naap.

Rule	Example	Sig. figs
Saare non-zero digits significant	2.345	4
Do non-zero ke beech wale zero significant	2005	4
Decimal ke baad, pehle non-zero se pehle wale zero significant NAHI	0.0042	2
Decimal ke baad aakhri (trailing) zero significant	4.200	4
Bina decimal ke trailing zero significant nahi (agar measured nahi)	4200	2
Scientific notation me sirf a ke digits ginte hain ($a \times 10^b$)	4.20×10^3	3

UNIT BADALNE SE SIG. FIGS NAHI BADALTE

2.30 m = 230 cm = 2.30×10^2 cm = 0.00230 km. Har jagah **3** significant figures. Isliye confusion se bachne ke liye scientific notation use karo.

Calculation me sig. figs

GUNA / BHAAG (× ÷)

Answer me utne hi **significant figures** jitne sabse kam sig. fig wale number me.

$4.237 \times 2.5 = 10.5925 \rightarrow \mathbf{11}$ (2 sig. figs)

JOD / GHATAV (+ −)

Answer me utne hi **decimal places** jitne sabse kam decimal wale number me.

$436.32 + 227.2 + 0.301 = 663.821 \rightarrow \mathbf{663.8}$

05 Rounding off

- Hataaya jaane wala digit **5 se kam**: pichla digit same. 2.743 → 2.74
- **5 se zyada**: pichla digit +1. 2.746 → 2.75
- **Bilkul 5** (aage kuch nahi): pichla digit **even** ho toh same, **odd** ho toh +1. 2.745 → 2.74, 2.735 → 2.74

EXACT NUMBERS

Formula ke pure numbers (jaise r = d/2 me 2, ya 2πr me 2) ke infinite significant figures maane jaate hain. Unse answer ke sig. figs kam nahi hote.

06 Dimensions

Kisi derived quantity ko base quantities ki **powers** me likhna, uska **dimensional formula** hai. Mechanics me teen brackets kaafi hain: [M], [L], [T].

EXAMPLE: FORCE

$$F = m\,a = kg \times m/s^2 \Rightarrow [M^1\,L^1\,T^{-2}]$$

Quantity	Formula	Dimensions	SI unit
Velocity	d/t	$[M^0\,L\,T^{-1}]$	m/s
Acceleration	v/t	$[M^0\,L\,T^{-2}]$	m/s²
Force	ma	$[M\,L\,T^{-2}]$	N
Work, energy	F × d	$[M\,L^2\,T^{-2}]$	J
Power	W/t	$[M\,L^2\,T^{-3}]$	W
Momentum, impulse	mv, FΔt	$[M\,L\,T^{-1}]$	kg·m/s
Pressure, stress	F/A	$[M\,L^{-1}\,T^{-2}]$	Pa
Density	m/V	$[M\,L^{-3}]$	kg/m³
Gravitational constant G	$F\,r^2/(m_1m_2)$	$[M^{-1}\,L^3\,T^{-2}]$	N·m²/kg²
Planck's constant h	E/v	$[M\,L^2\,T^{-1}]$	J·s
Strain, angle, refractive index	ratio	dimensionless	no unit

Electric, magnetic aur heat wali quantities (JEE/NEET me bahut poochte hain)

Quantity	Dimensions	Quantity	Dimensions
Charge q = It	$[AT]$	Potential V = W/q	$[ML^2T^{-3}A^{-1}]$
Resistance R = V/I	$[ML^2T^{-3}A^{-2}]$	Capacitance C = q/V	$[M^{-1}L^{-2}T^4A^2]$
Electric field E = F/q	$[MLT^{-3}A^{-1}]$	Magnetic field B = F/(IL)	$[MT^{-2}A^{-1}]$
Inductance L	$[ML^2T^{-2}A^{-2}]$	Magnetic flux Φ = BA	$[ML^2T^{-2}A^{-1}]$
Permittivity ε_0	$[M^{-1}L^{-3}T^4A^2]$	Permeability μ_0	$[MLT^{-2}A^{-2}]$
Specific heat c = Q/(mΔT)	$[L^2T^{-2}K^{-1}]$	Latent heat L = Q/m	$[L^2T^{-2}]$
Boltzmann constant k	$[ML^2T^{-2}K^{-1}]$	Viscosity η	$[ML^{-1}T^{-1}]$
Surface tension, spring constant	$[MT^{-2}]$	Angular velocity, frequency	$[T^{-1}]$

YE RATIOS TIME [T] KE BARABAR HAIN

L/R, RC, $\sqrt{(LC)}$: teeno ki unit second hai. Aur $1/\sqrt{(\mu_0\varepsilon_0)}$ = speed of light, toh dimensions $[LT^{-1}]$.

Unit aur dimension ka rishta

Statement	Sahi / galat
Jiski unit nahi, uski dimension bhi nahi	**Sahi**
Jo dimensionless hai, uski unit nahi hogi	**Galat**: angle dimensionless hai par unit radian hai
Same dimensions wali do quantities same hi hongi	**Galat**: work aur torque dono $[ML^2T^{-2}]$ par alag cheezein hain
Alag dimensions wali do quantities same ho sakti hain	**Galat**

Category	Example
Dimensionless constant	π, e, pure numbers
Dimensional constant	G, h, c, ε_0
Dimensionless variable	Angle, strain, refractive index, μ (friction)
Dimensional variable	Velocity, force, length

SHORTCUT

Same dimensions wali quantities: work = energy = torque $[ML^2T^{-2}]$; pressure = stress = energy density $[ML^{-1}T^{-2}]$; momentum = impulse $[MLT^{-1}]$; Planck constant = angular momentum $[ML^2T^{-1}]$.

07 Dimensional analysis ke 3 use

(1) Equation sahi hai ya nahi check karna

Principle of homogeneity: equation ke har term ke dimensions same hone chahiye. Jaise $s = ut + \frac{1}{2}at^2$: s → [L], ut → $[LT^{-1}][T] = [L]$, at^2 → $[LT^{-2}][T^2] = [L]$. Teeno same, equation dimensionally sahi.

DHYAN DO

Dimensionally sahi equation zaroori nahi ki bilkul sahi ho. ½ jaise number dimensions se pata nahi chalte. Par dimensionally galat equation pakka galat hai.

(2) Ek unit system se doosre me badalna

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

Example: 1 J ko erg me (CGS). $[ML^2T^{-2}]$: $n_2 = 1 \times (1000\ g/1\ g)^1 \times (100\ cm/1\ cm)^2 = 10^3 \times 10^4 = \mathbf{10^7\ erg}$.

(3) Formula banana (relation nikalna)

Example: simple pendulum ka time period T, length l, mass m aur g pe depend kar sakta hai. Maano $T = k\, m^a\, l^b\, g^c$.

$[T^1] = [M]^a\,[L]^b\,[LT^{-2}]^c \Rightarrow M: a = 0;\ L: b + c = 0;\ T: -2c = 1 \Rightarrow c = -\frac{1}{2},\ b = \frac{1}{2}$

$$T = k\,\sqrt{(l\,/\,g)}$$

Experiment se k = 2π. Mass pe depend nahi karta!

LIMITATIONS

- Constant k (jaise 2π) ki value nahi milti.
- sin, log, e^x wale formula nahi ban sakte.
- 3 se zyada quantities pe depend karne wala formula (sirf M, L, T se) nahi nikal sakte.
- Formula me + ya - hai toh nahi nikal sakte.

08 Errors in measurement (JEE/NEET)

Har naap me thodi galti hoti hai. **Accuracy** = asli value ke kitna paas; **precision** = kitna baarik naapa (least count) aur baar-baar naapne pe kitna same aaya.

EXAMPLE: ACCURACY VS PRECISION

Asli length 3.678 cm. Ek student ne 3.5 cm naapa (precision 0.1 cm), doosre ne 3.38 cm (precision 0.01 cm). Pehla zyada **accurate** hai (asli ke paas), doosra zyada **precise** hai (baarik naap) par kam accurate.

Error ka type	Kyun aata hai	Kaise kam karein
Systematic	Instrument me kharabi (zero error), galat tareeka, personal aadat	Instrument theek karo, sahi method
Random	Achanak badlav (temperature, voltage)	Bahut baar naap ke average lo
Least count error	Instrument ki sabse chhoti reading ki limit	Zyada precise instrument

FORMULAS

Mean value: $a_{mean} = (a_1 + a_2 + \ldots + a_n)/n$

Absolute error: $\Delta a_i = |a_{mean} - a_i|$, mean absolute error $\Delta a_{mean} = \Sigma|\Delta a_i|/n$

Relative error $= \Delta a_{mean}/a_{mean}$, percentage error $=$ relative error $\times 100\%$

Error kaise judte hain (combination)

Operation	Error
Z = A + B ya Z = A − B	$\Delta Z = \Delta A + \Delta B$ (absolute errors hamesha judte hain)
Z = A × B ya Z = A / B	$\Delta Z/Z = \Delta A/A + \Delta B/B$ (relative errors judte hain)
$Z = A^n$	$\Delta Z/Z = n\,(\Delta A/A)$
$Z = A^p B^q / C^r$	$\Delta Z/Z = p\,\Delta A/A + q\,\Delta B/B + r\,\Delta C/C$

YAAD RAKHO

Ghatav me bhi errors **judte** hain, ghatte nahi. Jis quantity ki power sabse badi hai, uski accuracy sabse zaroori hai.

09 JEE Extra + Tricks

JEE LEVEL

- Error rules: Z = A·B ya A/B me relative errors **judte**: $\Delta Z/Z = \Delta A/A + \Delta B/B$. $Z = A^n$ me $\Delta Z/Z = n \cdot \Delta A/A$. Jod/ghata me **absolute** errors judte.
- Vernier LC = 1 MSD − 1 VSD; screw gauge LC = pitch / circular divisions. Zero error: reading − (sign ke saath zero error).
- Same dimensions trick: Planck constant h = angular momentum $[ML^2T^{-1}]$; work = torque = energy $[ML^2T^{-2}]$; pressure = stress = energy density $[ML^{-1}T^{-2}]$.
- Dimensional analysis se 2π, ½ jaise constants nahi milte; terms ka jod aur exponential/trig functions nahi sambhalta.
- Significant figures: ×/÷ me sabse kam sig figs; +/− me sabse kam decimal places.

10 Solved numericals

Q1. In numbers me significant figures batao: (a) 0.007 (b) 2.64×10^{24} (c) 0.2370 (d) 6.320 (e) 6.032
(a) 1 (b) 3 (c) 4 (d) 4 (e) 4. **Leading zero kabhi significant nahi; decimal ke baad trailing zero hamesha.**

Q2. Rectangle ki length 4.234 m aur breadth 1.005 m hai. Area sahi sig. figs ke saath?
4.234 × 1.005 = 4.255170 m². Dono me 4 sig. figs ⇒ **Ans: 4.255 m²**

Q3. Chaand ko Earth ke do door ke points se dekha, basis b = 1.276×10^7 m (Earth ka diameter), parallax angle θ = 1° 54′. Chaand ki doori?
θ = 1° 54′ = 114′ = 114 × 60″ = 6840″. 1″ = 4.85×10^{-6} rad ⇒ θ = 3.32×10^{-2} rad. D = b/θ = 1.276×10^7 / 3.32×10^{-2} ≈ 3.84×10^8 m. **Ans: ≈ 3.84×10^8 m**

Q4. Check karo: ½mv² = mgh dimensionally sahi hai?
LHS: $[M][LT^{-1}]^2 = [ML^2T^{-2}]$. RHS: $[M][LT^{-2}][L] = [ML^2T^{-2}]$. Same. **Ans: Haan, dimensionally sahi**

Q5. 1 N ko dyne me badlo (CGS: g, cm, s).
$[MLT^{-2}]$: $n_2 = 1 \times (1000)^1 \times (100)^1 \times (1)^{-2} = 10^5$. **Ans: 1 N = 10^5 dyne**

Q6. Circular orbit me ghoomte object ki speed v, radius r aur force F ke liye $F \propto m^a v^b r^c$. a, b, c nikalo.
$[MLT^{-2}] = [M]^a[LT^{-1}]^b[L]^c$ ⇒ a = 1; T: −b = −2 ⇒ b = 2; L: b + c = 1 ⇒ c = −1. **Ans: F = k mv²/r**

Q7. Ek pendulum ke 5 readings: 2.63, 2.56, 2.42, 2.71, 2.80 s. Mean, mean absolute error aur % error?
Mean = 13.12/5 = 2.624 ≈ 2.62 s. Errors: 0.01, 0.06, 0.20, 0.09, 0.18 ⇒ mean error = 0.54/5 = 0.108 ≈ 0.11 s. % error = 0.11/2.62 × 100 ≈ 4%. **Ans: (2.62 ± 0.11) s, ≈ 4%**

Q8. Z = A^4 B^(1/3) / (C D^(3/2)). A, B, C, D me relative errors 1%, 2%, 3%, 4%. Z ka % error?
ΔZ/Z = 4(1) + (1/3)(2) + 1(3) + (3/2)(4) = 4 + 0.67 + 3 + 6 = 13.67%. **Ans: ≈ 13.7%**

11 Common mistakes

- 4200 me 4 sig. figs maan lena. Bina decimal ke trailing zero significant nahi (2 hain).
- Jod me sig. figs ka rule lagana. Jod/ghatav me **decimal places** dekhte hain.
- Parallax me angle ko degree me hi daal dena. Pehle radian me badlo.
- Ghatav (A − B) me errors ghata dena. Errors hamesha **judte** hain.
- "Dimensionally sahi hai toh equation pakka sahi" maan lena.
- Unit symbol ka plural (kgs) ya galat case (Kg, Newton) likhna.

12 Formula sheet

Quantity	$Q = n\,u,\ n_1u_1 = n_2u_2$
Plane angle / solid angle	$\theta = s/r,\ \Omega = A/r^2$
Parallax distance	$D = b/\theta$ (θ in rad)
1 light year / 1 parsec	9.46×10^{15} m / 3.08×10^{16} m
1 AU / 1 Å / 1 fermi	1.496×10^{11} m / 10^{-10} m / 10^{-15} m
1 u (amu)	1.66×10^{-27} kg
Unit conversion	$n_2 = n_1\,(M_1/M_2)^a\,(L_1/L_2)^b\,(T_1/T_2)^c$
Mean absolute error	$\Delta a = \Sigma\lvert a_{mean} - a_i\rvert\ /\ n$
Sum / difference	$\Delta Z = \Delta A + \Delta B$
Product / quotient	$\Delta Z/Z = \Delta A/A + \Delta B/B$
Power	$\Delta Z/Z = n\,\Delta A/A$

13 Practice questions

1. 0.05080 me kitne significant figures hain?
2. 3.0 × 10² + 2.23 × 10² ka answer sahi sig. figs ke saath?
3. Surface tension (force/length) ke dimensions?
4. Agar unit of length 2 guna aur unit of time 3 guna kar di jaaye, toh 1 newton nayi unit me kitna hoga? (mass unit same)
5. Kinetic energy E = ½mv². Agar m me 2% aur v me 3% error hai, toh E me % error?

ANSWERS

1) 4 · 2) 5.2 × 10² · 3) [M T⁻²] · 4) $n_2 = 1 \times (1/2)^1 \times (3)^2 = 4.5$ · 5) 2 + 2×3 = 8%

14 Quick revision: exam se pehle 5 minute

UNITS

- 7 base units: m, kg, s, A, K, mol, cd.
- Supplementary: rad, sr (dimensionless).
- Q = nu; unit badi ⇒ number chhota.
- D = b/θ; θ radian me.
- 1 pc > 1 ly > 1 AU.

SIGNIFICANT FIGURES

- Leading zero: nahi; beech ke zero: haan.
- Decimal ke baad trailing zero: haan.
- × ÷ : kam se kam sig. figs.
- + − : kam se kam decimal places.
- Bilkul 5: even same, odd +1.

DIMENSIONS

- F $[MLT^{-2}]$, E $[ML^2T^{-2}]$, P $[ML^2T^{-3}]$.
- Pressure $[ML^{-1}T^{-2}]$, G $[M^{-1}L^3T^{-2}]$, h $[ML^2T^{-1}]$.
- Har term ke same dimensions (homogeneity).
- Constants, sin/log, + − wale formula nahi milte.

ERRORS

- + ya −: absolute errors judte hain.
- × ya ÷: relative errors judte hain.
- Power n: error × n.
- Random error: zyada readings ka average.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.