Physical World

1. Fundamental Forces

① **Gravitational Force** - weakest fundamental force - attraction between two masses - $F = \frac{G m_1 m_2}{r^2}$. - not dependent on medium between the masses.

② **Electromagnetic Force**
- force acting b/w charged particles - $F = \frac{K q_1 q_2}{r^2}$ (for charges at rest).
- when charges are in motion, magnetic field is produced - depends on the medium between the charged particle
- attractive/repulsive

③ **Strong Nuclear Force** - binding force b/w neutron & proton
- charge-independent - short range force (order = 10^{-15} m)

④ **Weak Nuclear Force** - force which appears only in certain processes (Eg - beta decay). - short range force (order = 10^{-16} m)

2. Relative strength

Strong Nuclear Force > EM Force > Weak Nuclear Force > Gravitational Force.

3.

Fundamental Force	Mediating Particle	Range
① Gravitational force	Graviton	∞
② Electromagnetic force	Photon	∞
③ Weak nuclear force	Boson/Weakons	10^{-16} m
④ Strong nuclear force	Gluons	10^{-15} m

Units and Dimensions

1. Fundamental Physical Quantities — AKA Base quantities

	(SI units)
Length – L	metre
Mass – M	kilogram
Time – T	second
Temperature – k	Kelvin
Electric current – A	ampere
Luminous Intensity – Cd	Candela
Amount of substance – Mol	Mol

2. Derived Physical Quantities – speed, force, acceleration, etc.....

3. Supplementary Physical Quantities – Plane angle (radian) θ
– solid angle (steradian) (Ω)

4. System of Units
① FPS / British engineering system – Foot, pound, second.
② CGS / Gaussian system – centimetre, gram, second.
③ MKS system – Metre, kilogram, second.
④ SI unit system / Rationalised MKS System.

5. Practical unit –
- light year (ly) – distance
- horse power (hp) – power.

6. Improper unit –
- mile (= 1.6 km)
- Kg-wt.

7. Conversion factor – $n_1 u_1 = n_2 u_2$
n_1 = physical value in system I
u_1 = unit in system I
n_2 = physical value in system II
u_2 = unit in system II.

8. Dimension – It is the power raised to the fundamental physical quantity.

Eg – $\underbrace{\text{Force}}_{\text{Physical quantity}} = N = \underbrace{kg\,m/s^2}_{\text{units}} = \underbrace{[MLT^{-2}]}_{\text{dimensions}}$

angle (θ) = $\frac{\text{radian}}{\text{unit}}$ = $[M^0 L^0 T^0]$ = dimensionless

9. Dimensions of Constant Values – G, h, ε_0, etc.

→ Relative density is dimension-less.

10. Principle of Homogenicity – two or more physical quantities can be added/subtracted and the result should be the same physical quantity.

Eg – If $F = at + bt^3$

$\Rightarrow [at] = [b][t^3] = [F] = [MLT^{-2}]$

$\therefore a = [MLT^{-3}]$ $\quad b = [MLT^{-5}]$.

11. $\sin(\theta)$, $\cos(\theta)$ → dimension less. (strain = dimension less)

→ $e^{(\cdots)}$ ⇒ dimension-less

→ $\ln(\cdots)$ ⇒ dimension-less.

12. Converting System of Units – $n_1 u_1 = n_2 u_2$

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

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

13. Checking Formula Using Dimensional Analysis

Eg – $T = 2\pi\sqrt{\frac{I}{g}}$ $\Rightarrow [T] = [1]\left[\sqrt{\frac{L}{LT^{-2}}}\right]$

$\Rightarrow [T] = [\sqrt{T^2}] \Rightarrow [T] = [T]$ $\therefore$ LHS = RHS.

$\therefore$ formula verified ✓

14. To find the formula – Eg – $f \propto M^a R^b v^c$

$\Rightarrow [MLT^{-2}] \propto [M^a L^{b+c} T^{-c}]$

$\therefore a = 1$

$b = -1$ $\quad \therefore f \propto \frac{mv^2}{R}$.

$c = 2$

15. Dimensions of Differential And Integral Co-efficients

→ $\left[\frac{d^n y}{dx^n}\right] = \left[\frac{y}{x^n}\right]$.

→ $\left[\int y\,dx\right] = [yx]$.

16. Significant Figures – ① 1234 = 4 ② 103 = 3
③ 0024 = 2 ④ 0.0023 = 2 ⑤ 0.2001 = 4
⑥ 0.200 = 3 ⑦ 100100 = 4 ⑧ 200 = 1
⑨ 100 kg = 3.

17. Scientific Notation – $a \times 10^b$
$(1 \leq a \leq 10)$.

For calculation, result should be expressed in the significant figures of the least SF given.

18. Rounding off ① greater than 50% ⇒ next digit
② lesser than 50% ⇒ same number
③ equal to 50% → if last digit is even ⇒ same
→ if last digit is odd ⇒ next.

19. order of magnitude $\boxed{0.5 \leq \frac{N}{10^x} < 5}$
x = order.

20. Accuracy and Precision – 1.1 ⇒ more accurate
1.12 ⇒ true value
1.523 ⇒ more precise.

21. Error < systematic error (controllable error)
gross error (due to human mistakes)
random error (cause of error is unknown)

If the number of observations is made n times, then random error reduces to $\frac{1}{n}$ times.

22. Absolute error (Δa) = difference between true value and individual measured values.

→ If true value is not mentioned, then —
true value = mean of measured values.

→ Mean absolute error / Final error = Mean of all Δa s.

→ Fractional error = $\frac{\text{Mean absolute error}}{\text{True value}}$ = Relative error

→ % error = (Fractional / Relative error) × 100.

23. Propagation of Error in Mathematical operations -

If $A = 10 \pm 0.2$
$B = 5 \pm 0.6$

⇒ $A + B = 15 \pm 0.8$
$A - B = 5 \pm 0.8$.

24. If $f = (\text{constant})\, x^a y^b z^c$

⇒ $\left(\frac{\Delta f}{f}\right)_{max} = a\frac{\Delta x}{x} + b\frac{\Delta y}{y} + c\frac{\Delta z}{z}$

Max fractional / permissible / possible error.

Eg - $a = (2 \pm 0.01)$ m

volume = $V = a^3$ $\qquad V = a^3 = 2^3 = 8$

⇒ $\frac{\Delta V}{V} = 3\frac{\Delta a}{a}$

⇒ $\frac{\Delta V}{8} = \frac{3 \times 0.01}{2}$ $\qquad \therefore \Delta V = 0.12\ m^3$

$\therefore V \pm \Delta V = (8 \pm 0.12)\ m^3$.

25. Least Count (LC) = max possible error in adjustment.

- mm scale = 1 mm
- vernier calliper = 0.1 mm
- screw gauge = 0.01 mm.

If error/least count is not given ⇒ place value = LC

Eg - $x = 2.\underline{33}$ ∴ LC = $0.\underline{01}$

26. Vernier Callipers

→ LC = 1 MSD − 1 VSD (LC = Vernier constant)

→ If length of a MSD coincides with length of b VSD

⇒ a × 1 MSD = b × 1 VSD

⇒ VSD = $\frac{a}{b}$ × MSD.

∴ LC = MSD − VSD

= $\left(\frac{b-a}{b}\right)$ × 1 MSD.

27. Screw Gauge (spherometer)

→ LC = $\frac{\text{Pitch}}{\text{No. of divisions on circular disc}}$ — pitch = $\frac{\text{Linear Scale Distance}}{\text{No. of rotations}}$

If $X = ab^2/c^3 = ab^2c^{-3}$.

→ Eg -

⇒ $\frac{\Delta X}{X} = \frac{\Delta a}{a} + 2\frac{\Delta b}{b} + 3\frac{\Delta c}{c}$