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PREFACE

We would like to thank all the students for helping me understand their problems and for making me work to get their solutions and the teachers who made by concepts and basics clear. We owe this book to them.

This book is meant for all students who are preparing for different entrance examinations, specially, ISEET/IIT JEE and AIEEE and NEET. The most important thing we found was the gap between the normal class XI and XII curriculum and the level of preparation required for clearing the entrance exams conducted after class XII. In this book we have tried to bridge that gap and give the student everything from the very basic concepts to the best possible application of the concepts.

We would request the students to first go through the complete concepts of your class XI and XII and then read the summary given in the beginning of each chapter in this book and finally try to attempt the questions given. Try your best to solve the questions on your own, even if a problem takes two to three days, keep thinking about the problem till you reach the solutions. You need to remember the concept and the application in a particular solution and not the question, as the chances of the same question being asked are rare, but all the questions asked in the exam will be based on one or the other concept of the problems discussed in this book.

Generally the questions asked in the exam are not just based on one concept but may be based on more than one concepts and hence reading the question carefully, understanding and thinking of the method to be applied is the most important part of problem solving.

We would like to again request the students to stick to the concepts and their applicability rather than concentrating on questions only. Each question should be seen as a method of solving that type of problems and should be remembered.

We wish you all the best. Do well.

AUTHORS

SYLLABUS

UNIT I : PHYSICAL WORLD AND MEASUREMENT **(Periods 10)**

Physics : Scope and excitement; nature of physical laws; Physics, technology and society.

Need for measurement: Units of measurement; systems of units; SI units, fundamental and derived units. Length, mass and time measurements; accuracy and precision of measuring instruments; errors in measurement; significant figures.

Dimensions of physical quantities, dimensional analysis and its applications.

UNIT II : KINEMATICS **(Periods 30)**

Frame of reference, Motion in a straight line: Position-time graph, speed and velocity. Uniform and non-uniform motion, average speed and instantaneous velocity. Uniformly accelerated motion, velocity time and position-time graphs, relations for uniformly accelerated motion (graphical treatment).

Elementary concepts of differentiation and integration for describing motion. Scalar and vector quantities: Position and displacement vectors, general vectors and notation, equality of vectors, multiplication of vectors by a real number; addition and subtraction of vectors. Relative velocity.

Unit vectors. Resolution of a vector in a plane – rectangular components.

Scalar and Vector products of Vectors. Motion in a plane. Cases of uniform velocity and uniform acceleration – projectile motion. Uniform circular motion.

UNIT III : LAWS OF MOTION **(Periods 16)**

Intuitive concept of force. Inertia, Newton's first law of motion; momentum and Newton's second law of motion; impulse; Newton's third law of motion. Law of conservation of linear momentum and its applications.

Equilibrium of concurrent forces. Static and kinetic friction, laws of friction, rolling friction, lubrication.

Dynamics of uniform circular motion: Centripetal force, examples of circular motion (vehicle on level circular road, vehicle on banked road).

UNIT IV : WORK, ENERGY AND POWER **(Periods 16)**

Work done by a constant force and a variable force; kinetic energy, work-energy theorem, power.

Notion of potential energy, potential energy of a spring, conservative forces; conservation of mechanical energy (kinetic and potential energies); non-conservative forces; motion in a vertical circle, elastic and inelastic collisions in one and two dimensions.

UNIT V : MOTION OF SYSTEM OF PARTICLES AND RIGID BODY **(Periods 18)**

Centre of mass of a two-particle system, momentum conservation and centre of mass motion. Centre of mass of a rigid body; centre of mass of uniform rod.

Moment of a force, torque, angular momentum, conservation of angular momentum with some examples.

Equilibrium of rigid bodies, rigid body rotation and equation of rotational motion, comparison of linear and rotational motions; moment of inertia, radius of gyration. Values of M.I. for simple geometrical objects (no derivation). Statement of parallel and perpendicular axes theorems and their applications.

UNIT VI : GRAVITATION **(Periods 14)**

Kepler's laws of planetary motion. The universal law of gravitation. Acceleration due to gravity and its variation with altitude and depth. Gravitational potential energy; gravitational potential. Escape velocity, orbital velocity of a satellite. Geostationary satellites.

UNIT VII : PROPERTIES OF BULK MATTER **(Periods 28)**

Elastic behaviour, Stress-strain relationship, Hooke's law, Young's modulus, bulk modulus, shear, modulus of rigidity, poisson's ratio; elastic energy.

Pressure due to a fluid column; Pascal's law and its applications (hydraulic lift and hydraulic brakes). Effect of gravity on fluid pressure.

Viscosity, Stokes' law, terminal velocity, Reynold's number, streamline and turbulent flow. Critical velocity, Bernoulli's theorem and its applications.

Surface energy and surface tension, angle of contact, excess of pressure, application of surface tension ideas to drops, bubbles and capillary rise.

Heat, temperature, thermal expansion; thermal expansion of solids, liquids, and gases. Anomalous expansion. Specific heat capacity: C_p, C_v – calorimetry; change of state – latent heat.

Heat transfer – conduction and thermal conductivity, convection and radiation. Qualitative ideas of Black Body Radiation, Wein's displacement law, and Green House effect.

Newton's law of cooling and Stefan's law.

UNIT VIII : THERMODYNAMICS **(Periods 12)**

Thermal equilibrium and definition of temperature (zeroth law of Thermodynamics). Heat, work and internal energy. First law of thermodynamics. Isothermal and adiabatic processes.

Second law of thermodynamics: Reversible and irreversible processes. Heat engines and refrigerators.

UNIT IX : BEHAVIOUR OF PERFECT GAS AND KINETIC THEORY **(Periods 8)**

Equation of state of a perfect gas, work done on compressing a gas.

Kinetic theory of gases: Assumptions, concept of pressure. Kinetic energy and temperature; rms speed of gas molecules; degrees of freedom, law of equipartition of energy (statement only) and application to specific heat capacities of gases; concept of mean free path, Avogadro's number.

UNIT X : OSCILLATIONS AND WAVES **(Periods 28)**

Periodic motion – period, frequency, displacement as a function of time. Periodic functions. Simple harmonic motion (SHM) and its equation; phase; oscillations of a spring – restoring force and force constant; energy in SHM – kinetic and potential energies; simple pendulum – derivation of expression for its time period; free, forced and damped oscillations (qualitative ideas only), resonance.

Wave motion. Longitudinal and transverse waves, speed of wave motion. Displacement relation for a progressive wave. Principle of superposition of waves, reflection of waves, standing waves in strings and organ pipes, fundamental mode and harmonics. Beats. Doppler effect.

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CONTENTS

1. UNITS AND MEASUREMENTS 1.1 – 1.34

2. KINEMATICS 2.1 – 2.52

3. LAWS OF MOTION 3.1 – 3.78

4. WORK, ENERGY AND POWER 4.1 – 4.46

5. MOTION OF SYSTEM OF PARTICLES AND RIGID BODY 5.1 – 5.46

6. GRAVITATION 6.1 – 6.38

7. PROPERTIES OF BULK MATTER 7.1 – 7.52

8. THERMODYNAMICS AND KINETIC THEORY OF GASES 8.1 – 8.50

9. WAVES AND OSCILLATIONS 9.1 – 9.52

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1

UNITS AND MEASUREMENTS

1.1 UNITS

A unit is an internationally accepted standard for measurements of quantities.

Measurement consists of a numeric quantity along with a relevant unit.

Fundamental quantities are those physical quantities that cannot be expressed in terms of other quantities. These are independent quantities. For example: Length, mass, time, temperature, electric current, amount of substance.

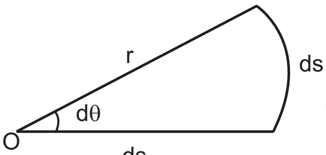
Derived quantities are those physical quantities that are derived from the combination of fundamental quantities. It is a dependent quantity. For example: force, density, volume, momentum etc.

Fundamental and derived units together form a system of snits.

Internationally accepted system of units is SystèmeInternationale d' Unites (French for International system of Units) or SI. It was developed and recommended by General Conference on Weights and Measures in 1971.

SI system lists 7 base or fundamental units as in the table below. Along with it, there are two units - radian or rad (unit for plane angle) and steradian or sr (unit for solid angle). They both are dimensionless.

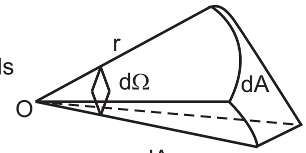
Base Quantity	Name	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd



$d\theta = \frac{ds}{r}$ radian

Plane angle (Unit - Radian)

Fig. 1.1



$d\Omega = \frac{dA}{r^2}$ steradian

Solid angle (Unit - Steradian)

Fig. 1.2

1.2 MEASUREMENT OF LENGTH

Length can be measured using metre scale (10^{-3} m to 10^{2} m), vernier callipers (10^{-4} m) and screw gauge and spherometer (10^{-5} m).

Range of Length:

Size of object or distance	Length (m)
Size of proton	10^{-15}
Size of atomic nucleus	10^{-14}
Length of typical virus	10^{-8}
Wavelength of light	10^{-7}
Thickness of paper	10^{-4}
Height of Mount Everest above sea level	10^{4}
Radius of earth	10^{7}
Distance of moon from earth	10^{8}
Distance of sun from earth	10^{11}
Distance of pluto from sun	10^{13}
Size of our galaxy	10^{21}
Distance to Andromeda Galaxy	10^{22}
Distance to observable universe boundaries	10^{26}

(Special length units)

Unit name	Unit symbol	Value in meters
fermi	f	10^{-15} m
angstrom	Å	10^{-10} m

astronomical unit (average distance of sun from earth)	AU	1.496×10^{11} m
light year (distance travelled by light in 1 year with velocity 3×10^{8} m/s)	ly	9.46×10^{11} m
parsec (distance at which average radius of earth's orbits subtends an angle of 1 arc second)	pc	3.08×10^{16} m

1.3 MEASUREMENT OF MASS

Mass is usually measured in terms of kg, but for atoms and molecules, **unified atomic mass unit** (u) is used.

1 u = $\frac{1}{12}$ of the mass of an atom of carbon-12 isotope including mass of electrons (1.66×10^{-27} kg).

Apart from using **balances** for normal weights, mass of planets is measured using **gravitational methods** and mass of atomic particles is measured using **mass spectrograph** (radius of trajectory is proportional to mass of charged particle moving in uniform electric and magnetic field).

Range of Mass:

Object	Mass (kg)
Electron	10^{-30}
Proton	10^{-27}
Red blood cell	10^{-13}
Dust particle	10^{-9}
Rain drop	10^{-6}
Mosquito	10^{-5}
Grapes	10^{-3}
Human	10^{2}
Automobile	10^{3}
Boeing 747 aircraft	10^{8}
Moon	10^{23}
Earth	10^{25}
Sun	10^{30}
Milky way Galaxy	10^{41}
Observable Universe	10^{55}

1.4 MEASUREMENT OF TIME

Time is measured using a clock. As a standard, **atomic standard of time** is now used, which is measured by **Cesium or Atomic clock**.

Range of Time:

Event	Time interval (s)
Life span of most unstable particle	10^{-24}
Period of x-rays	10^{-19}
Period of light wave	10^{-15}
Period of radio wave	10^{-6}
Period of sound wave	10^{-3}
Wink on an eye	10^{-1}
Travel time of light from moon to earth	10^{0}
Travel time of light from sun to earth	10^{2}
Rotation period of the earth	10^{5}
Revolution period of the earth	10^{7}
Average human life span	10^{9}
Age of Egyptian pyramids	10^{11}
Time since dinosaur extinction	10^{15}
Age of Universe	10^{17}

1.5 ACCURACY AND PRECISION OF INSTRUMENTS

Any uncertainty resulting from measurement by a measuring instrument is called error. They can be systematic or random.

Accuracy of a measurement is how close the measured value is to the true value.

Precision is the resolution or closeness of a series of measurements of a same quantity under similar conditions.

If the true value of a certain length is 3.678 cm and two instruments with different resolutions, up to 1 (less precise) and 2 (more precise) decimal places respectively, are used. If first measures the length as 3.5 and the second as 3.38, then the first has more accuracy, but less precision; while the second has less accuracy and more precision.

1.6 TYPES OF ERRORS

1. Systematic errors:

A systematic error is one that results from a persistent issue and leads to a consistent error in the measurements. It can be completely removed by changing the instrument or experimental techniques or experimenting under proper atmospheric conditions and techniques etc.

They are of following types:

(a) Instrument errors: These arise from imperfect design or calibration error in the instrument. Worn off scale, zero error in a weighing scale are some examples of instrument errors.

(b) Imperfections in experimental techniques: If the technique is not accurate (for example measuring temperature of human body by placing thermometer under armpit resulting in lower temperature than actual) and due to the external conditions like temperature, wind, humidity, these kinds of errors occur.

(c) Personal errors: Errors occurring due to human carelessness, lack of proper setting, taking down incorrect reading are called personal errors.

2. Random errors:

Random error describes errors that fluctuate due to the unpredictability or uncertainty inherent in the measuring process, or the variation in the quantity we trying to measure.

They cannot be completely removed but only be minimized.

These occur due to unpredictable fluctuations in experimental conditions like temperature, voltage supply, mechanical vibrations, personal errors etc.

Calculation of errors in a series of measurements:

Suppose the values obtained in several measurements are $a_1, a_2, a_3, \ldots, a_n$.

(a) Arithmetic mean, $a_{mean} = \dfrac{(a_1 + a_2 + a_3 + \ldots + a_n)}{n}$

$$= \frac{1}{n}\sum_{i=1}^{n} a_i$$

(b) Absolute error: The magnitude of the difference between the true value of the quantity and the individual measurement value is called absolute error of the measurement. It is denoted by $|\Delta a|$ (or Mod of Delta a). The mod value is always positive even if Δa is negative. The individual errors are:

$$\Delta a_1 = a_{mean} - a_1,\ \Delta a_2 = a_{mean} - a_2,\ \ldots\ldots,\ \Delta a_n = a_{mean} - a_n$$

(c) Mean absolute error is the arithmetic mean of all absolute errors. It is represented by Δa_{mean}.

$$\Delta a_{mean} = \frac{(|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \ldots + |\Delta a_n|)}{n}$$

For single measurement, the value of 'a' is always in the range $a_{mean} \pm \Delta a_{mean}$.

So, $a = a_{mean} \pm \Delta a_{mean}$

or $a_{mean} - \Delta a_{mean} < a < a_{mean} + \Delta a_{mean}$

(d) Relative error: It is the ratio of mean absolute error to the mean value of the quantity measured.

$$\text{Relative error} = \frac{\Delta a_{mean}}{a_{mean}}$$

(e) Percentage error: It is the relative error expressed in percentage. It is denoted by δa.

$$\delta a = \left(\frac{\Delta a_{mean}}{a_{mean}}\right) \times 100$$

1.7 COMBINATIONS OF ERRORS

If a quantity depends on two or more other quantities, the combination of errors in the two quantities helps to determine and predict the errors in the resultant quantity.

1. For summation:

If $z = x + y$, then $\Delta z = \pm (\Delta x + \Delta y)$

Therefore, the maximum relative or fractional error,

$$\frac{\Delta z}{z} = \frac{\Delta x + \Delta y}{x + y}$$

2. For difference:

If $z = x - y$, then the maximum absolute error will be

$$\Delta z = \pm (\Delta x + \Delta y)$$

Hence the maximum fractional error,

$$\frac{\Delta z}{z} = \frac{\Delta x + \Delta y}{x - y}$$

3. For product:

If $z = xy$, then the maximum fractional error,

$$\frac{\Delta z}{z} = \pm\left(\frac{\Delta x}{x} + \frac{\Delta y}{y}\right)$$

4. For division:

If $z = \dfrac{x}{y}$, then the maximum fractional error,

$$\frac{\Delta z}{z} = \pm\left(\frac{\Delta x}{x} + \frac{\Delta y}{y}\right)$$

5. **For power:**

If $z = x^n$, then $\frac{\Delta z}{z} = n \cdot \frac{\Delta x}{x}$

Similarly if $z = \frac{A^K B^L}{C^M}$, then the maximum fractional error in z is,

$$\frac{\Delta z}{z} = K\frac{\Delta A}{A} + L\cdot\frac{\Delta B}{B} + M\cdot\frac{\Delta C}{C}$$

1.8 SIGNIFICANT FIGURES

Every measurement results in a number that includes reliable digits and uncertain digits. Reliable digits plus the first uncertain digit are called **significant digits or significant figures.**

These indicate the precision of measurement which depends on least count of measuring instrument.

Example, period of oscillation of a pendulum is 1.62 s. Here 1 and 6 are reliable and 2 is uncertain. Thus, the measured value has three significant figures.

1.9 RULES FOR DETERMINING NUMBER OF SIGNIFICANT FIGURES

1. All non-zero digits are significant figures.

e.g.

Number	Significant Figures (S.F.)
8	1
82	2
862	3
8621	4

2. All zeros occurring between non-zero digits are significant figures.

e.g.

Number	Significant Figures (S.F.)
802	3
108.002	6

3. All zeros to the right of the last non-zero digit are not significant figures.

e.g.

Number	Significant Figures (S.F.)
60	1
640	2
6480	3

4. All zeros to the right of a decimal point and to the left of a non-zero digit are not significant figures.

e.g.

Number	Significant Figures (S.F.)
0.04	1
0.003	1
0.0123	3
0.132	3

5. All zeros to the right of a decimal point and to the right of a non-zero digit are significant figures.

e.g.

Number	Significant Figures (S.F.)
0.30	2
0.320	3
0.07800	4

6. All zeros to the right of a decimal point are significant, if they are not followed by a non-zero digit.

e.g.

Number	Significant Figures (S.F.)
70.00	4
470.00	5

7. The powers of ten are not counted as significant figures.

e.g. 1.49×10^{-7} has only S.F. = 3

Note:

(a) **Change of units should not change number of significant digits.** Example, 4.700 m = 470.0 cm = 4700 mm. In this, first two quantities have 4 significant figures, but third quantity has 2 significant figures.

(b) **Use scientific notation to report measurements.** Numbers should be expressed in powers of 10 like $\mathbf{a \times 10^b}$, where b is called order of magnitude. Example, 4.700 m = 4.700×10^2 cm = 4.700×10^3 mm = 4.700×10^{-3} km. In all the above, since powers of 10 are irrelevant, number of significant figures are 4.

1.10 RULES FOR ARITHMETIC OPERATION WITH SIGNIFICANT FIGURES

Type	Multiplication or Division	Addition or Subtraction
Rule	The final result should retain as many significant	The final result should retain as many decimal

	figures as there in the original number with the lowest number of significant digits.	places as there in the original number with the least decimal places.
Example	Density = $\frac{\text{Mass}}{\text{Volume}}$ If mass = 4.237 g (4 significant figures) and volume = 2.51 cm^3 (3 significant figures) Density = $\frac{4.237 \text{ g}}{2.51 \text{ cm}^3}$ = 1.68804 g cm^{-3} = 1.69 g cm^{-3} (3 significant figures)	Addition of 436.32 (2 digits after decimal), 227.2 (1 digit after decimal) and 0.301 (3 digits after decimal) is = 663.821 Since 227.2 is precise up to only 1 decimal place, hence, the final result should be 663.8.

1.11 RULES FOR ROUNDING OFF THE UNCERTAIN DIGITS

Rounding off is necessary to reduce the number of insignificant figures to adhere to the rules of arithmetic operation with significant figures.

Rule Number	Insignificant digit	Preceding digit	Example (rounding off to two decimal places)
1	Insignificant digit to be dropped is more than 5.	Preceding digit is raised by 1.	Number: 3.137 Result: 3.14
2	Insignificant digit to be dropped is less than 5.	Preceding digit is left unchanged.	Number: 3.132 Result: 3.13
3	Insignificant digit to be dropped is equal to 5.	If preceding digit is even, it is left unchanged.	Number: 3.125 Result: 3.12
4	Insignificant digit to be dropped is equal to 5.	If preceding digit is odd, it is raised by 1.	Number: 3.135 Result: 3.14

1.12 RULES FOR DETERMINING UNCERTAINTY IN RESULTS OF ARITHMETIC CALCULATIONS

To calculate the uncertainty, following process should be used.

- **Add a lowest amount of uncertainty in the original numbers.** Example uncertainty for 3.2 will be ± 0.1 and for 3.22 will be ± 0.01. Calculate these in percentage also.
- **After the calculations, the uncertainties get multiplied/divided/added/subtracted.**
- **Round off the decimal place in the uncertainty to get the final uncertainty result.**

Example, s for a rectangle, if length l = 16.2 cm and breadth b = 10.1 cm, then, take l = 16.2 ± 0.1 cm or 16.2 cm ± 0.6% and breadth = 10.1 ± 0.1 cm or 10.1 cm ± 1%.

On multiplication, Area = Length × Breadth = 163.62 cm^2 ± 1.6% or 163.62 ± 2.6 cm^2.

Therefore after rounding off, area = 164 ± 3 cm^2.

Hence 3 cm^2 is the uncertainty or the error in estimation.

Rules:

1. **For a set of experimental data of 'n' significant figures, the result will be valid to 'n' significant figures or less (only in case of subtraction).**

   Example: 12.9 − 7.06 = 5.84 or 5.8 (rounding off to lowest number of decimal places of original number).

2. **The relative error of a value of number specified to significant figures depends not only on n, but also on the number itself.**

   Example, accuracy for two numbers 1.02 and 9.89 is ± 0.01. But relative errors will be:

   For 1.02, $\left(\frac{\pm 0.01}{1.02}\right) \times 100\% = \pm 1\%$

   For 9.89, $\left(\frac{\pm 0.01}{9.89}\right) \times 100\% = \pm 0.1\%$

   Hence, the relative error depends upon number itself.

3. **Intermediate results in multi-step computation should be calculated to one more significant figure in every measurement than the number of digits in the least precise measurement.**

   Example: $\frac{1}{9.58} = 0.1044$

Now, $\frac{1}{0.104} = 9.56$ and $\frac{1}{0.1044} = 9.58$

Hence, taking one extra digit gives more precise results and reduces rounding off errors.

1.13 DIMENSIONS OF A PHYSICAL QUANTITY

Dimensions of a physical quantity are powers (exponents) to which base quantities are raised to represent that quantity. They are **represented by square brackets** around the quantity.

Dimensions of the 7 base quantities are Length [L], Mass [M], time [T], electric current [A], thermodynamic temperature [K], luminous intensity [cd] and amount of substance [mol].

Examples: Volume = Length × Breadth × Height = [L] × [L] × [L] = $[L]^3 = [L^3]$

Force = Mass × Acceleration = $\frac{[M][L]}{[T]^2} = [MLT^{-2}]$

Dimensions do not take into account the magnitude of a quantity

1.14 DIMENSIONAL FORMULA AND DIMENSIONAL EQUATION

Dimensional formula is the expression which shows how and which of the base quantities represent the dimensions of a physical quantity.

Dimensional equation is an equation obtained by equating a physical quantity with its dimensional formula.

Dimensional Formulae with S.I. Units of Physical Quantities

Sr. No.	Physical Quantity	Physical Formula	Dimensional Formula		S. I. Unit
1.	Mass	Mass	$[ML^\circ T^\circ]$	= $[ML^\circ T^\circ]$	kg
2.	Length/Distance/ Displacement/Height	Length	$[M^\circ L T^\circ]$	= $[M^\circ L T^\circ]$	m
3.	Time	Time	$[M^\circ L^\circ T]$	= $[M^\circ L^\circ T]$	s
4.	Area	Length × Breadth	$L \times L = L^2$	= $[M^\circ L^2 T^\circ]$	m^2
5.	Volume	Length × Breadth × Height	$L \times L \times L = L^3$	= $[M^\circ L^3 T^\circ]$	m^3
6.	Density	$\frac{\text{Mass}}{\text{Volume}}$	$\frac{M}{L^3} = ML^{-3}$	= $[ML^{-3} T^\circ]$	kg. m^{-3}
7.	Specific Gravity	$\frac{\text{Denisty of material}}{\text{Density of water at 4° C}}$	No dimension	–	–
8.	Speed/Velocity	$\frac{\text{Distance}}{\text{Time}}$ or $\frac{\text{Displacment}}{\text{Time}}$	$\frac{L}{T} = LT^{-1}$	= $[M^\circ LT^{-1}]$	ms^{-1}
9.	Linear Acceleration (a) or Acceleration due to gravity (g)	$\frac{\text{Velocity}}{\text{Time}}$	$\frac{LT^{-1}}{T} = LT^{-2}$	= $[M^\circ LT^{-2}]$	ms^{-2}
10.	Linear momentum (p) or Impulse (I)	Mass × Velocity Force × Time	$M \times LT^{-1} = MLT^{-1}$ $MLT^{-2} \times T = MLT^{-1}$	= $[MLT^{-1}]$ = $[MLT^{-1}]$	kg ms^{-1} or Ns
11.	Force/Thrust/Tensions (T) Weight	Mass × Acceleration	$M \times LT^{-2} = MLT^{-2}$	= $[MLT^{-2}]$	newton (N)
12.	Force constant or Surface Tension	$\frac{\text{Force}}{\text{Change in length}}$	$\frac{M\,LT^{-2}}{L} = MT^{-2}$	= $[ML^\circ T^{-2}]$	Nm^{-1}