SAMPLE CONTENT

Challenger

NEET - UG & JEE (Main)
PHYSICS Vol - I

As per latest syllabus issued by NMC & NTA

2012 MCQs with Hints

For all Medical and Engineering Entrance Examinations held across India.

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Challenger

NEET (UG) & JEE (Main)

Physics Vol. I

Now with more study techniques

Updated as per latest syllabus for:
NEET (UG) 2024 issued by **NMC on 6th October, 2023**
JEE (Main) 2024 issued by **NTA on 1st November, 2023**

Salient Features

- Concise theory for every topic
- Eclectic coverage of MCQs under each sub-topic
- Exhaustive coverage of questions including selective questions from previous years' NEET (UG) and JEE (Main) examinations updated upto year 2023:
  - **2012** MCQs
  - **95** Numerical Value type (NVT)
  - Solutions to the questions are provided for better understanding
- Inclusion of '**Problems To Ponder**' to engage students in scientific enquiry.
- Multiple Study Techniques to Enhance Understanding and Problem Solving.
- Includes Question Papers and Answer Keys (Solutions through Q.R. code) of:
  - NEET (UG) 2021
  - NEET (UG) 2022
  - NEET (UG) 2023
  - JEE (Main) 2021 24th February (Shift - I)
  - JEE (Main) 2022 25th July (Shift - I)
  - JEE (Main) 2023 24th Jan (Shift - II)
- Q.R. codes provide:
  - Video links for boosting conceptual retention
  - Question Paper along with Answers and Solutions of NEET (UG) 2023 (Manipur)
  - Solutions of previous years' exam papers of years 2021 to 2023
- Separate list of questions excluded from the NEET (UG) and JEE (Main) 2024 syllabus

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PREFACE

'Challenger Physics Vol - I' is a compact guidebook, extremely handy for preparation of various competitive exams like NEET, JEE (Main). This edition provides an unmatched comprehensive amalgamation of theory with MCQs. The chapters are aligned with the syllabus for NEET (UG) and JEE (MAIN) examinations and run parallel to NCERT curriculum. The book provides the students with scientifically accurate context, several study techniques and skills required to excel in these examinations.

In this book the Theoretical Concepts are presented in the form of pointers, tables, charts and diagrams that form a vital part of preparation of any competitive examination.

Multiple Choice Questions have been specially created and compiled with the following objective in mind – to help students solve complex problems which require strenuous effort and understanding of multiple-concepts. The assortment of MCQs is a beautiful blend of questions based on higher order thinking, theory, and multiple concepts.

MCQs in each chapter are segregated into following sections.

- **Concept Building Problems** section is designed to boost prerequisite understanding of concepts.
- **Practice Problems** section contains questions crafted for thorough revision .
- **Numerical Value Type** section cater to newly added NVT questions in JEE (MAIN).
- **Problems to Ponder** section offers questions of diverse pattern created to instill the attitude of concentrating on the problems and to understand the application of various concepts in Physics.

All the features of this book pave the path of a student to excel in examination.The features are designed keeping the following elements in mind: Time management, easy memorization or revision and non-conventional yet simple methods for MCQ solving.

Previous Years' Question Papers:

To keep students updated, Question Papers along with Answers and Solutions (through Q.R. code) of following papers have been provided to offer students glimpse of the complexity of questions asked in entrance examination. These papers of latest competitive examinations have been provided and split unit-wise to let the students know which of the units were more relevant as per latest Question paper.

- NEET (UG) **2021, 2022, 2023** and **2023 (Manipur)**
- JEE (Main) **2021** 24th February (Shift - I), **2022** 25th July (Shift - I), **2023** 24th January (Shift - II)

Considering the latest modifications in the syllabus of NEET (UG) and JEE (Main) examinations, a list of questions based on the concepts excluded from the syllabus is provided. The purpose of providing these questions is to display various question types and their level of difficulty that have been asked in previous examinations.

We hope the book benefits the learner as we have envisioned.

A book affects eternity; one can never tell where its influence stops.

Publisher

Edition: Fifth

The journey to create a complete book is strewn with triumphs, failures and near misses. If you think we've nearly missed something or want to applaud us for our triumphs, we'd love to hear from you.

Please write to us on: mail@targetpublications.org

KEY FEATURES

Time Saver

'Time Saver' illustrates quick method over lengthy conventional method of solving numerical. *This is our attempt to benefit students by saving their time wherever possible.*

Smart tip

'Smart tips' comprise important theoretical or formula based short tricks considering their usage in solving MCQ.
This is our attempt to highlight content that would come handy while solving questions.

Caution

'Caution' apprises students about mistakes which are made while solving an MCQs.
This is our attempt to make a student aware of possible common mistakes.

Q.R. Code

'Q.R. code' provides access to a video in order to boost understanding of a concept or activity.
This is our attempt to facilitate learning with visual aids.

Formulae

'Formulae' includes all of the key formulae in the chapter.
This is our attempt to offer students tools of formulae accessible while solving problems and last minute revision at a glance.

Learning Pointers

'Learning Pointers' provide compilation of additional notes which involve fusion of two concepts from different chapters or come as indirect extensions of subtopics.
This is our attempt to offer gist of knowledge required from examination point of view as a snippet.

KEY FEATURES

Mind Over Matter

'Mind Over Matter' offers insight in solving brain-racking questions.
This is our attempt to build a framework for focused, guided thinking.

Clock Symbol

'Clock Symbol' instructs students that given MCQ can be solved apace by applying either Smart Tips, Learning Pointers, Time Saver or Thinking Hatke.
This is our attempt to make students attentive towards their perception of approaches possible for solving an MCQ.

Miscellaneous

Miscellaneous MCQs covers concept of different sub-topics of same chapter or from different chapters.
This is our attempt to develop cognitive thinking in the students essential to solve questions involving fusion of multiple key concepts.

Thinking Hatke

'Thinking Hatke' reveals quick witted approach to crack the specific question.
This is our attempt to develop skill of lateral thinking in students.

Memory Map

'Memory Map' summarizes the key points in the chapter.
This is our attempt to provide chapter overview succinctly.

Frequently Asked Questions

- **Why Challenger Series?**

Gradually, every year the nature of competitive entrance exams is inching towards conceptual understanding of topics. Moreover, it is time to bid adieu to the stereotypical approach of solving a problem using a single conventional method.

To be able to successfully crack the NEET examination, it is imperative to develop skills such as data interpretation, appropriate time management, knowing various methods to solve a problem, etc. With Challenger Series, we are sure, you'd develop all the aforementioned skills and take a more holistic approach towards problem solving. The way you'd tackle advanced level MCQs with the help of hints, Smart tips, Smart codes and Thinking Hatke section would give you the necessary practice that would be a game changer in your preparation for the competitive entrance examinations.

- **What is the intention behind the launch of Challenger Series?**

The sole objective behind the introduction of Challenger Series is to severely test the student's preparedness to take competitive entrance examinations. With an eclectic range of critical and advanced level MCQs, we intend to test a student's MCQ solving skills within a stipulated time period.

- **What do I gain out of Challenger Series?**

After using Challenger Series, students would be able to:

a. assimilate the given data and apply relevant concepts with utmost ease.

b. tackle MCQs of different pattern such as match the columns, diagram based questions, multiple concepts and assertion-reason efficiently.

c. garner the much needed confidence to appear for competitive exams.

d. easy and time saving methods to tackle tricky questions will help ensure that time consuming questions do not occupy more time than you can allot per question.

- ***Can the Questions presented in Problems to Ponder section be a part of the NEET Examination?***

No, the questions would not appear as it is in the NEET Examination. However, there are fair chances that these questions could be covered in parts or with a novel question construction.

Best of luck to all the aspirants!

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Note: ◑ *Part of the chapter excluded from the NEET (UG) and JEE (Main) 2024 syllabus (in index)*

Scan the adjacent QR Code in Quill - The Padhai App to view ***Question Paper and Solution of NEET (UG) 2023 (Manipur).***

Questions that are based on the concepts excluded from NEET (UG) and JEE (Main) 2024 Syllabus

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2. Scalars and Vectors 2.2 Types of vectors	Theory	-	32 and 33
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16. Wave Mechanics 16.8 Doppler effect	Theory	-	617 and 618
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Numerical Value Type Questions (NVT)	-	10	-

Note: i. *The above table contains the list of chapters/subtopics/question numbers that are excluded from the latest syllabus of NEET (UG) and JEE (Main) 2024.*

ii. *Only the concepts highlighted in italics are excluded from the latest syllabus within the specified subtopics.*

iii. *These questions are covered to give an idea about the variety and difficulty levels of questions asked in the examination over the years.*

1 Physical World and Measurement

1.1 Physics related to technology
1.2 Unit of measurement and system of units
1.3 Accuracy, precision and least count of measuring instruments
1.4 Errors in measurement
**1.5 Significant figures
1.6 Dimensions of physical quantities
1.7 Dimensional analysis and its

1.1 Physics related to technology

i. *Physics is the branch of science which deals with the study of nature and natural phenomena.*
ii. Following table shows the link between technology and basic principles of Physics:

No.	Technology	Basic Principles
i.	Rocket propulsion	Newton's laws of motion.
ii.	Aeroplane	Bernoulli's principle in fluid dynamics.
iii.	Steam engine	Laws of Thermodynamics.
iv.	Sonar	Reflection of ultrasonic waves.
v.	Electric generator	Faraday's laws of electromagnetic induction.
vi.	Hydroelectric power	Conversion of gravitational potential energy into electrical energy.
vii.	Radio and Television	Generation, propagation and detection of electromagnetic waves.
viii.	Electron microscope	Wave nature of electrons.
ix.	Optical fibres	Total internal reflection of light.
x.	Lasers	Light amplification by stimulated emission of radiation.
xi.	Computers	Digital logic
xii.	Fusion test reactor	Magnetic confinement of plasma

iii. Following table shows the contribution of physicists:

Name	Major contribution / discovery
Archimedes	Principle of buoyancy; Principle of the lever
Galileo Galilei	Law of inertia
Isaac Newton	Universal law of gravitation; Laws of motion; Reflecting Telescope
Christian Huygens	Wave theory of light
Michael Faraday	Laws of electromagnetic induction
James Clerk Maxwell	Electromagnetic theory; Light-an electromagnetic wave
Heinrich Rudolf Hertz	Generation of electromagnetic waves
J.C. Bose	Ultra short radio waves
W.K. Roentgen	X-rays
Marie Sklodowska Curie	Radium and polonium; Studies on natural radioactivity
Albert Einstein	Explanation of photoelectric effect; Theory of relativity
Victor Francis Hess	Cosmic Radiation
R.A. Millikan	Measurement of electronic charge
J.J. Thomson	Electron
Ernest Rutherford	Nuclear Model of atom
Niels Bohr	Quantum model of hydrogen atom
James Chadwick	Neutron

C.V. Raman	Inelastic scattering of light by molecules
Louis Victor de Broglie	Wave nature of matter
M.N. Saha	Thermal ionisation
S.N. Bose	Quantum statistics
Wolfgang Pauli	Exclusion principle
Enrico Fermi	Controlled nuclear fission
Werner Heisenberg	Quantum Mechanics; Uncertainty principle
Paul Dirac	Relativistic theory of electron; Quantum statistics
Edwin Hubble	Expanding Universe
Ernest Orlando Lawrence	Cyclotron
Hideki Yukawa	Theory of nuclear forces
Homi Jehangir Bhabha	Cascade process of cosmic radiation
Lev Davidovich Landau	Theory of condensed matter; Liquid helium
S. Chandrasekhar	Chandrashekhar limit, structure and evolution of stars
John Bardeen	Transistors; Theory of super conductivity
C.H. Townes	Maser; Laser
Abdus Salam	Unification of weak and electromagnetic interactions

1.2 Unit of Measurement and System of Units

i. A physical quantity is represented completely by its magnitude and unit.

Physical quantity (Q) = Magnitude × Unit = n × u

ii. As the unit (u) changes, the magnitude (n) will also change but the product 'nu' remains constant.

∴ $n \times u = \text{constant} \Rightarrow n_1u_1 = n_2u_2$

iii. **S.I. system of units:**

a. It is internationally accepted system of units based on seven fundamental units and two supplementary units.

b. Various fundamental units and supplementary units in S.I. are given below:

No.	Quantity	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
8.	Plane Angle	radian	rad
9.	Solid Angle	steradian	sr

Students can scan the adjacent QR code to get information about ***Redefining SI unit of mass; kilogram*** *with the aid of a linked video.*

CAUTION

Degree though widely used is not SI unit.

c. *Unit which is obtained from two or more fundamental units is called derived unit.* For example, joule (J) for work, newton (N) for force, pascal (Pa) for pressure etc.

iv. Practical units: Some units (though outside SI), such as litre (1 L = 1 dm^3 = 10^{-3} m^3), standard atmospheric pressure (1 atm = 1.013 × 10^5 Pa), curie (1 Ci = 3.7 × 10^{10} /s) etc. are retained for general use.

1.3 Accuracy, Precision and Least Count of Measuring Instruments

i. *Accuracy of measuring instruments is the closeness of the measurement to the true or known value.*

ii. Precision describes the limitation of measuring instruments. It gives an idea to what limit the quantity is measured by a measuring instrument.

Students can scan the adjacent QR code to get conceptual clarity about ***accuracy and precision*** *with the aid of a linked video.*

iii. *Least count (L.C.) of a measuring instrument is defined as the smallest measurement that can be made accurately with the help of that instrument.* Smaller the least count, greater is the precision.
Least count for:
a. Vernier callipers:
1. Least count of vernier calipers = 1 M.S.D. – 1 V.S.D.
2. $\text{L. C.} = \dfrac{\text{Value of samallest division on main scale}}{\text{Total number of division on vernier scale}}$
$= 0.01$ cm ….(commonly)
b. Micrometer screw gauge/Spherometer:
1. Pitch of screw = Distance covered by screw in one rotation.
2. $\text{L.C.} = \dfrac{\text{Pitch of screw}}{\text{Total number of division on circular scale}}$
$= 0.001$ cm ….(commonly)

iv. If measuring instruments possess zero error then,

Type	Meaning	Corrected reading
Negative	Zero mark on vernier/circular scale is **ahead** of the main scale zero.	Original/observed reading + zero error.
Positive	Zero mark on vernier/circular scale is **behind** the main scale zero.	Original/observed reading – zero error.

v. **Rules for rounding-off in measurement:**

If the digit to be dropped is	The preceding digit is
less than 5	left unchanged
more than 5	raised by one
5 followed by digits other than zero	raised by one
5 or 5 followed by zeroes	left unchanged, if it is even
5 or 5 followed by zeroes	raised by one, if it is odd

1.4 Errors in Measurement

i. **Absolute error (Δa):** *It is the magnitude of the difference between the mean (true) value and the measured value of the quantity.*
∴ $\Delta a_i = a_m - a_i$
Absolute errors may be positive or negative.

ii. **Mean absolute error $\left(\overline{\Delta a}\right)$:** *It is the arithmetic mean of the magnitudes of absolute errors in all the measurements of the quantity.*
∴ $\overline{\Delta a} = \dfrac{1}{n}\sum_{i=1}^{n} |\Delta a_i|$

iii. **Relative error or fractional error:** *It is the ratio of mean absolute error to the mean value of the quantity measured.*

∴ Relative error, $\delta a = \frac{|\Delta a|}{a_m}$

iv. **Percentage error:** *When the relative error is expressed in percentage, we call it as percentage error.*

∴ Percentage error $= \frac{|\Delta a|}{a_m} \times 100\%$

Combination of percentage errors:

Quantity	x	a ± b	a × b or $\frac{a}{b}$	a^n
% error	$\frac{\Delta x}{x} \times 100$	$\left(\frac{\Delta a + \Delta b}{a \pm b}\right) \times 100\%$	$\left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times 100\%$	$n\left(\frac{\Delta a}{a}\right) \times 100\%$

1.5 Significant Figures

➢ **Order of magnitude:**

i. *The order of magnitude of a physical quantity is defined as the value of its magnitude rounded - off to the nearest integral power of 10.*

ii. Any physical quantity (P) can be expressed in the form, $P = A \times 10^n$
where, 'A' is a number such that, $0.5 \le A < 5$ and 'n' is an integer, called the order of magnitude.

➢ **Significant figures:**

It is the sum of reliable digits and the first uncertain digit in the measured value of a physical quantity.

➢ **Rules for counting the number of significant figures are:**

i. All non-zero digits are significant.
ii. A zero becomes significant figure if it appears between two non-zero digits.
iii. Leading zeros or the zeros placed on the left hand side of the number are not significant.
iv. Trailing zeros or the zeros on the right hand side of the number are significant.

Smart tip - 1

i. An exact number has infinite number of significant figures. For example, 6 can be written as 6.0 or 6.00 or 6.000 and so on.
ii. Significant figures do not change if we measure a physical quantity in different units.

v. In exponential notation, the numerical portion gives the number of significant figures.

➢ **Rules for arithmetic operations with significant figures:**

i. In multiplication or division, the final result should retain as many significant figures as are there in the original number with the least significant figures.
Hence, in the example below, density should be reported to three significant figures.

Density $= \frac{6.105}{2.15\ cm^3} = 2.84\ cm^{-3}$

ii. In addition or subtraction, the final result should retain as many decimal places as are there in the number with the least decimal places.
For example, the sum of the masses 306.32 g, 227.2 g and 0.404 g by mere arithmetic addition, is 533.924 g. but the least precise decimal place. The final result should, therefore, be rounded off to 533.9 g.

1.6 Dimensions of Physical Quantities

i. *The dimensions of a physical quantity are the powers to which the fundamental unit must be raised to represent the unit of a given physical quantity.*

ii. The dimensional formula is written in terms of the dimensions of mass [M], length [L], time [T], temperature [K], electric current [A], luminous intensity [C] and amount of substance [mol].

Page no. 5 are purposely left blank.

To see complete chapter buy **Target Notes** or **Target E-Notes**

Time saver - 3

Dimensionless quantities i.e., trigonometric functions, exponential functions, logarithms, angles, pure numbers can be eliminated to simplify the equation to approach the correct answer.

Example:

Force is given by the expression F = A cos(Bx) + C cos(Dt) where x is displacement and t is time. The dimension of $\left[\frac{D}{B}\right]$ is same as that of

(A) velocity.
(B) velocity gradient.
(C) angular velocity.
(D) angular momentum.

Conventional Method:

$F = A\cos(Bx) + C\cos(Dt)$

But,

$F = A\cos\left(\frac{2\pi x}{\lambda}\right) + C\cos\left(\frac{2\pi t}{T}\right)$

on comparing we get,

$B = \frac{2\pi}{\lambda} = \text{metre}^{-1}$

and, $D = \frac{2\pi}{T} = \text{second}^{-1}$

i.e., $\frac{D}{B} = \frac{\text{second}^{-1}}{\text{metre}^{-1}} = \frac{\text{metre}}{\text{second}}$

$\therefore \left[\frac{D}{B}\right] = [\text{velocity}]$

Ans: (A)

Quick method:

Trigonometric functions being dimensionless, argument of cos is dimensionless.

$\Rightarrow [B] = \frac{1}{[x]}$ and $[D] = \frac{1}{[t]}$

$\therefore \left[\frac{D}{B}\right] = \left[\frac{x}{t}\right] = \left[\frac{L}{T}\right] = [\text{velocity}]$

Ans: (A)

➢ **Dimensions, units, formulae of some quantities:**

Quantity	Formula	Unit	Dimension
Speed	$\frac{\text{Distance}}{\text{Time}}$	ms^{-1}	$[M^0L^1T^{-1}]$
Acceleration	$\frac{\text{Change in velocity}}{\text{Time}}$	ms^{-2}	$[M^0L^1T^{-2}]$
Force	Mass × Acceleration	N (newton)	$[M^1L^1T^{-2}]$
Pressure	$\frac{\text{Force}}{\text{Area}}$	Nm^{-2}	$[M^1L^{-1}T^{-2}]$
Density	$\frac{\text{Mass}}{\text{Volume}}$	kg m^{-3}	$[M^1L^{-3}T^0]$
Work	Force × distance	joule	$[M^1L^1T^{-2}]\ [L^1] = [M^1L^2T^{-2}]$
Energy	Force × distance	joule	$[M^1L^1T^{-2}]\ [L^1] = [M^1L^2T^{-2}]$
Power	$\frac{\text{Work}}{\text{Time}}$	watt	$[M^1L^2T^{-3}]$
Momentum	Mass × Velocity	kg ms^{-1}	$[M^1L^1T^{-1}]$
Impulse	Force × Time	Ns	$[M^1L^1T^{-1}]$
Torque	$\vec{\tau} = \vec{r} \times \vec{F}$	N-m	$[M^1L^1T^{-2}]\ [L] = [M^1L^2T^{-2}]$
Moment of inertia (I)	$\sum_{i=1}^{n} m_i r_i^2$	kg m^2	$[M^1L^2T^0]$
Temperature (T)	--	kelvin	$[M^0L^0T^0K^1]$
Heat (Q)	Energy	joule	$[M^1L^2T^{-2}]$
Specific heat (c)	$\frac{Q}{m\theta}$	joule/kg-K	$[M^0L^2T^{-2}K^{-1}]$

Formulae

1. **Measure of physical quantity:** $Q = nu$

2. **Relation between numerical value and size of unit:** $n_1u_1 = n_2u_2$

3. **Average value or mean value:**

$$\bar{a}_m = \frac{a_1 + a_2 + a_3 + .. + a_n}{n} = \frac{1}{n}\sum_{i=1}^{n} a_i$$

4. **Absolute error:**

$|\Delta a| = |$ Average value – Measured value $|$

$= |a_m - a_n|$

5. **Mean absolute error:**

$$\overline{\Delta a} = \frac{|\Delta a_1| + |\Delta a_2| + ... + |\Delta a_n|}{n} = \frac{1}{n}\sum_{i=1}^{n} \Delta a_i$$

6. **Relative (fractional) error** $\delta a = \dfrac{\overline{|\Delta a|}}{a_m}$

7. **Percentage error** $= \dfrac{\overline{|\Delta a|}}{a_m} \times 100\%$

8. **Combination of percentage errors:**

a. If $x = a \pm b$ then, the percentage error in x is,

$$\frac{\Delta x}{x} \times 100 = \left(\frac{\Delta a + \Delta b}{a \pm b}\right) \times 100\%$$

b. If $x = a \times b$ or $x = \frac{a}{b}$ then, the percentage error in x is,

$$\frac{\Delta x}{x} \times 100 = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b}\right) \times 100\%$$

c. If $x = a^n$ then, the percentage error in x is,

$$\frac{\Delta x}{x} \times 100 = n\left(\frac{\Delta a}{a}\right) \times 100\%$$

➢ **To express large or small magnitudes following prefixes are used:**

Power of 10	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecta	H
10	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

➢ **A few quick conversions:**

i. Pressure:
$1\ N/m^2 = 10\ dyne/cm^2$ or
$1\ dyne/cm^2 = 0.1\ N/m^2$.

ii. Density:
$1\ kg/m^3 = 10^{-3}\ g/cm^3$ or
$1\ g/cm^3 = 10^3\ kg/m^3$.

iii. Coefficient of viscosity:
SI units is decapoise (Ns/m^2) and CGS unit is poise.
1 poise = 10^{-1} decapoise or
1 decapoise = 10 poise.

iv. Magnetic induction:
SI unit is tesla (Wb/m^2) and CGS unit is gauss.
1 gauss = 10^{-4} tesla or
1 tesla = 10^4 gauss.

v. Magnetic flux:
SI unit is weber and CGS unit is maxwell.
1 Wb = 10^8 maxwell or
1 maxwell = 10^{-8} Wb.

➢ **Practical units:**

i. Length:
1 A.U. = 1.5×10^{11} m
1 ly = 9.46×10^{15} m
1 par sec = 3.08×10^{16} m

ii. Mass:
1 metric ton = 10^3 kg
1 quintal = 10^2 kg
1 amu = 1.66×10^{-27} kg

Learning Pointers

1. A hypothesis is a supposition without assuming that it is true. An axiom is a self – evident truth while a model is a theory proposed to explain observed phenomena.

2. A dimensionless quantity has the same numeric value in all the system of units.

3. If units or dimensions of two physical quantities are same, these need not represent the same physical characteristics. For example, torque and work have the same units and dimensions but their physical characteristics are different.

Concept Building Problems

1.1 Physics Related to Technology

1. Match the following

	A		B
a.	Rocket propulsion	e.	Bernoulli's principle in fluid dynamics
b.	Aeroplane	f.	Total internal reflection of light
c.	Optical fibres	g.	Newton's laws of motion
d.	Fusion test reactor	h.	Magnetic confinement of plasma
		i.	Photoelectric effect

	(a)	(b)	(c)	(d)
(A)	g	f	e	h
(B)	g	e	f	i
(C)	i	e	f	g
(D)	g	e	f	h

2. Match the following

	A		B
a.	Michael Faraday	e.	Quantum model of Hydrogen atom
b.	Niel Bohr	f.	Laws of electromagnetic induction
c.	J.J. Thomson	g.	Discovery of Neutron
d.	Chadwick	h.	Discovery of Electron

	(a)	(b)	(c)	(d)
(A)	h	g	e	f
(B)	e	f	h	g
(C)	f	e	h	g
(D)	g	e	h	f

3. Match List-I (Fundamental Experiment) with List-II (its conclusion) and select the correct option from the choices given below the list:

	List-I		List-II
(p)	Frank-Hertz experiment	(i)	Particle nature of light
(q)	Photo-electric experiment	(ii)	Discrete energy levels of atom
(r)	Davison-Germer experiment	(iii)	Wave nature of electron
		(iv)	Structure of atom

[JEE (Main) 2015]

(A) (p) – (i) (q) – (iv) (r) – (iii)
(B) (p) – (ii) (q) – (iv) (r) – (iii)
(C) (p) – (ii) (q) – (i) (r) – (iii)
(D) (p) – (iv) (q) – (iii) (r) – (ii)

1.2 Unit of Measurement and System of Units

1. Mass can be expressed as a derived quantity in terms of
(A) Length and time
(B) Length and temperature
(C) Length, time and temperature
(D) Neither length, time and temperature.

2. **Assertion:** Parallax method cannot be used for measuring distance of stars more than 100 light years away.
Reason: For long distances, parallax angle reduces to a very small value.
(A) Assertion is True, Reason is True; Reason is a correct explanation for Assertion.
(B) Assertion is True, Reason is True; Reason is not a correct explanation for Assertion.
(C) Assertion is True, Reason is False.
(D) Assertion is False, Reason is True.

3. The unit of permittivity of free space ε_0 is
(A) (newton metre)/coulomb
(B) newton metre^2/coulomb^2
(C) coulomb^2/(newton metre^2)
(D) coulomb^2/(newton metre)^2

4. If the unit of length and force is doubled then the unit of energy is
(A) Increased 4 times
(B) Increased 8 times
(C) Increased 16 times
(D) Decreased 16 times

5. Young's modulus of a material has the same units as
(A) Strain (B) Pressure
(C) Compressibility (D) Force

6. Coefficient of thermal conductivity is the product of heat, distance and reciprocal of (area × difference in temperature × time). What would be the new value of unit coefficient of thermal conductivity if fundamental units are 5 kg, 1 decimetre, 2 K and 1 minute?
(A) 1.99×10^{-6} (B) 1.224×10^{-6}
(C) 2.34×10^{-6} (D) 1.157×10^{-6}

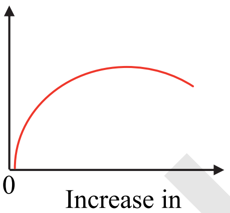
1.3 Accuracy, Precision and Least Count of Measuring Instruments

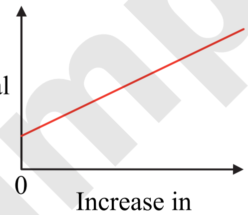
1. The accuracy of a measurement is independent of
(A) procedural errors.
(B) precision.
(C) manual errors.
(D) none of these.

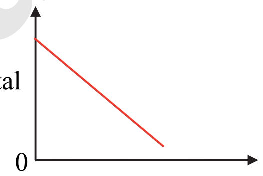
2. From the options given, the most likely reason to maintain the national standard of time interval second through four caesium atomic clocks is
   (A) having only 1 clock reduces precision.
   (B) having only 1 clock reduces accuracy.
   (C) having only 1 clock reduces accuracy and precision.
   (D) having four clocks reduce errors due to random electronic transitions.

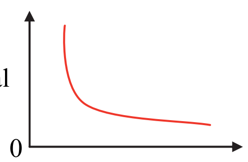
3. Rajesh has two wires each of length 2.55 m and 2.57 m. He wants to measure the difference in the length of these wires. Which of the following is the correct option to get the most accurate answer?
   (A) He should simply subtract both the values of the wire.
   (B) He should measure the difference directly keeping the wires side-by-side.
   (C) Both (A) and (B) will give him the accurate answer.
   (D) None of the above.

4. Which of the following graph indicates zero setting error in vernier calliper

(A)


(B)


(C)


(D)


5. The instrument most likely to be used for attempting to see the nucleus of oxygen molecule is
   i. optical microscope.
   ii. compound microscope.
   iii. tunneling microscope.
   iv. electron microscope.
   (A) Only (iii) (B) Only (iv)
   (C) Both (iii) and (iv) (D) All of the above

6. Two weighing machines tested against different objects with mass equivalent to a standard 1 kg mass. The readings of the two weighing machines are

	Machine A	**Machine B**
Tomato	5.61 N	9.86 N
Book	5.58 N	9.83 N
Oil	5.63 N	9.92 N
Kitten	5.52 N	9.78 N

In an experiment involving greater accuracy, one should use
   (A) Machine B
   (B) Machine A by adding zero error of 0.063
   (C) Machine B by subtracting zero error of 0.047
   (D) Machine B by adding zero error of 0.049

7. In an experiment, the angles are required to be measured using an instrument. 59 divisions of the main scale coincide with 60 divisions of the vernier scale. If the smallest division of the main scale is half a degree (= 0.5°), then the least count of the instrument is
   (A) half minute (B) one degree
   (C) half degree (D) one minute

8. The main scale of a vernier callipers has n divisions/cm. n divisions of the vernier scale coincide with (n – 1) divisions of main scale. The least count of the vernier callipers is,
[NEET (Odisha) 2019]
   (A) $\frac{1}{n(n+1)}$ cm (B) $\frac{1}{(n+1)(n-1)}$ cm
   (C) $\frac{1}{n}$ cm (D) $\frac{1}{n^2}$ cm

9. The diameter of a cylinder is measured using a vernier callipers with no zero error. It is found that the zero of the vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The vernier scale has 50 divisions equivalent to 2.40 cm. The 22^{nd} division of the vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is
   (A) 5.134 cm (B) 5.112 cm
   (C) 5.144 cm (D) 5.148 cm

10. A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a thin sheet of aluminium. Before starting the measurement, it is found that when the two jaws of the screw gauge are brought in contact, the 45th division coincides with the main scale line and that the zero of the main scale is barely visible. What is the thickness of the sheet if the main scale reading is 0.5 mm and the 25th division coincides with the main scale line? **[JEE (Main) 2016]**
(A) 0.80 mm (B) 0.70 mm
(C) 0.50 mm (D) 0.75 mm

11. A student measured the diameter of a small steel ball using a screw gauge of least count 0.001 cm. The main scale reading is 5 mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of –0.004 cm, the correct diameter of the ball is **[NEET (UG) 2018]**
(A) 0.521 cm (B) 0.525 cm
(C) 0.053 cm (D) 0.529 cm

1.4 Errors in Measurement

1. The reason behind holding thermometer in the mouth instead of the armpit is to reduce
(A) instrumental errors.
(B) procedural errors.
(C) personal errors.
(D) random errors.

2. A voltmeter reads 4.94 V for 5 V of P.D. in the first reading. In the second reading it reads 6.44 V for 6.5 V of P.D. If the error in the reading is not constant error, then what possible error it might be?
i. Personal error ii. Persistent error
iii. Instrumental error
(A) Both (i) and (ii) (B) Only (ii)
(C) Only (i) (D) Both (ii) and (iii)

3. Time intervals measured by a clock give the following readings :
1.25 s, 1.24 s, 1.27 s, 1.21 s and 1.28 s
What is the percentage relative error of the observations? **[NEET (UG) P-II 2020]**
(A) 1.6 % (B) 2 %
(C) 4 % (D) 16 %

4. In an experiment, the percentage of error occurred in the measurement of physical quantities A, B, C and D are 1%, 2%, 3% and 4% respectively. Then the maximum percentage of error in the measurement X, where $X = \dfrac{A^2 B^{\frac{1}{2}}}{C^{\frac{1}{3}} D^3}$, will be: **[NEET (UG) 2019]**
(A) –10 % (B) 10 %
(C) $\left(\dfrac{3}{13}\right)\%$ (D) 16 %

5. If the length of rod A is 3.25 ± 0.02 cm, and that of B is 4.19 ± 0.03 cm, then the rod B is longer than rod A by
(A) 0.94 ± 0.00 cm (B) 0.94 ± 0.01 cm
(C) 0.94 ± 0.02 cm (D) 0.94 ± 0.05 cm

6. The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given that length is 10.0 cm and radius is 2.0 cm, the percentage error in the calculated value of the area will be
(A) 1% (B) 2% (C) 1.5% (D) 2.5%

7. You measure two quantities as A = 1.0 m ± 0.2 m, B = 2.0 m ± 0.2 m. We should report correct value for $\sqrt{AB}$ as **[NCERT Exemplar]**
(A) 1.4 m ± 0.4 m (B) 1.41 m ± 0.15 m
(C) 1.4 m ± 0.3 m (D) 1.4 m ± 0.2 m

8. The current voltage relation of diode is given by I = $(e^{500V/T} – 1)$ mA, where the applied V is in volts and the temperature T is in degree kelvin. If a student makes an error measuring ± 0.02 V while measuring the current of 7 mA at 200 K, what will be the error in the value of current in mA?
(A) 0.4 mA (B) 0.04 mA
(C) 0.5 mA (D) 0.05 mA

9. The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\dfrac{L}{g}}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1 s resolution. The accuracy in the determination of g is **[JEE (Main) 2015]**
(A) 2 % (B) 3% (C) 1% (D) 5%

10. The density of the material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is: **[JEE (Main) 2018]**
(A) 4.5% (B) 6%
(C) 2.5% (D) 3.5%

11. The following observations were taken for determining surface tension T of water by capillary method:
diameter of capillary, D = 1.25×10^{-2} m
rise of water, h = 1.45×10^{-2} m.
Using g = 9.80 m/s^2 and the simplified relation $T = \dfrac{rhg}{2} \times 10^3$ N/m, the possible error in surface tension is closest to: **[JEE (Main) 2017]**
(A) 0.15 % (B) 1.5 %
(C) 2.4 % (D) 10 %

12. Two resistors A and B have values (3.0 ± 0.1) kΩ and (9.0 ± 0.3) kΩ respectively. If they are connected in parallel, the percentage error in the equivalent resistance is
(A) 8.33% (B) 9.16%
(C) 6.66% (D) 3.33%

1.5 Significant Figures

1. Which of the following depends only on numerical value of physical quantity and is independent of units in which it is expressed?
(A) Order of magnitude
(B) Significant figures
(C) Order of magnitude and significant figures
(D) Neither order of magnitude nor significant figures.

2. The order of magnitude of 4.9 and 51
(A) is same (B) is double
(C) differ by 1 (D) is four

3. The length of a rod is 0.5×10^2 m, the order of magnitude of the length of the rod is
(A) 3 (B) 2 (C) 1 (D) −1

4. Three measurements are made as 18.436 cm, 7.20 cm and 5.1 cm. The sum of measurements upto correct number of significant figure is
(A) 30.736 cm (B) 30.74 cm
(C) 30.73 cm (D) 30.7 cm

Mind over Matter

The key to crack this question lies in comprehending that, the equivalent resistance of the resistances in parallel is given as, $\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$.

5. The radius of a uniform wire is r = 0.021 cm. the value of π is given to be 3.142. What is the area of cross section of the wire upto approximate significant figures?
(A) 0.0014 cm^2 (B) 0.00139 cm^2
(C) 0.001386 cm^2 (D) 0.0013856 cm^2

6. Taking into account of the significant figures, what is the value of 9.99 m – 0.0099 m?
[NEET (UG) P-I 2020]
(A) 9.98 m (B) 9.980 m
(C) 9.9 m (D) 9.9801 m

7. The length of the string of a simple pendulum is 65.4 cm and the diameter of the bob is 1.24 cm. The length of the pendulum expressed in significant figures is
(A) 66.02 cm (B) 66.00 cm
(C) 66.0 cm (D) 66 cm

Mind over Matter

The key to crack this question lies in comprehending that, the effective length of the simple pendulum is the sum of length of the string and radius of the bob.

8. A vernier callipers is used to measure the side of a cube of mass 3.213 g. 10 divisions of vernier scale coincide with 9 divisions of the main scale. The smallest division of main scale is 1 mm. If the main scale reads 4.8 mm and the 2nd division of vernier scale coincides with the main scale line, then the density of cube in approximate significant figures is
(A) 26 g/cm^3 (B) 25.704 g/cm^3
(C) 25.70 g/cm^3 (D) 0.0257 g/cm^3

1.6 Dimensions of Physical Quantities

1. Dimensional formula for electrical field is.
(A) $[M^1L^2T^{-3}A^{-2}]$ (B) $[M^1L^1T^{-3}A^{-1}]$
(C) $[M^1L^2T^{-3}A^{-1}]$ (D) $[M^1L^1T^{-2}A^{-1}]$

2. Surface tension has the same dimensions as that of
(A) coefficient of viscosity
(B) spring constant
(C) momentum
(D) frequency

3. If $X^2 = 2$ YZ, then the dimension of Y in MKS system, if X and Z are the dimensions of capacity and magnetic field respectively, is
(A) $[M^{-3}L^{-2}T^{-4}A^{-1}]$ (B) $[ML^{-2}]$
(C) $[M^{-3}L^{-4}T^{10}A^{5}]$ (D) $[M^{-3}L^{-2}T^{8}A^{4}]$

4 Newton's law of viscosity is given by $F = \eta\ A\left(\frac{dv}{dx}\right)$, where, 'F' is the viscous force acting between the adjacent liquid layers of area 'A' and velocity gradient $\left(\frac{dv}{dx}\right)$. The dimensional formula for coefficient of viscosity 'η' is
(A) $[M^{-1}L^1T^1]$ (B) $[M^1L^{-1}T^{-3}]$
(C) $[M^1L^{-1}T^{-1}]$ (D) $[M^1L^{-1}T^1]$

5. Match the following two columns.

Column I		Column II	
(a)	Electrical resistance	(p)	$[M^1L^3T^{-3}A^{-2}]$
(b)	Electrical potential	(q)	$[ML^2T^{-3}A^{-2}]$
(c)	Specific resistance	(r)	$[ML^2T^{-3}A^{-1}]$
(d)	Specific conductance	(s)	None of these

(A) a – q, b – s, c – r, d – p
(B) a – q, b – r, c – p, d – s
(C) a – p, b – q, c – s, d – r
(D) a – p, b – r, c – q, d – s

6. Match the list-I with list-II

	List-I		List-II
P	Boltzmann constant	(I)	$[ML^0T^0]$
Q	Coefficient of viscosity	(II)	$[ML^{-1}T^{-1}]$
R	Water equivalent	(III)	$[MLT^{-3}K^{-1}]$
S	Coefficient of thermal conductivity	(IV)	$[ML^2T^{-2}K^{-1}]$

(A) P – III, Q – I, R – II, S – IV
(B) P – III, Q – II, R – I, S – IV
(C) P – IV, Q – II, R – I, S – III
(D) P – IV, Q – I, R – II, S – III

7. The dimensions of the ratio of magnetic flux (ϕ) and permeability (μ) are
(A) $[M^0L^1T^0A^1]$ (B) $[M^0L^{-3}T^0A^1]$
(C) $[M^0L^1T^1A^{-1}]$ (D) $[M^0L^2T^0A^1]$

1.7 Dimensional analysis and its applications

1. If r is the radius of the nucleus with A as its mass number and constant C = 1.2 f, then most likely dimensional relation between them would be
i. $r = \sqrt{CA}$ ii. $r = CA^{\frac{1}{3}}$
iii. $r = \sqrt{C^2A^{\frac{1}{3}}}$ iv. $r = \sqrt{CA^{\frac{1}{3}}}$
(A) Only (ii) (B) (ii) and (iii)
(C) (i) and (iv) (D) (ii), (iii) and (iv)

2. The gas equation is given by $\left(P + \frac{a}{V^2}\right)(V - b) = RT$.
The dimension of (a/b) are same as that of
(A) Power
(B) Force
(C) Energy
(D) Angular momentum

3. Physical quantity x depends upon y and z as x = Ay + Bz + C where A, B and C are physical constant. Which one of the following relations is incorrect?
(A) $\left[\frac{A}{B}\right] = \left[\frac{z}{y}\right]$
(B) $\left[\frac{B}{C}\right] = \left[\frac{1}{z}\right]$
(C) $[BC] = \frac{[x^2]}{[z]}$
(D) None of the above.

4. In C.G.S. system, the magnitude of the energy is 100 joule. In another system where the fundamental physical quantities are kilogram, metre and minute, the magnitude of the energy is
(A) 0.036 (B) 0.36
(C) 3.6 (D) 36

5. Find the dimensions of (a/b) in the equation $P = \frac{a - t^2}{bx}$, where P is pressure, x is distance and t is time.
(A) $[M^1L^1T^{-2}]$ (B) $[M^{-1}L^0T^2]$
(C) $[M^{-1}L^{-2}T^2]$ (D) $[M^1L^0T^{-2}]$

6. Force is given by the expression F = A cos(B*x*) + C cos(Dt) where x is displacement and t is time. The dimension of $\left[\frac{D}{B}\right]$ is same as that of
(A) velocity.
(B) velocity gradient.
(C) angular velocity.
(D) angular momentum.

7. When a wave traverses a medium, the displacement of a particle located at x at a time t is given by y = a sin(ct – dx), where a, c and d are constants of the wave. Which of the following is a quantity with dimensions?
(A) $\frac{c}{d}$ (B) ct (C) dx (D) $\frac{y}{a}$

8. If L, C and R denote the inductance, capacitance and resistance respectively, the dimensional formula for C^2 LR is
(A) $[ML^{-2}T^{-1}I^0]$ (B) $[M^0L^0T^3I^0]$
(C) $[M^{-1}L^{-2}T^6I^2]$ (D) $[M^0L^0T^2I^0]$

9. In a system of units if force (F), acceleration (A) and time (T) are taken as fundamental units, then the dimensional formula of surface tension (S) is
(A) $[FA^2T]$ (B) $[FA^{-1}T^{-2}]$
(C) $[F^2AT]$ (D) $[FAT]$

10. In dimension of critical velocity v_c, of liquid following through a tube are expressed as $(\eta^x\rho^yr^z)$, where η, ρ and r are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of x, y and z are given by **[AIPMT RE-TEST 2015]**
(A) 1, 1, 1 (B) 1, –1, –1
(C) –1, –1, 1 (D) –1, –1, –1

11. If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be **[AIPMT 2015]**
(A) $[E V^{-2}T^{-1}]$ (B) $[E V^{-1}T^{-2}]$
(C) $[E V^{-2}T^{-2}]$ (D) $[E^{-2}V^{-1}T^{-3}]$

12. If momentum (p), area (A) and time (T) are taken to be fundamental quantities, then energy has the dimensional formula **[NCERT Exemplar]**
(A) $[pA^{-1}T^1]$ (B) $[p^2AT]$
(C) $[pA^{-1/2}T]$ (D) $[pA^{1/2}T^{-1}]$

13. If the dimensions of length are expressed as $P^x c^y h^z$; where P, c and h are the pressure, speed of light and Planck's constant respectively, then
(A) $x = \frac{-1}{2}, y = \frac{1}{2}, z = \frac{1}{2}$
(B) $x = \frac{1}{2}, y = \frac{3}{2}, z = \frac{1}{2}$
(C) $x = \frac{-1}{4}, y = \frac{1}{4}, z = \frac{1}{4}$
(D) $x = \frac{1}{2}, y = \frac{3}{2}, z = \frac{-1}{2}$

14. The velocity of sound v in air depends on the pressure P and the density of air ρ. Which of the following relations is true?
(A) $v \propto \frac{P}{\rho}$ (B) $v \propto P\rho$
(C) $v \propto (\rho P)^{1/2}$ (D) $v \propto \sqrt{P/\rho}$

15. A highly rigid cubical block A of small mass M and side L is fixed rigidly on another cubical block B of the same dimensions and of modulus of rigidity η such that the lower face of A completely covers the upper face of B. The lower face of B is rigidly held on a horizontal surface. A small force F is applied perpendicular to one of the side faces of A. After the force is withdrawn, block A executes small oscillations, the frequency of which is given by
(A) $\frac{1}{2\pi}\sqrt{\frac{M}{\eta L}}$ (B) $\frac{1}{2\pi}\sqrt{\frac{\eta L}{M}}$
(C) $\frac{1}{2\pi}\sqrt{M\eta L}$ (D) $\frac{1}{2\pi}\sqrt{\frac{L}{M\eta}}$

16. The dimension of impulse is $[M^{3b} L^{2a} T^{4c}]$ then the value of 2a + 3b – 4c will be
(A) 2 (B) 1
(C) 3 (D) 4

17. Planck's constant (h), speed of light in vacuum (c) and Newton's gravitational constant (G) are three fundamental constants. Which of the following combinations of these has the dimension of length? **[NEET P-II 2016]**
(A) $\sqrt{\frac{Gc}{h^{3/2}}}$ (B) $\frac{\sqrt{hG}}{c^{3/2}}$
(C) $\frac{\sqrt{hG}}{c^{5/2}}$ (D) $\sqrt{\frac{hc}{G}}$

18. A physical quantity of the dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is universal constant of gravitation and e is charge]: **[NEET (UG) 2017]**
(A) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (B) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$
(C) $\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{1/2}$ (D) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$

19. A spherical liquid drop is placed on a horizontal plane. A small disturbance causes the volume of the drop to oscillate. The time period of oscillation (T) of the liquid drop depends on radius (r) of the drop, density (ρ) and surface tension (S) of the liquid. Which among the following will be a possible expression for T (where k is a dimensionless constant)?
(A) $k\sqrt{\frac{\rho r}{S}}$ (B) $k\sqrt{\frac{\rho^2 r}{S}}$
(C) $k\sqrt{\frac{\rho r^3}{S}}$ (D) $k\sqrt{\frac{\rho r^3}{S^2}}$

20. In the relation $J = \frac{\alpha}{\beta}e^{-\frac{\alpha x}{t}}$, J is impulse, x is the distance, and t is the time. The dimensional formula of (1/β) will be same as
(A) Energy (B) Force
(C) Surface tension (D) Power

21. If $\int \frac{dx}{\sqrt{8ax - x^2}} = a^n \sin^{-1}\left(\frac{x - 4a}{4a}\right)$, where 'x' and 'a' represent distance, then the value of 'n' using dimensional analysis is
(A) –1 (B) 1 (C) 0 (D) 2

Practice Problems

1.1 Physics Related to Technology

1. Match list I with list II and select the correct answer.

	List I		List II
i.	R.A. Millikan	a.	Wave nature of matter
ii.	Yukawa	b.	Measurement of electronic charge
iii.	de Broglie	c.	Theory of nuclear forces
iv.	Maxwell	d.	Electromagnetic theory

	i.	ii.	iii.	iv.
(A)	b	c	a	d
(B)	b	c	d	a
(C)	c	a	b	d
(D)	b	d	a	c

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11. A stone is lying in a fluid stream. The force acting on it depends on the density of the fluid, the velocity of flow and the maximum area of cross-section perpendicular to the direction of flow. The force F and the velocity v of flow are related as:

(A) $F \propto \frac{1}{v}$ (B) $F \propto v$

(C) $F \propto \frac{1}{v^2}$ (D) $F \propto v^2$

12. The position x of a particle at time t is given by $x = \frac{V_0}{a}\left(1 - e^{-at}\right)$, where V_0 is constant and $a > 0$. The dimensions of V_0 and a are

(A) $[M^0LT^0]$ and $[T^{-1}]$
(B) $[M^0LT^{-1}]$ and $[T^{-1}]$
(C) $[M^0LT^{-1}]$ and $[LT^{-2}]$
(D) $[M^0LT^{-1}]$ and [T]

Numerical Value Type Questions

1. A person measures the depth of a well by measuring the time interval between dropping a stone and hearing the sound of impact with the bottom of the well. The error in his measurement of time is 0.02 s and he measures the depth of the well to be 20 m. If the acceleration due to gravity $g = 10\ ms^{-2}$ and the velocity of sound is $340\ ms^{-1}$, then, the fractional error in the measurement of depth while falling, is _______%.
[Ans: 1.89]

2. An i-smart next generation technology in SUV suggests driver a safety speed limit in poor weather conditions. The determination of this value is based on dimensional analysis. It assumes that speed (v) depends on density (ρ) of fog, power of engine (P) and elevation of road (h). If the relation is such that v is directly proportional to $\rho^{1/n}$, value of n is _______.
[Ans: –3]

3. The current voltage relation of diode is given by $I = (e^{1000V/T} - 1)$mA, where the applied voltage V is in volt and the temperature T is in kelvin. If a student makes an error of ± 0.04 V while measuring the current of 10 mA at 297 K, the error in the value of current (in mA) will be _______.
[Ans: 1.48]

4. Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density ρ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point of the surface of the expanding sphere is proportional to R^n. The value of n is _______.
[Ans: 1]

5. The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t)$, where $\alpha = 0.5\ s^{-1}$. The measurement of A has an error of 1.25 %. If the error in the measurement of time is 1.50 %, the maximum percentage error in the value of E (t) at t = 4 s is _______ %.
[Ans: 5.5]

6. The Schrodinger equation for a free electron of mass m and energy E written in terms of the wave function ψ is $\frac{d^2\psi}{dx^2} + \frac{8\pi^2 mE}{h^2}\psi = 0$. The dimensions of the coefficient of ψ in the second term is $[M^a L^b T^n]$. Value of n is _______.
[Ans: 0]

Answers to MCQs

Concept Building Problems

1.1 : 1. (D) 2. (C) 3. (C)

1.2 : 1. (D) 2. (A) 3. (C) 4. (A) 5. (B) 6. (D)

1.3 : 1. (D) 2. (B) 3. (B) 4. (B) 5. (C) 6. (C) 7. (A) 8. (D) 9. (C) 10. (A) 11. (D)

1.4 : 1. (B) 2. (B) 3. (A) 4. (D) 5. (D) 6. (C) 7. (D) 8. (A) 9. (B) 10. (A) 11. (B) 12. (D)

1.5 : 1. (B) 2. (C) 3. (B) 4. (D) 5. (A) 6. (A) 7. (C) 8. (A)

1.6 : 1. (B) 2. (B) 3. (C) 4. (C) 5. (B) 6. (C) 7. (A)

1.7 : 1. (B) 2. (C) 3. (D) 4. (A) 5. (D) 6. (A) 7. (A) 8. (B) 9. (B) 10. (B) 11. (C) 12. (D) 13. (C) 14. (D) 15. (B) 16. (C) 17. (B) 18. (A) 19. (C) 20. (A) 21. (C)

Practice Problems

1.1 : 1. (A)

1.2 : 1. (B) 2. (D) 3. (B) 4. (B) 5. (D)

1.3 : 1. (A) 2. (C) 3. (D) 4. (C) 5. (C) 6. (A) 7. (B)

1.4 : 1. (C) 2. (B) 3. (C) 4. (B) 5. (A) 6. (D)

1.5 : 1. (A) 2. (C) 3. (C) 4. (A) 5. (A) 6. (B)

1.6 : 1. (D) 2. (C) 3. (D) 4. (C) 5. (B) 6. (D)

1.7 : 1. (B) 2. (D) 3. (A) 4. (C) 5. (C) 6. (A) 7. (B) 8. (C) 9. (C) 10. (B) 11. (D) 12. (B)

Hints to MCQs

Concept Building Problems

1.2 Unit of Measurement and System of Units

1. Because mass is a fundamental quantity.

3. $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{r^2}$

$\therefore$ $\varepsilon_0 \propto \frac{Q^2}{F\times r^2}$

So ε_0 has units of C^2/Nm^2

4. Energy = force × distance, so if both are doubled, then energy will increase by 4 times.

5. $Y = \frac{\text{Stress}}{\text{Strain}}$

$= \frac{\text{Force / Area}}{\text{Dimensionless quantity}}$

$\therefore$ Y = Pressure.

6. $K = \frac{Q\times x}{A\times\Delta\theta\times t}$

$K = \frac{\frac{m\times x^2}{t^2}\times x}{x^2\times\Delta\theta\times t}$

$K = \frac{m\times x}{\Delta\theta\times t^3}$

$= \frac{5\times 0.1}{2\times(60)^3}$

$= 1.157\times 10^{-6}$

1.3 Accuracy, Precision and Least Count of Measuring Instruments

1. Accuracy of measurement depends upon the resolution of the measuring instrument. Hence, accuracy of a measurement is compromised based on the procedural errors, manual errors and precision of the instrument used.

2. Countries maintain a network of atomic clocks which are inter compared and kept synchronized to maintain an accuracy of 10^{-9} sec per day. These clocks collectively define a continuous and stable time scale.

3. To get a more accurate answer for two nearly equal quantities, one should always measure the difference directly instead of measuring the quantities and then calculating the difference because subtraction of nearly equal quantities destroys accuracy.

4. When vernier calliper is not set properly i.e., zero reading of main scale doesn't coincide with zero reading of vernier scale then, there is always a constant error in reading of vernier calliper, deviating from its zero position. This error can be positive or negative.

5. Optical microscope and compound microscope are the basic types of microscope used to study molecules or bacteria. The resolution of such microscope is about 0.2 microns = 200 nm

Electron microscope and tunneling microscope are used at atomic level to study atoms of molecules. Electron microscope has resolution of about 50 pm and tunnelling microscope has

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4. Sum of the measurement is correct only upto one place of decimal corresponding to the least number of decimal places.

∴ $18.436 + 7.20 + 5.1 = 30.736 = 30.7$

5. Area, $A = \pi r^2 = 3.142 \times (0.021)^2$

$= 0.00138562\ \text{cm}^2$

$\approx 0.0014\ \text{cm}^2$

CAUTION

There are only two significant figures in 0.021 cm. Hence, the result must be rounded off to two significant figures.

6. Performing subtraction we get,

$9.99 - 0.0099 = 9.9801$

But number of significant digits after decimal place in 9.99 is 2 and number of significant digits after decimal place in 0.0099 is also 2. Hence, subtraction carried out should be considered upto 2 significant figures after decimal, i.e., 9.98

7. Length of simple pendulum = length of string + radius of bob

$= 65.4 + 0.62$

$= 66.02$ cm

But, since the length of string is correct only upto one decimal place,

∴ Length of simple pendulum = 66.0 cm

8. L.C of vernier callipers

$= \dfrac{\text{Smallest division on main scale}}{\text{Number of divisions in Vernier scale}}$

$= \dfrac{1}{10} = 0.1$ mm

∴ Length of side of cube = M.S.R + (L.C × V.S.D)

$= 4.8 + (0.1 \times 2)$

$= 5.0$ mm

$= 0.50$ cm

$\text{Density} = \dfrac{\text{Mass}}{\text{Volume}} = \dfrac{3.213}{(0.50)^3}$

$= 25.704\ \text{g/cm}^3$

$= 26\ \text{g/cm}^3$ ….(Rounded off to two significant digits)

1.6 Dimensions of Physical Quantities

1. Electric Field = Force/Charge

∴ $[E] = \dfrac{[MLT^{-2}]}{[AT]} = [M^1L^1T^{-3}A^{-1}]$

2. Refer *Smart tip – 2*,

$[\text{Surface tension}] = [M^1L^0T^{-2}]$

$[\text{spring constant}] = \dfrac{[\text{Force}]}{[\text{length}]}$

$= \dfrac{[M^1L^1T^{-2}]}{[L]} = [M^1L^0T^{-2}]$

3. $Y = \dfrac{X^2}{2Z} = \dfrac{\left[M^{-1}L^{-2}T^4A^2\right]^2}{\left[M^1L^0T^{-2}A^{-1}\right]} = [M^{-3}L^{-4}T^{10}A^5]$

4. $\eta = \dfrac{F}{A\left(\dfrac{dv}{dx}\right)}$

$[\eta] = \dfrac{[M^1L^1T^{-2}]}{[L^2][T^{-1}]} = [M^1L^{-1}T^{-1}]$

6. Using $k = \dfrac{PV}{T}$, $[k] = [M^1L^2T^{-2}K^{-1}]$

Using $\eta = \dfrac{F}{A} \cdot \dfrac{1}{\left(\dfrac{dv}{dx}\right)}$, $[\eta] = [M^1L^{-1}T^{-1}]$

$[w] = [M^1L^0T^0]$

[Water equivalent is defined as the amount of water that would absorb the same amount of heat as the calorimeter per degree rise in temperature.]

Using $K = \dfrac{\Delta Q}{\Delta t}\left(\dfrac{\Delta x}{\Delta T}\right) \times \dfrac{1}{A}$, $[K] = [M^1L^1T^{-3}K^{-1}]$

7. Magnetic flux = $\phi = BA$,

where, B = magnetic field, A = area

Permeability = $\mu = \dfrac{B}{H}$,

where, H = magnetic intensity

∴ $\dfrac{\phi}{\mu} = \dfrac{BA}{\left(\dfrac{B}{H}\right)}$ = Area × magnetic intensity

Now,

$[\text{Area}] = [A] = [L^2]$

Magnetic intensity $= H = nI$

$= \dfrac{\text{number of turns}}{\text{metre}} \times \text{current}$

$[H] = \left[\dfrac{A}{L}\right]$ ....(∵ [Current] = [A])

∴ $\left[\dfrac{\phi}{\mu}\right] = \left[L^2 \times \dfrac{A}{L}\right] = [LA]$

∴ $\left[\dfrac{\phi}{\mu}\right] = [M^0L^1T^0A^1]$

1.7 Dimensional Analysis and its Applications

1. r has dimensions of length, A has no dimensions and C too has dimensions of length. Hence, dimensionally correct equations are (ii) and (iii).

2. Refer *Time Saver – 1*,

In the equation, $\left(P + \dfrac{a}{V^2}\right)(V - b) = RT$

Dimensions of P and a / V^2 are same, similarly V and b have same dimensions.

Page no. **24** to 28 are purposely left blank.

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∴ $[P] = [M^1L^{-1}T^{-2}]$ ....(ii)

From equations (i) and (ii),

$\frac{1}{[ac]} = [P]$

10. Let $m \propto E^x t^y F^z$

∴ $[M^1] = [M^1L^2T^{-2}]^x [T^1]^y [M^1L^1T^{-2}]^z$

equating powers on both sides we get,

$x + z = 1$ ....(i)

$2x + z = 0$ ....(ii)

$-2x + y - 2z = 0$ ....(iii)

From equations (i) and (ii), we get,

$x = -1$

$\Rightarrow z = 2$ and $y = 2$

∴ $[m] = [E^{-1}t^2F^2]$

11. Let $F \propto d^x v^y A^z$

∴ $[M^1L^1T^{-2}] = [M^1L^{-3}]^x [L^1T^{-1}]^y [L^2]^z$

$= [M^x L^{-3x+y+2z} T^{-y}]$

∴ $x = 1, y = 2, z = 1$

$\Rightarrow F \propto v^2$

12. Refer ***Time Saver – 3***,

Power of exponential is dimensionless,

∴ $[a] = \frac{1}{[t]} = [T^{-1}]$

Also, $[x] = \frac{[V_0]}{[a]}$

∴ $[V_0] = [x][a] = [M^0L^1T^{-1}]$

Numerical Value Type Questions

1. Distance covered by the stone,

$s = \frac{1}{2}gt_1^2 = \frac{1}{2} \times 10 \times t_1^2$ ....($\because u = 0$)

$\Rightarrow t_1 = \sqrt{\frac{s}{5}}$

Time taken by sound wave reflected upward to listener after impact,

$t_2 = \frac{s}{v}$, where v = velocity of sound in air

Total error in measuring time,

$dt = dt_1 + dt_2$

$dt = \frac{1}{\sqrt{5}}\frac{1}{2}s^{-1/2}\,ds + \left(\frac{1}{340}ds\right)$

$dt = \frac{1}{2\sqrt{5}}\frac{1}{\sqrt{20}}\,ds + \frac{ds}{340}$

$0.02 = ds\left(\frac{1}{20} + \frac{1}{340}\right)$

$0.02 = ds\left(\frac{9}{170}\right)$

∴ $ds = \frac{17}{45}$

$\frac{ds}{s} \times 100 = \frac{17}{45} \times \frac{1}{20} \times 100 = \frac{17}{9} \approx 1.89\ \%$

2. Let $v = k(\rho)^x (P)^y (h)^z$, where k = constant.

$[L^1T^{-1}] = k\left[\frac{M}{L^3}\right]^x [M^1L^2T^{-3}]^y [L]^z$

$\Rightarrow$ Equating power of M, $x + y = 0$

$\Rightarrow$ Equating power of T, $-1 = -3y$

∴ $y = \frac{1}{3}$ and $x = -\frac{1}{3}$

$\Rightarrow v \propto \rho^{-1/3}$

$\Rightarrow n = -3$

3. Given: $I = e^{1000\,V/T} - 1$

$I + 1 = e^{1000\,V/T}$

Taking log on both sides, we get

$\log(I + 1) = \frac{1000\,V}{T}$

On differentiating,

$\frac{dI}{I+1} = \frac{1000}{T}dV$

$dI = \frac{1000}{T} \times (I + 1)\,dV$

$\Rightarrow dI = \frac{1000}{297} \times (10 + 1) \times 0.04 = \frac{40}{27}$ Ma = 1.48 mA

4. $m = \frac{4\pi R^3}{3} \times \rho$

On taking log both sides, we have

$\log m = \log\left(\frac{4\pi}{3}\right) + \log\rho + 3\log R$

On differentiating with respect to time,

$0 = 0 + \frac{1}{\rho}\frac{d\rho}{dt} + \frac{3}{R}\frac{dR}{dt}$

∴ $\left(\frac{dR}{dt}\right) = \frac{-R}{3} \times \frac{1}{\rho}\left(\frac{d\rho}{dt}\right)$

But, $\frac{dR}{dt} = v$

∴ $v = \frac{-R}{3} \times \frac{1}{\rho}\left(\frac{d\rho}{dt}\right)$

For $\frac{1}{\rho}\left(\frac{d\rho}{dt}\right)$ = constant

$v \propto R \Rightarrow n = 1$

5. $E(t) = A^2 e^{-\alpha t}$ ....(i)

Given: $\alpha = 0.5\ s^{-1}$, and

$\left(\frac{dA}{A}\right) \times 100 = 1.25\ \%$

$\left(\frac{dt}{t}\right) \times 100 = 1.50$

$\Rightarrow (dt \times 100) = 1.5\,t = 1.5 \times 4 = 6$

Taking log on both sides of equation (i),

$\log E = 2\log A - \alpha t$

Maximum possible error,

$$\frac{dE}{E} = 2\frac{dA}{A} + \alpha\, dt$$

$\therefore$ $$\left(\frac{dE}{E}\right) \times 100 = 2\left(\frac{dA}{A}\right) \times 100 + \alpha\,(dt \times 100)$$

$$= 2\,(1.25) + 0.5\,(6)$$
$$= 2.5 + 3$$
$$= 5.5\ \%$$

6. Dimensionally,

$$\left[\frac{mE\psi}{h^2}\right] = [M^0L^0T^0]$$

$\therefore$ $$[\psi] = \left[\frac{h^2}{mE}\right] = \frac{\left[M^1L^2T^{-1}\right]^2}{\left[M^1\right]\left[M^1L^2T^{-2}\right]} = [M^0L^2T^0]$$

$\Rightarrow n = 0$

Thinking Hatke - Q. 6

By dimensional analysis, the dimensions of each term in an equation must be the same. In the first term the second derivative with respect to distance x indicates the dimensions of the coefficient of ψ to be $[L^2]$ i.e., $[M^0L^2T^0]$

Problems To Ponder

1. Estimate the number of times a person's heart beats throughout his/her average life span.

Ans: An average person is estimated to have a life span of 80 years.

A normal heart rate ranges between 60 to 100 beats per minute. The heart rate varies due to various factors/conditions such as sleep, anxiety, stress. For calculation purpose, let us take an average value of 80 beats per minute.

We know, 1 year = 365 days in a year = 24 hours in a day = 60 minutes in an hour.

From the relation,

Minutes in a year = $1 \times 365 \times 24 \times 60$

$= 5 \times 10^5$ minutes

$\therefore$ In 80 years, there will be $(80\times5\times10^5)$ $= 4 \times 10^7$ minutes.

If a person's heart beats 80 times per minute, then it beats, $(80\times4\times10^7) = 3 \times 10^9$ times approximately in his/her life span.

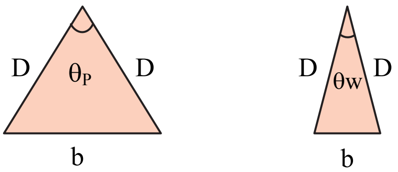
2. The parallax method of measurement can be described as below:

When an observer holds a pen in front of him against a specific point on the background wall and looks at it through right eye closing the left eye and then looks it through left eye closing the right eye, he notices the position of the pen appears to change with respect to point on the wall. This is called parallax. The distance between the two eyes is called the basis.

Considering the procedure, along with pen, the position of the wall too appears to change. If the reference itself varies its position, isn't the parallax method flawed?

Justify your answer.

Ans:



For pen **For wall**

Parallax method depends upon the apparent movement of object. If a pen is held in front of the background, then both pen and background change their positions. But as pen is held at shorter distance than the wall, the angle subtended by pen (θ_P) is greater than that subtended by wall (θ_W). As pen moves through greater angle as compared to base, the parallax method is justified.

3. Amongst two vernier callipers with different number of equal divisions on the vernier scale, one with 10 and other with 100 divisions, which one would be more accurate?

Ans: Vernier calliper with smaller least count will be more accurate. The least count of 1st calliper is $\frac{1}{10} = 0.1$ mm and of second is $\frac{1}{100} = 0.01$ mm. As second calliper has least count of 0.01 mm, it is more accurate.

4. Stem is a part of vernier callipers which is used in measuring depths of objects. While measuring the depth of a rectangular block having volume 25.5 cm³, using vernier calliper, main scale of vernier scale shows a reading of 1.7 cm and vernier scale shows a reading of 0.03 cm. If volume of rectangular block is changed to 12.5 cm³ by making its breadth double and keeping its length constant then, find the main scale reading of vernier calliper for the new depth.

Ans: $V_1 = 25.5\ cm^3$, $V_2 = 12.5\ cm^3$

$h_1 = 1.7 + 0.03 = 1.73$ cm

Given, $b_2 = 2b_1$, $l_2 = l_1$

$\therefore$ $$\frac{V_1}{V_2} = \frac{l_1 \times b_1 \times h_1}{l_2 \times b_2 \times h_2}$$

$\therefore$ $$\frac{25.5}{12.5} = \frac{l_1 \times b_1 \times 1.73}{l_1 \times 2b_1 \times h_2}$$

$$h_2 = \frac{12.5\times1.73}{2\times25.5}$$

$h_2 = 0.42$ cm

Hence, the main scale reading for new depth will be 0.42 cm.

MEMORY MAP

*Scan the adjacent **Q.R. Code** for a chapter revision video.*

PHYSICAL WORLD AND MEASUREMENT

Physics and the fundamental forces

1. Physics is the branch of science which deals with the study of nature and natural phenomena.
2. The four fundamental forces in nature are:
   i. Gravitational Force: It is the force of mutual attraction between any two objects by virtue of their masses.
   ii. Electromagnetic force: It is the force which exists between the charged particles.
   iii. Strong nuclear force: It is the force which binds protons and neutrons in a nucleus.
   iv. Weak nuclear force: It appears only in certain nuclear processes such as β-decay of a nucleus.

Unit of measurement and system of units

1. Unit of measurement:
   Physical quantity (Q) = Magnitude × Unit
2. System of units: i. CGS system: centimetre (cm), gram (g) and second (s)
   ii. MKS system: metre (m), kilogram (kg) and second (s)
   iii. FPS system: foot, pound and second
3. SI Unit:

	Fundamental Units							Supplementary Units	
Sr .No.	i.	ii.	iii.	iv.	v.	vi.	vii.	viii.	ix.
Quantity	Length	Mass	Time	Electric Current	Temperature	Amount of substance	Luminous Intensity	plane angle	Solid angle
Unit	metre (m)	kilogram (kg)	second (s)	ampere (a)	kelvin (K)	mole (mol)	candela (cd)	radian (rad)	steradian (sr)

Fundamental and derived units

1. Fundamental units: Units which can neither be derived nor be resolved into other units are called fundamental units. All fundamental units are different from one another.
2. Derived units: A unit which is obtained by multiplying or dividing two or more fundamental units is called derived unit.

Accuracy, precision and least count of measuring instruments

1. Accuracy: It is the closeness of the measurement to the true or known value.
2. Least count: It is defined as the smallest measurement that can be made accurately with the help of the instrument.
3. Precision: It is determined by the least count of the measuring instrument.
4. Rounding-off in the measurement: If digit to be dropped is:
   i. Less than 5, then preceding digit is left unchanged.
   ii. More than 5, then preceding digit is raised by one.
   iii. 5 followed by digits other than zero, then preceding digit is raised by one.
   iv. 5 or 5 followed by zeroes then preceding digit is left unchanged, if it is even.
   v. 5 or 5 followed by zeroes,then preceding digit is raised by one, if it is odd.

Errors in measurement

1. Absolute error: If $a_1, a_2, a_3, \ldots.. a_n$ are n values of a physical quantity then mean value $a_m = \dfrac{a_1 + a_2 + \ldots + a_n}{n}$ and absolute errors in the measured values of the quantity are $\Delta a_1 = a_m - a_1,\ \Delta a_2 = a_m - a_2,\ \ldots\ldots,\ \Delta a_n = a_m - a_n$
2. Mean absolute error:
   $\overline{\Delta a} = \dfrac{|\Delta a_1| + |\Delta a_2| + \ldots + |\Delta a_n|}{n}$ Hence the final result of measurement may be written as, $a = a_m \pm \overline{\Delta a}$
3. Relative error or fractional error:
   Relative error or Fractional error(δa) $= \dfrac{\text{Mean absolute error}}{\text{Mean value}} = \dfrac{|\overline{\Delta a}|}{a_m}$
4. Percentage error:
   Percentage error $= \dfrac{|\overline{\Delta a}|}{a_m} \times 100\%$

Significant figures

1. Order of magnitude: Any physical quantity (P) can be expressed in the form, $P = A \times 10^n$ where 'A' is a number such that, $0.5 \le A < 5$ and 'n' is an integer, called the order of magnitude.
2. Significant figures: i. All non-zero digits are significant.
   ii. A zero becomes significant figure if it appears between two non-zero digits.
   iii. Leading zeros or the zeros placed on the left hand side of the number are not significant.
   iv. Trailing zeros or the zeros on the right hand side of the number are significant.
   v. In exponential notation, the numerical portion gives the number of significant figures.

Dimensions of physical quantities

1. In mechanics, the dimensional formula is written in terms of the dimensions of mass, length and time [M,L,T].
2. In heat and thermodynamics, in addition to M, L and T, the dimension of temperature in kelvin [K] is to be mentioned.
3. In electricity and magnetism, in addition to M, L and T, the dimension of current or charge per unit time [I] or [A] is to be mentioned.