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MASTER THE NCERT

PHYSICS-I

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Class-XI

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ARIHANT PRAKASHAN (Series), MEERUT

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PREFACE

In the present dynamic scenario of competitions, NCERT Books are gaining importance day by day. On an average about 30% questions asked in various competitions are from NCERT. Similarly with the incorporation of Board weightage in competitions the necessity of dual synchronous preparation *i.e.,* to study NCERT for School Exams and for Competitive Exams, is increasing day by day. **Arihant's Master the NCERT Series** is framed with the philosophy of such synchronous preparation in mind.

The book consists of 15 chapters, in each of which questions are framed on each & every line of NCERT text. Some special features of Master the NCERT books which make these books stand apart from other NCERT based books are

- Each chapter has a Key Notes for quick revision of whole NCERT content.
- Each chapter has topically divided objective questions based on NCERT content to cover all the topics of NCERT text.
- Separate section in each chapter having special types questions for NEET, JEE and Other exams.
- Complete coverage of NCERT & NCERT Exemplar objective questions in each chapter.
- Detailed explanations for selected questions.

The variety in types of questions framed will be helpful in analysis of self-performance and exposures to face tough problems of competitions. **Previous Years' Medical, Engineering & Other Entrances Questions** have also been incorporated at appropriate places so that the students get the exposure of type of questions asked in various competitions on the same topic.

Huge efforts have been made from our side to keep this book error free, but inspite of that if any error or whatsoever is skipped in the book then that is purely incidental, apology for the same, please write to us about that so that it can be corrected in the further edition of the book. Suggestions for further improvement of the book will also be welcomed & incorporated in further editions.

Publisher

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CHAPTER › 01

Physical World

KEY NOTES

- The word science originates from the Latin verb *Scientia* meaning 'to know'.
- **Science** is a systematic attempt to understand natural phenomena in as much detail and depth as possible; and use the knowledge so gained to predict, modify and control the phenomena.
- The scientific method involves several steps; systematic observation, controlled experiment, qualitative and quantitative reasoning, mathematical modelling, prediction and verification or falsification of theories.
- **Physics** is a basic discipline in the category of natural sciences, which also includes other disciplines like Chemistry and Biology.
- Physics refers to the study of the physical world, i.e. the study of the basic laws of nature and their manifestation in different natural phenomena.
- In physics, we attempt to explain diverse physical phenomenon in terms of a few concepts and laws. The attempts to unify fundamental forces of nature due to which various phenomenon exists is called **unification**.
- When we try to derive the properties of a bigger, more complex system from the properties and interactions of its constituent simpler parts, this approach is called **reductionism**.

Scope and Excitement of Physics

- Macroscopic domain includes phenomena at the laboratory, terrestrial and astronomical scales. It includes the subjects like mechanics, electrodynamics, thermodynamics and optics, etc.
- Classical physics deals mainly with macroscopic phenomena and includes the following subjects
  (i) **Mechanics** founded on Newton's laws of motion and the law of gravitation is concerned with the motion (or equilibrium) of particles, rigid and deformable bodies and general systems of particles.
  (ii) **Electrodynamics** deals with electric and magnetic phenomena associated with charged and magnetic bodies.
  (iii) **Optics** deals with the phenomena involving light.
  (iv) **Thermodynamics** deals with systems in macroscopic equilibrium and is concerned with changes in internal energy, temperature, entropy, etc. of the system through external work and transfer of heat.
- The microscopic domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei and their interaction with different probes such as electrons, protons and other elementary particles.
- Everything in physics cannot be proved. There are some facts or assumptions from which we can derive certain relationships or formulae. These assumptions are called **hypothesis** or **axioms** or **postulates** and models, etc.
- A **hypothesis** is a supposition without assuming that it is true. An axiom is a self- evident truth. A model is a theory proposed to explain observed phenomena.

Physics, Technology and Society

- The connection between physics, technology and society can be seen in many examples. Sometimes technology gives rise to new physics; at other times physics generates new technology.
- The most significant area to which physics has and will contribute is the development of alternative energy resources.

Fundamental Forces in Nature

- In the macroscopic world, besides the gravitational force, we encounter several kinds of forces : muscular forces, contact forces between bodies, friction (a contact force parallel to the surfaces in contact), the forces exerted by compressed or elongates springs or taut strings and ropes (tension), etc.
- In the microscopic domain again, we have electric and magnetic forces, nuclear forces involving protons and neutrons, interatomic and intermolecular forces, etc.
- The laws for derived forces (such as spring force, friction) are not independent of the laws of fundamental forces in nature. The origin of these derived forces is however, very complex.
- The force of mutual attraction between any two objects by virtue of their masses is called **gravitational force**. It is a universal force and it acts on all objects in the universe.

  Strength $\rightarrow 10^{-39}$ and Range $\rightarrow$ Infinite
- Gravitational force plays a key role in the large scale phenomena of the universe, such as formation and evolution of stars, galaxies and galactic clusters.
- The force between two charged particles is called **electromagnetic force.** It acts over large distances and does not need any intervening medium.

  It is enormously strong as compared to gravity. This force is 10^{36} times greater than gravitational force.

  Strength $\rightarrow 10^{-2}$ and Range $\rightarrow$ Infinite
- It is mainly the electromagnetic force that governs the structure of atoms & molecules, the dynamics of chemical reactions & the mechanical and thermal & other properties of materials.
- Gravity is always attractive, while electromagnetic force can be attractive or repulsive.
- The force that binds protons and neutrons in a nucleus is called **strong nuclear force.** This is the strongest of all the fundamental forces.

  Strength $\rightarrow$ 1 and Range $\rightarrow$ Short, nuclear size ($\sim 10^{-15}$ m)
- The **weak nuclear force** appears only in certain nuclear processes such as the β-decay of a nucleus. In β-decay, the nucleus emits an electron and an uncharged particle called **neutrino**.

  Strength $\rightarrow 10^{-13}$ and Range $\rightarrow$ Very short, sub-nuclear size ($\sim 10^{-16}$ m)
- Great advances in physics often amount to unification of different theories and domains.
  - (i) Newton unified terrestrial and celestrial domains under a common law of gravitation.
  - (ii) The experimental discoveries of Oersted and Faraday showed that electric and magnetic phenomena are in general inseparable.
  - (iii) Maxwell unified electromagnetism and optics with the discovery that light is an electromagnetic wave.
  - (iv) The electromagnetic and the weak nuclear force have now been unified and are seen as aspects of a single electroweak force.

Nature of Physical Laws

- The physical quantities that remain constant in a process are called **conserved quantities.**
- When all forms of energy, e.g. heat, mechanical energy, electrical energy, etc are counted, it turns out that energy is conserved.
- The general laws of conservation of energy is true for all forces and for any kind of transformation between different forms of energy.

  It is valid across all domains of nature, from the microscopic to the macroscopic. Such as
  - (i) A chemical reaction is basically a rearrangement of atoms among different molecules. If the total binding energy of the reacting molecules is less than the total binding energy of the product molecules, the difference appears as heat and the reaction is exothermic. The opposite is true for energy absorbing (endothermic) reactions.
  - (ii) According to Einstein's theory, mass m is equivalent to energy E given by the relation $E = mc^2$, where c is speed of light in vacuum.
  - (iii) In a nuclear process, mass gets converted to energy (or *vice-versa*). This is the energy which is released in a nuclear power generation and nuclear explosions.
- Conservation laws have a deep connection with symmetries of nature.
- Symmetry of nature with respect to translation (i.e. displacement) in time is equivalent to the law of conservation of energy.
- Laws of nature are the same everywhere in the universe, while the phenomena may differ from place to place because of differing conditions at different locations.
- The symmetry of the laws of nature with respect to translation in space gives rise to conservation of linear momentum.
- In the same way, isotropy of space (no intrinsically preferred direction in space), underlies the law of conservation of angular momentum.
- Symmetries of space and time and other abstract symmetries play a central role in modern theories of fundamental forces in nature.

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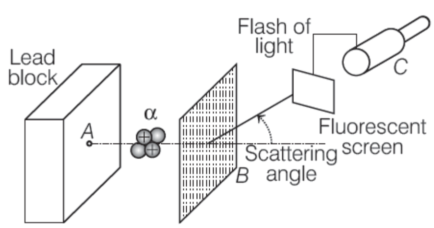
MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ Physics : Scope and Excitement

1 In 1913, Niels Bohr gave a theory on the basis of
(a) quantum theory of helium atom
(b) nuclear model of atom
(c) classical theory of helium atom
(d) classical theory of hydrogen atom

2 In Rutherford, α-scattering experiment as shown in figure.



Here, A, B and C refer to
(a) polonium sample, aluminium foil, microscope
(b) polonium sample, gold foil, microscope
(c) uranium sample, gold foil, microscope
(d) polonium sample, aluminium foil, telescope

3 Maxwell's set of equation encapsulated basic laws such as
(a) Coulomb and Oersted's laws
(b) Ampere and Faraday's laws
(c) Faraday's and Optic laws
(d) Both (a) and (b)

4 In Physics, quantitative measurement is central to the growth of science because
(a) laws of nature are expressible in precise mathematical equations
(b) basic laws universally apply in different contexts
(c) strategy of approximation turned out to be very successful
(d) All of the above

5 What is full form of GMRT?
(a) Ground Mobile Receive Terminal
(b) Geometric Mean Reciprocal Titer
(c) Giant Metrewave Radio Telescope
(d) General Maintenance and Repair Technician

TOPIC 2 ~ Fundamental Forces in Nature

6 Macroscopic forces are
(a) contact forces between bodies
(b) viscous force
(c) surface tension of a liquid
(d) All of the above

7 Forces acting on microscopic domain are
(a) electric forces (b) magnetic forces
(c) nuclear forces (d) All of these

8 The elastic spring force arises due
(a) to net attraction between the neighbouring atoms of the spring
(b) to net repulsion between the neighbouring atoms of the spring
(c) Both (a) and (b)
(d) None of the above

9 In gravitational force,
(a) there is mutual force of attraction between any two objects by virtue of their masses
(b) it is a universal force
(c) it causes formation and evolution of stars, galaxies and galactic clusters
(d) All of the above

10 Gravitational force dominates in terrestrial phenomena because
(a) masses involved are quite large
(b) distances are quite large
(c) masses are small
(d) distances are small

11 Electromagnetic force is
(a) the force between charged particles
(b) due to charges in motion
(c) 10^{36} times the gravitational force between two protons for any fixed distance
(d) All of the above

12 Electromagnetic force dominates microscopic phenomena because
(a) masses involved are quite large
(b) distances are quite large
(c) masses are small
(d) distances are small

13 Which of the following is the weakest force?
(a) Gravitational force (b) Strong nuclear force
(c) Weak nuclear force (d) Electric force

14 Electric force manifest itself in atmosphere, where
(a) atoms are non-ionised
(b) atoms are ionised and that leads to lightning
(c) atoms are ionised
(d) atoms are electrically neutral

15 When we hold a book in our hand, we are balancing the gravitational force on the book due to
(a) normal force provided by our hand
(b) friction force provided by our book
(c) Both (a) and (b)
(d) None of the above

16 Protons and neutrons are built out of
(a) neutrino (b) quarks (c) anti-neutrino (d) electron

17 The unification of electromagnetism and optics leads to the
(a) celestial and terrestrial mechanics
(b) discovery of uncertainty principle
(c) discovery of optical fibres
(d) discovery of light as an electromagnetic wave

TOPIC 3 ~ *Nature of Physical Laws*

18 For motion under an external conservative force, which quantity is conserved?
(a) Kinetic energy
(b) Mechanical energy
(c) Potential energy
(d) None of the above

19 Prior to the advent of the Einstein's theory of relativity, it was concluded that
(a) matter was thought to be indestructible
(b) total binding energy of the reacting molecules is greater than total binding energy of product molecules
(c) small change in the binding energy are too small to be measured as changes in mass
(d) All of the above

20 According to law of conservation of energy and momentum for β-decay, the existence of a new particle along with electron was predicted, which was
(a) electron (b) proton (c) neutron (d) neutrino

21 Conservation laws are such that
(a) it cannot be proved but can be verified
(b) it can neither be proved nor can be verified
(c) it can be proved and verified
(d) it can be proved but not verified

22 Energy evolved in a chemical reaction comes from
(a) conversion of mass into energy
(b) conversion of binding energy into heat energy
(c) Both (a) and (b)
(d) Neither (a) nor (b)

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. Nos. 23-26) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*
(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

23 **Assertion** Spring force, friction force, normal force, tension in rope, etc. are similar forces.
Reason They arise out of the gravitational force between the particles.

24 **Assertion** Electric force and magnetic force are jointly called electromagnetic force.
Reason Electric and magnetic effects are inseparable.

25 **Assertion** In universe, gravitational force dominates in long distance and electric force dominates in short distance.

Reason For gravitational force $\propto \frac{(\text{mass})^2}{\text{distance}^2}$ and electric force $\propto \frac{\text{charge}^2}{\text{distance}^2}$

26 **Assertion** In spite of repulsion between two protons in the nucleus, it is difficult to kick them out of the nucleus.

Reason Nuclear force is weaker than electromagnetic force.

II. Statement Based Questions

27 I. Science is ever static.

II. There is no final theory in science and no unquestioned authority among scientists.

Which of the following statement(s) is/are correct?

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

28 I. Optics deal with the phenomena involving light.

II. The efficiency of heat engines and refrigerator, the direction of a physical or chemical process, etc., involves thermodynamics.

III. Macroscopic domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei.

Which of the following statement(s) is/are incorrect?

(a) Both I and II (b) Only II (c) Only I (d) Only III

29 I. In 1938, Hahn and Meitner discovered the phenomenon of neutron-induced fission of uranium.

II. In 20th century, silicon chip triggered revolutionary changes in technology of computer system.

III. The fossil fuels of the planet are dwindling fast and there is an urgent need to discover new source of energy.

IV. The international year of physics was declared as 2005.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and II
(c) Only III (d) I, II, III and IV

30 I. Aristotle had given wrong ideas about the concept of force.

II. The corrective notion of force was arrived at by Isaac Newton in his famous laws of motion.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and II
(c) Only II (d) Neither I nor II

31 I. Strong nuclear force binds protons and neutrons in a nucleus.

II. Nuclear force is charge independent and acts equally between a proton and a proton.

III. Nuclear range is extremely small of about nuclear dimensions (10^{-15} m).

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and II
(c) Only III (d) I, II and III

32 Which of the following statement(s) is/are correct?

I. The concept of energy is central to physics and expression for energy can be written for every physical system.

II. Law of conservation of energy is not valid for all forces and for any kind of transformation between different forms of energy.

(a) Only I (b) Only II
(c) Both I and II (d) None of these

33 Which one of the following statement(s) is/are incorrect?

I. Conservation laws have a deep connection with symmetries of nature.

II. Space is heterogeneous and there is no preferred location in the universe.

(a) Only I (b) Only II
(c) Both I and II (d) None of these

34 Which of the following statement(s) is/are correct?

I. Symmetry of laws of nature with respect to translation in space give rise to conservation of linear momentum.

II. Isotropy of space underlies the law of conservation of angular momentum.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

35 Which of the following statement is incorrect?

(a) Science originates from the Greek word *Scientia* meaning ''to know''.
(b) Science is a systematic attempt to understand natural phenomena.
(c) The scientific method involves; systematic observation, controlled experiment, qualitative and quantitative reasoning, mathematical modeling, prediction and verification, etc.
(d) Physics is a study of the basic laws of nature and their manifestation in different natural phenomena.

36 Which of the following statement is correct?

(a) Physics is a basic discipline in the category of natural sciences, which does not induced other disciplines.
(b) In physics, we attempt to explain similar physical phenomena in terms of a few concepts and laws.
(c) The attempts to unify fundamental forces of nature is called unification.
(d) An approach to derive the properties of a smaller system from the properties and interactions of its bigger part is called reductionism.

37 Which of the following statement is correct?

(a) The same law of gravitation does not describes the fall of an apple to the ground, the motion of the moon around the sun.

(b) The basic laws of electromagnetism governs only magnetic phenomena.

(c) The subjects of thermodynamics, deals with bulk systems in terms of macroscopic quantities such as temperature, internal energy, entropy, etc.

(d) The subjects of kinetic energy and statistical mechanics interpreted microscopic quantities in terms of the properties of the molecular constituents of the bulk system.

38 Which of the following statement is incorrect?

(a) Physics is the study of nature and natural phenomena.

(b) Physics and technology are not related to each other.

(c) Electrodynamics deals with electric and magnetic phenomena associated with charged and magnetic bodies.

(d) The most significant area to which physics has and will contribute is the development of alternative energy resources.

39 Which of the following statement is incorrect?

(a) Classical physics deals mainly with macroscopic phenomena and includes subject like mechanics, electrodynamics, optics and thermodynamics.

(b) All physics and also mathematics, is based on assumptions, each of which is variously called hypothesis or axiom or postulate, etc.

(c) A hypothesis is a supposition with assuming that it is true.

(d) An axiom is a self-evident truth while a model is a theory proposed to explain observed phenomena.

40 Which of the following statement is incorrect?

(a) The universal law of gravitation proposed by Newton is an assumption or hypothesis.

(b) Universal law of gravitation can be verified and substantiated by experiments and observations.

(c) Einstein's special theory of relativity is also based on two postulates, the constancy as the speed of electromagnetic radiation and the validity of physical laws in all inertial frame of reference.

(d) Euclid's statement that parallel lines never meet is a supposition with assuming that it is true.

41 Which of the following statement is correct?

(a) Technology gives rise to new physics.

(b) Wireless communication followed the discovery of basic laws of electricity and magnetism.

(c) Bohr had dismissed the possibility of tapping energy from atoms.

(d) Both (a) and (b)

42 Which of the following statement is correct?

(a) The laws for derived forces are independent as the laws of fundamental forces in nature.

(b) Like gravitational force, electromagnetic force acts over large distances and does not need any intervening medium.

(c) Gravity is always attractive while electromagnetic force is repulsive.

(d) The weak nuclear force is not as weak as electromagnetic force but weaker than the strong nuclear force.

43 Which of the following statement is incorrect?

(a) Some special physical quantities, however remain constant in time. They are the conserved quantities of nature.

(b) The law of conservation of energy is thought to be valid across all domains of nature, from the microscopic to the macroscopic.

(c) All conserved quantities are scalars.

(d) Symmetry of nature with respect to translation (i.e. displacement) in time is equivalent to the law of conservation of energy.

44 Which of the following statement is correct?

(a) Conservation of energy, momentum, angular momentum, charge, etc, are considered to be fundamental laws in physics.

(b) The phenomena are the same everywhere in the universe.

(c) Law of gravitation is different on the moon and the earth.

(d) Symmetries of space and time and other abstract symmetries does not play a central role in modern theories as fundamental forces in nature.

III. Matching Type

45 Match the Column I (domains) with Column II (relation) and select the correct answer from the codes given below.

	Column I		Column II
A.	Mechanics	1.	electric and magnetic fields
B.	Electrodynamics	2.	macroscopic equilibrium
C.	Thermodynamics	3.	minute scales of atoms and nuclei
D.	Microscopic	4.	Newton's law of motion

	A	B	C	D		A	B	C	D
(a)	4	2	3	1	(b)	4	1	2	3
(c)	1	2	4	3	(d)	2	3	1	4

46 Match the Column I (physical quantities) with Column II (scale) and select the correct answer from the codes given below.

	Column I		Column II
A.	Size of electron or proton	1.	10^{-30} kg
B.	Mass of an electron	2.	10^{-14} m
C.	Extent of universe	3.	10^{26} m
D.	Mass of observable universe	4.	10^{55} kg

	A	B	C	D
(a)	2	1	3	4
(b)	2	3	1	3
(c)	4	1	3	2
(d)	2	1	2	3

47 Match the Column I (name of physicists) with Column II (contribution/discovery) and select the correct answer from the codes given below.

Column I	Column II
A. Galileo Galilei	1. explanation of photoelectric effect
B. JC Bose	2. law of inertia
C. Albert Einstein	3. discovery of ultra short radiowaves
D. JJ Thomson	4. discovery of electron

	A	B	C	D
(a)	2	3	1	4
(b)	1	2	4	3
(c)	1	2	3	4
(d)	3	4	1	2

48 Match the Column I (name of physicists) with Column II (contribution/discovery) and select the correct answer from the codes given below.

Column I	Column II
A. SN Bose	1. discovery of neutron
B. James Chadwick	2. contribution in quantum statistics
C. John Bardeen	3. theory of superconductivity and transistors
D. Abdus Salam	4. unification of weak and electromagnetic interactions

	A	B	C	D
(a)	2	1	3	4
(b)	1	2	4	3
(c)	4	3	2	1
(d)	1	4	3	2

49 Match the Column I (technology) with Column II (scientific principle) and select the correct answer from the codes given below.

Column I	Column II
A. Nuclear reactor	1. photoelectric effect
B. Rocket propulsion	2. reflection of ultrasonic waves
C. SONAR	3. controlled nuclear fission
D. Photocell	4. Newton's laws of motion

	A	B	C	D
(a)	1	3	2	4
(b)	3	1	2	4
(c)	1	2	3	4
(d)	3	4	2	1

50 Match the Column I (force) with Column II (relative strength) and select the correct answer from the codes given below.

Column I	Column II
A. Gravitational force	1. 10^{-13}
B. Weak nuclear force	2. 1
C. Electromagnetic force	3. 10^{-2}
D. Strong nuclear force	4. 10^{-39}

	A	B	C	D
(a)	4	1	3	2
(b)	4	1	2	3
(c)	1	3	2	4
(d)	4	2	3	1

Answers

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1 (b)	2 (b)	3 (d)	4 (d)	5 (c)	6 (d)	7 (d)	8 (c)	9 (d)	10 (a)
11 (d)	12 (d)	13 (a)	14 (b)	15 (a)	16 (b)	17 (d)	18 (b)	19 (a)	20 (d)
21 (a)	22 (b)								

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23 (c)	24 (a)	25 (a)	26 (c)	27 (b)	28 (d)	29 (d)	30 (b)	31 (d)	32 (a)
33 (b)	34 (c)	35 (a)	36 (c)	37 (d)	38 (b)	39 (c)	40 (d)	41 (d)	42 (b)
43 (c)	44 (a)	45 (b)	46 (a)	47 (a)	48 (a)	49 (d)	50 (a)		

Hints & Explanations

1 (*b*) Using the result of experiment of scattering of alpha particles by gold foil, in 1911 Ernest Rutherford established the nuclear model of the atom. This nuclear model then became the basis of the quantum theory of hydrogen atom given by Niels Bohr in 1913.

10 (*a*) Gravitational force becomes very high in terrestrial and astronomical phenomena because the bodies involved are huge like planets, stars, etc.

Their masses are quite large and gravitational force is proportional to products of masses involved.

12 (*d*) At microscopic level, it is electromagnetic force which dominates gravitational force. The reason is that the distance between bodies under electromagnetic force is very small at this level.

13 (*a*) Gravitational force is the weakest among these forces. The correct order of strength of four fundamental forces is

Gravitational force < Weak nuclear force < Electromagnetic force < Strong nuclear force

15 (*a*) When we hold a book in our hand, we are balancing the gravitational force on the book due to the huge mass of the earth by the 'normal force' provided by our hand.

17 (*d*) The unification of electromagnetism and optics is done by James Clerk Maxwell in 1873. It showed that light is an electromagnetic wave.

18 (*b*) For motion under an external conservative force, the total mechanical energy, i.e. the sum of kinetic and potential energy of a body is a constant. The familiar example is the free fall of an object under gravity.

19 (*a*) Until the advent of Einstein's theory of relativity, the law of conservation of mass was regarded as basic conservation law of nature, since matter was thought to be indestructible.

A chemical reaction is basically a rearrangement of atoms among different molecules. If the total binding energy of the reacting molecules is less than the total binding energy of the product molecules, the difference appears as heat.

However, since the atoms are merely rearranged but not destroyed, the total mass of the reactants is the same as the total mass of the products in a chemical reaction. The change in the binding energy are too small to be measured as changes in mass.

20 (*d*) Using the conservation laws of energy and momentum for β-decay, Wolfgang Pauli (1900-1958) correctly predicted in 1931, the existence of a new particle called neutrino emitted in β-decay along with the electron.

21 (*a*) A conservation law is a hypothesis based on observation and experiments. It is important to remember that a conservation law cannot be proved. It can be verified or disproved by experiments.

23 (*c*) The origin of spring force, friction force, normal force, tension in rope is electromagnetic force

which is one of the four fundamental forces found in nature.

Therefore, Assertion is correct but Reason is incorrect.

24 (*a*) Charges in motion produces magnetic effects and a magnetic field gives rise to a force on a moving charge. So, electric and magnetic effects are inseparable.

Therefore, it is named as electromagnetic force.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

25 (*a*) Gravitational force $= \dfrac{k\, m_1\, m_2}{r^2}$. In case of

measurement regarding stars and galaxies, gravitational force dominates due to large mass of stars, etc.

And electric force $= \dfrac{k\, q_1\, q_2}{r^2}$ is due to infinite-simal

small distances, thus electric field dominates at microscopic level.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

26 (*c*) Nuclear force which is attractive in nature at nuclear level keeps all the protons together in the nucleus in spite of their mutual repulsion. So, it is difficult to kick them out of the nucleus.

This is because these are stronger than the electromagnetic force.

Therefore, Assertion is correct but Reason is incorrect.

27 (*b*) Statement II is correct but I is incorrect and it can be corrected as,

Science is ever dynamic.

28 (*d*) Statement III is incorrect and it can be corrected as, The macroscopic domain of physics includes phenomenon at the laboratory, terrestrial and astronomical scales.

Rest statements are correct.

32 (*a*) Statement I is correct but II is incorrect and it can be corrected as,

the general law of conservation of energy is valid for all forces and for any kind of transformation between different forms of energy.

33 (*b*) Statement I is correct but II is incorrect and it can be corrected as,

Space is homogeneous and there is no preferred location in the universe i.e. the laws of nature are the same everywhere in the universe.

35 (*a*) The statement given in option (a) is incorrect and it can be corrected as,

The word science originates from the Latin verb *Scientia* meaning ''to know''.

36 (*c*) Statement given in option (c) is correct and rest are incorrect and these can be corrected as,

Physics is a basic discipline in the category of natural sciences, which also includes other disciplines like Chemistry and Biology. The word physics comes from a Greek word meaning nature.

In physics, we attempt to explain diverse physical phenomena in terms of a few concepts and laws.

A related effect is to derive the properties of a bigger, more complex system from the properties and interactions of its constituent simpler parts. This approach is called reductionism.

37 (*d*) Statement given in option (d) is correct and rest are incorrect and these can be corrected as,

The same law of gravitation (given by Newton) describes the fall of an apple to the ground, the motion the of moon around the earth and the motion of planets around the sun.

Similarly, the basic laws of electromagnetism (Maxwell's equations) governs all electric and magnetic phenomena.

The subjects of thermodynamics, deals with bulk systems in terms of microscopic quantities such as temperature, internal energy, entropy, etc.

38 (*b*) The statement given in option (b) is incorrect and it can be corrected as,

Physics and technology are related with each other, like the discipline of thermodynamics arose from the need to understand and improve the working of heat engines.

Sometimes technology gives rise to new physics, at other times physics generates new technology.

39 (*c*) The statement given in option (c) is incorrect and it can be corrected as,

A hypothesis is a supposition without assuming that it is true.

40 (*d*) The statement given in option (d) is incorrect and it can be corrected as,

Euclid's statement that parallel lines never meet is a hypothesis. This means that, if we suppose this without assuming it is true, then with this statement, we can explain several properties of straight lines.

41 (*d*) Both statements given in options (a) and (b) are correct but statement in option (c) is incorrect, which can be is corrected as,

The Ernest Rutherford had dismissed the possibility of tapping energy from atoms.

42 (*b*) The statement given in option (b) is correct, rest are incorrect and these can be corrected as,

The laws for derived forces (such as spring force, friction) are not independent of the law of fundamental forces in nature.

Gravity is always attractive while electromagnetic force can be attractive or repulsive.

The weak nuclear force is not as weak as the gravitational force, but much weaker than the strong nuclear and electromagnetic forces.

43 (*c*) The statement given in option (c) is incorrect and it can be corrected as,

All conserved quantities are not necessarily scalars.

44 (*a*) Only statement given in option (a) is correct, rest are incorrect. These can be corrected as,

The laws of nature are the same everywhere in the universe. The phenomena may differ from place to place because of different conditions at different locations.

e.g. the acceleration due to gravity at the moon is one-sixth that at the earth, but the law of gravitation is the same both on the moon and the earth.

Symmetries of space and time and other abstract symmetries play a central role in modern theories of fundamental forces in nature.

45 (*b*) Mechanics founded on Newton's laws of motion and the law of gravitation is concerned with the motion (or equilibrium) of particles, rigid and deformable bodies and general systems of particles.

Electrodynamics deals with electric and magnetic phenomena associated with charged and magnetic bodies.

Thermodynamics in contrast to mechanics, does not deal with the motion of bodies as a whole. Rather, it deals with systems in macroscopic equilibrium and is concerned with changes in internal energy, temperature, entropy, etc., of the system through external work and transfer of heat.

The microscopic domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei.

Hence, $A \rightarrow 4$, $B \rightarrow 1$, $C \rightarrow 2$ and $D \rightarrow 3$.

CHAPTER > 02

Units and Measurements

KEY NOTES

- All the quantities which are used to describe the laws of physics are called physical quantities, e.g. length, mass, volume, etc.
- Physical quantities are of two types, first is **fundamental quantities** which are independent of other physical quantities and second is **derived quantities** which can be derived from the fundamental quantities.

Units

- Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, internationally accepted reference standard called **unit**.
- The units which are used to represent fundamental quantities are called **fundamental** or **base units**.
  However, the unit of derived quantities which are represented in terms of fundamental units are called **derived units**.
- Some of the commonly used systems of units for measurement with the base units for length, mass and time are given as
  (i) **CGS system** (Centimetre, Gram and Second, respectively)
  (ii) **FPS system** (Foot, Pound and Second, respectively)
  (iii) **MKS system** (Metre, Kilogram and Second, respectively)

International System of Units (SI)

- The system of units which is at present internationally accepted for measurement is the international system of units.
- This system contains 7 fundamental units and 2 supplementary units which are tabulated as follows.

Fundamental units

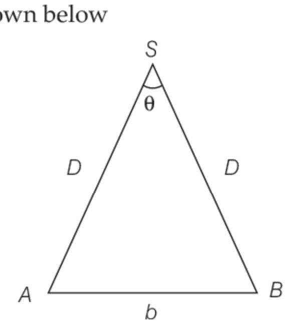
Fundamental quantity	Fundamental unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary units

Supplementary quantity	Supplementary unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

Measurement of Length

- There are two methods for the measurement of length as follows.
  (i) **Direct Method** In this method, measurement of length involves the use of
    (a) a metre scale (10^{-3} to 10^{2} m)
    (b) Vernier callipers (upto 10^{-4} m)
    (c) screw gauge and spherometer (upto 10^{-5} m)
  (ii) **Indirect Method** This method is used to measure large distances such as the distance of planet or a star from the earth. e.g **Parallax method**, etc.
- The apparent shift in the position of an object with respect to another when we shift our eye sidewise is called **parallax**. The distance between two points of observation is called the **basis**.
- While measuring the distance D of a far away planet S by the parallax method observing from two different positions (A and B) as shown below



We get, $D = \frac{b}{\theta}$, where θ is called the **parallax angle** or **parallactic angle**.

- Some special units of length for **measurement of short lengths** are as follows

  1 fermi (f) $= 10^{-15}$ m

  1 angstrom (Å) $= 10^{-10}$ m
- Some special units of length for **measurement of large lengths** are as follows

  1 astronomical unit (1 AU) $= 1.496 \times 10^{11}$ m

  1 light year (ly) $= 9.46 \times 10^{15}$ m

  1 parsec $= 3.08 \times 10^{16}$ m

Measurement of Mass

- For measuring mass of atoms and molecules, we use **unified atomic mass unit** (u), where

  1 atomic mass unit (u) $= 1.66 \times 10^{-27}$ kg

  Other units that are used for measuring mass are
  (i) Pound = 0.4536 kg
  (ii) Slug = 14.59 kg
- Large masses in universe like planets, stars, etc. based on Newton's law of gravitation can be measured by using **gravitational method**.
- Small masses of atomic/subatomic particles, etc. can be measured by the use of **mass spectrograph**.

Measurement of Time

- To measure any time interval, we use atomic standard of time, which is based on the periodic vibrations produced in a cesium atom.

  This is the basis of the cesium clock, called **atomic clock**.
- This clock has very high accuracy of part in 10^{3}.

Accuracy, Precision of Instruments and Errors of Measurement

- The **accuracy** of a measurement is a measure of how close the measured value is to the true value, while **precision** tells us to what resolution the quantity is measured.
- Difference in the true value and the measured value of a quantity is called **error of measurement**.
- The errors in measurement can be broadly classified as systematic and random errors
  (i) The **systematic errors** are those errors that tend to be in one direction, either positive or negative. Some sources of systematic errors are given as
    (a) **Instrumental Errors** It arises due to imperfect design or calibration of the measuring instrument.
    (b) **Imperfection in Experimental Technique or Procedure** It occurs due to external conditions such as change in temperature, humidity, wind velocity, pressure, etc. during experiment.
    (c) **Personal Errors** It arises due to an individual's bias, lack of proper setting of the apparatus or individual's carelessness in taking observations without observing proper precautions.
  (ii) The **random errors** are those errors which occur irregularly and hence are random with respect to sign.
- The **least count error** is the error associated with the resolution of the instrument. It occurs with both random and systematic errors.

- The smaller the least count, greater is the precision for a measuring instrument.
- Some mathematical terms used for error calculations are given below

(i) **Absolute Error** The magnitude of the difference between the individual measurement and the true value of the quantity is called the absolute error of the measurement.

The absolute error in individual measurement value from the true value are

$$|\Delta a_1| = |a_1 - a_{\text{mean}}|, \ |\Delta a_2| = |a_2 - a_{\text{mean}}|$$

and $|\Delta a_n| = |a_n - a_{\text{mean}}|$

where, $a_{\text{mean}} = \dfrac{a_1 + a_2 + a_3 + \ldots + a_n}{n}$

(ii) **Mean Absolute Error** The arithmetic mean of all the absolute errors is taken as the final or mean absolute error of the value of the physical quantity a and represented by Δa_{mean}.

$$\therefore \quad \Delta a_{\text{mean}} = \frac{|\Delta a_1| + |\Delta a_2| + \ldots + |\Delta a_n|}{n}$$

(iii) **Fractional or Relative Error** The relative error is the ratio of the mean absolute error Δa_{mean} to the mean value of a_{mean} of the quantity measured.

i.e. Relative error $= \dfrac{\Delta a_{\text{mean}}}{a_{\text{mean}}}$

(iv) **Percentage Error** When the relative error is expressed in per cent, it is called percentage error δa.

$$\therefore \quad \delta a = \frac{\Delta a_{\text{mean}}}{a_{\text{mean}}} \times 100\%$$

Combination of Errors

Combination of the errors in various mathematical operations are as follows

(i) **Error of a Sum or a Difference** When two quantities are added or subtracted, the absolute error in the final result is the sum of the absolute error in the individual quantities.

If $Z = A + B$ or $Z = A - B$, then error ΔZ is given by

$$\pm \Delta Z = \pm \Delta A \pm \Delta B$$

However, the maximum value of the error ΔZ is given as

$$\Delta Z = \Delta A + \Delta B$$

(ii) **Error of a Product or a Quotient** When two quantities are multiplied or divided, the relative error in the result is the sum of the relative errors in the multipliers.

If $\quad Z = AB$ or $\dfrac{A}{B}$,

then $\quad \dfrac{\Delta Z}{Z} = \pm\left(\dfrac{\Delta A}{A} + \dfrac{\Delta B}{B}\right)$

The maximum relative error, $\dfrac{\Delta Z}{Z} = \dfrac{\Delta A}{A} + \dfrac{\Delta B}{B}$

(iii) **Error in Case of a Measured Quantity Raised to a Power** The relative error in a physical quantity raised to the power k is the k times the relative error in the individual quantity.

If $\quad Z = \dfrac{A^p B^q}{C^r}$,

then $\quad \dfrac{\Delta Z}{Z} = p\left(\dfrac{\Delta A}{A}\right) + q\left(\dfrac{\Delta B}{B}\right) + r\left(\dfrac{\Delta C}{C}\right)$

Significant Figures

- For a number which is the result of a measurement, the digits that are known reliable plus the first uncertain digits are known as **significant digits** or **significant figures**.
- A choice of change of different units does not change the number of significant digits or figures in a measurement.
- **Rules for determining significant figures**

(i) All the non-zero digits are significant.

(ii) All the zeros between two non-zero digits are significant, no matter where the decimal point is, if at all.

(iii) If the number is less than 1, the zeros on the right of decimal point but to the left of the first non-zero digit are not significant.

e.g. In $\underline{0.00}2308$, the underlined zeros are not significant. The zero between 3 and 8 is significant.

So, the number of significant figures are 4.

(iv) The terminal or trailing zeros in a number without a decimal point are not significant.

Thus, 123 m = 12300 cm = 123000 mm has three significant figures.

(v) The trailing zeros in a number with a decimal point are significant.

The numbers 3.500 or 0.06900 have four significant figures each.

(vi) For a number greater than 1, without any decimal, the trailing zeros are not significant.

- To remove the ambiguities in determining the number of significant figures, every number is expressed as $a \times 10^b$, where a is number between 1 and 10 and b (known as to be **order of magnitude**) is any positive or negative exponent (or power) of 10.

Such type of notation is called **scientific notation.**

- Rules for arithmetic operations with significant figures are as follows
  (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.
  (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.

Rounding Off

- The process of omitting the non-significant digits and retaining only the desired number of significant digits, in corporating the required modifications to the last significant digit is called **rounding off** the number.
- **Rules for rounding off a measurement**
  (i) If the number lying to the right of cut-off digit is less than 5, then the cut-off digit is retained as such. However, if it is more than 5, then the cut-off digits is increased by 1.
  e.g. $x = 5.34$ is rounded off to 5.3 to two significant digits and $x = 5.328$ is rounded off to 5.33 to three significant digits.
  (ii) If the insignificant digit to be dropped is 5, then the rule is
  (a) If the preceding digit is even, the insignificant digit is simply dropped, e.g. $x = 6.265$ is rounded off to to $x = 6.26$ to three significant digits.
  (b) If the preceding digit is odd, the preceding digit is raised by 1. e.g. $x = 6.275$ is rounded off to $x = 6.28$ to three significant digits.
- **Rules for determining the uncertainty in the results of arithmetic calculations**
  (i) If a set of experimental data is specified to n-significant figures, a result obtained by combining the data will also be valid to n-significant figures.
  (ii) The relative error of a value of number specified to significant figures depend not only on number of significant figures but also on the number itself.
  (iii) Intermediate results in a multi-step computation should be calculated to one and more significant figures in every measurement than the number of digits in the least precise measurement.

Dimensions Analysis

- **Dimensions** of any physical quantity are those powers which are raised on fundamental units to express the unit of that physical quantity.
- Dimensional symbols of seven fundamental quantities are given as Length $\rightarrow$ [L], Mass $\rightarrow$ [M], Time $\rightarrow$ [T], Electric current $\rightarrow$ [A], Temperature $\rightarrow$ [K], Luminous intensity $\rightarrow$ [cd], Amount of substance $\rightarrow$ [mol].
- **Dimensional formula** of a physical quantity is an expression which shows how and which of the fundamental quantities represent the dimensions.
- An equation obtained by equating a physical quantity with its dimensional formula is called the **dimensional equation** of the physical quantity.
- **Principle of Homogeneity of Dimensions** Only those physical quantities can be added or subtracted which have same dimensions.
- **Applications of dimensions**
  (i) To check the correctness of any physical quantity.
  (ii) To convert any physical quantity from one system of units to another system of units.
  $$n_1u_1 = n_2u_2$$
  where, n_1 & n_2 are the magnitudes and u_1 & u_2 are the units of any physical quantity in two systems of units.
  (iii) To find a relation between interdependent physical quantities.

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ International System of Units

1 Amongst the following physical quantities which one has the same unit in all three system of units?
(a) Length
(b) Mass
(c) Time
(d) None of the above

2 The solid angle subtended by the periphery of an area 1 cm^2 at a point situated symmetrically at a distance of 5 cm from the area is
(a) 2×10^{-2} sr (b) 4×10^{-2} sr
(c) 6×10^{-2} sr (d) 8×10^{-2} sr

3 If the value of work done is $10^{10}\text{gcm}^2\text{s}^{-2}$, then its value in SI units will be
(a) $10\text{ kg-m}^2\text{s}^{-2}$ (b) $10^2\text{ kg-m}^2\text{s}^{-2}$
(c) $10^4\text{ kg-m}^2\text{s}^{-2}$ (d) $10^3\text{ kg-m}^2\text{s}^{-2}$

4 The unit of thermal conductivity is ***NEET 2019***
(a) $\text{J m}^{-1}\text{K}^{-1}$ (b) W mK^{-1} (c) $\text{W m}^{-1}\text{K}^{-1}$ (d) J mK^{-1}

5 The damping force on an oscillator is directly proportional to the velocity. The unit of the constant of proportionality is ***CBSE AIPMT 2012***
(a) kg-ms^{-1} (b) kg-ms^{-2} (c) kgs^{-1} (d) kg-s

TOPIC 2 ~ Measurement of Length, Mass and Time

6 The moon is observed from two diametrically opposite points A and B on earth. The angle θ subtended at the moon by the two directions of observation is $1°54'$; given that the diameter of the earth to be about 1.276×10^7m. Compute the distance of the moon from the earth.
(a) 4.5×10^9 m (b) 3.83×10^8 m
(c) 2.5×10^4 m (d) 4×10^7 m

7 The ratio of the volume of the atom to the volume of the nucleus is of the order of
(a) 10^{15} (b) 10^{25}
(c) 10^{20} (d) 10^{10}

8 Which of the technique is not used for measuring small time intervals?
(a) Electrical oscillator
(b) Atomic clock
(c) Spring oscillator
(d) Decay of elementary particles

9 Age of the universe is about 10^{10} yr, whereas the mankind has existed for 10^6 yr. For how many seconds would the man have existed, if age of universe were 1 day?
(a) 9.2 s (b) 10.2 s
(c) 8.6 s (d) 10.5 s

TOPIC 3 ~ Accuracy, Precision of Instruments and Errors in Measurement

10 To reduce the least count error, instruments need higher
(a) precision (b) accuracy
(c) mean value (d) true value

11 A device which is used for measurement of length to an accuracy of about 10^{-4}m, is
(a) screw gauge (b) spherometer
(c) vernier callipers (d) Either (a) or (b)

12 Two clocks are being tested against a standard clock located in a national laboratory. At 12:00:00 noon by the standard clock, the readings of the two clocks are

	Clock 1	Clock 2
Monday	12 : 00 : 05	10 : 15 : 06
Tuesday	12 : 01 : 15	10 : 14 : 59
Wednesday	11 : 59 : 08	10 : 15 : 18
Thursday	12 : 01 : 50	10 : 15 : 07
Friday	11 : 59 : 15	10 : 14 : 53
Saturday	12 : 01 : 30	10 : 15 : 24
Sunday	12 : 01 : 19	10 : 15 : 11

If you are doing an experiment that requires precision time interval measurements, which amongst the two clocks will you prefer?

(a) Clock 1
(b) Clock 2
(c) Either (a) and (b)
(d) Neither (a) nor (b)

13 In successive experiments while measuring the period of oscillation of a simple pendulum. The readings turn out to be 2.63 s, 2.56 s, 2.42 s, 2.71s and 2.80 s. Calculate the mean absolute error.

(a) 0.11 s (b) 0.42 s
(c) 0.92 s (d) 0.10 s

14 While performing some experiments, five readings are observed as : 80.0, 80.5, 81.0, 81.5 and 82. Calculate the mean percentage error in these observations. ***AIIMS 2019***

(a) 0.74% (b) 1.74%
(c) 0.38% (d) 1.36%

15 The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 20 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 1s resolution. What is the percentage error in the determination of g?

(a) 5% (b) 3%
(c) 4% (d) 7%

16 Calculate the relative errors in measurement of two masses 1.02 g $\pm$ 0.01g and 9.89g $\pm$ 0.01g .

(a) $\pm$ 1% and $\pm$ 0.2%
(b) $\pm$ 1% and $\pm$ 0.1%
(c) $\pm$ 2% and $\pm$ 0.3%
(d) $\pm$ 3% and $\pm$ 0.4%

17 The density of a 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) 2.5% (b) 3.5%
(c) 4.5% (d) 6%

18 The following observations were taken for determining surface tension T of water by capillary method. Diameter of capillary, $d = \mathbf{1.25} \times 10^{-2}$ m rise of water, $h = \mathbf{1.45} \times 10^{-2}$ m. Using $g = 9.80\ \text{m/s}^2$ and the simplified relation $T = \frac{rhg}{2} \times 10^3\ \text{N/m}$, the possible error in surface tension is closest to ***JEE Main 2017 (Offline)***

(a) 1.5 % (b) 2.4 %
(c) 10 % (d) 5 %

19 A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stop watch with 1s resolution measures the time taken for 40 oscillations to be 50 s. The accuracy in g is ***JEE Main 2020***

(a) 2.40 % (b) 5.40 %
(c) 4.40 % (d) 3.40 %

20 Two resistors of resistances $R_1 = 100 \pm 3\Omega$ and $R_2 = 200 \pm 4\Omega$ are connected in parallel. The equivalent resistance of the parallel combination is

(a) $(66 \pm 1)\Omega$ (b) $(66.7 \pm 1.8)\Omega$
(c) $(66.3 \pm 2)\Omega$ (d) $(67 \pm 3)\Omega$

21 For a conducting wire, its resistance, $R = 65 \pm 1\ \Omega$, length, $l = 5 \pm 0.1$ mm and diameter, $d = 10 \pm 0.5$ mm. Find error in calculation of its resistivity. ***JIPMER 2018***

(a) 21% (b) 13% (c) 16% (d) 41%

22 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 error in the measurement of X, where $X = \frac{A^2 B^{1/2}}{C^{1/3} D^3}$ will be ***NEET (National) 2019***

(a) 16% (b) -10%
(c) 10% (d) $\left(\frac{3}{13}\right)\%$

23 In an experiment, four quantities a, b, c and d are measured with percentage error 1%, 2%, 3% and 4%, respectively. Quantity P is calculated as follows

$P = \frac{a^3 b^2}{cd}$, percentage error in P is ***NEET 2013***

(a) 14% (b) 10%
(c) 7% (d) 4%

TOPIC 4 ~ *Significant Figures*

24 In 4700 m, significant figures are

(a) 2 (b) 3
(c) 4 (d) 5

25 The number of significant figures in the numbers 4.8000×10^4 and 48000.50 are respectively,

(a) 5 and 6 (b) 5 and 7
(c) 2 and 7 (d) 2 and 6

26 Each side of a cube is measured to be 7.203 m. What are the total surface area and the volume of the cube to appropriate significant figures?

(a) $373.7 \text{ m}^2, 311.3 \text{ m}^3$ (b) $311.3 \text{ m}^2, 373.7 \text{ m}^3$
(c) $273.4 \text{ m}^2, 342.4 \text{ m}^3$ (d) $423.4 \text{ m}^2, 437.4 \text{ m}^3$

27 5.74 g of a substance occupies 1.2 cm^3. Express its density by keeping the significant figures in view.

(a) 4.9 g cm^{-3} (b) 5.2 g cm^{-3}
(c) 4.8 g cm^{-3} (d) 4.4 g cm^{-3}

28 Find the value of 12.9 g − 7.06 g. Keeping significant figures in consideration.

(a) 5.84 g (b) 5.8 g (c) 5.86 g (d) 5.9 g

29 If 3.8×10^{-6} is added to 4.2×10^{-5}, then the result in significant figures will be

(a) 4.58×10^{-5} (b) 4.6×10^{-5}
(c) 45×10^{-5} (d) None of these

30 The numbers 5.355 and 5.345 on rounding off to 3 significant figures will give

(a) 5.35 and 5.34 (b) 5.36 and 5.35
(c) 5.35 and 5.35 (d) 5.36 and 5.34

31 The relative error in the value of a number specified to significant figures depends on

(a) number of significant figure
(b) number itself
(c) Both (a) and (b)
(d) None of the above

TOPIC 5 ~ *Dimensional Analysis*

32 The quantity having same dimension as that of Planck's constant is

(a) work (b) linear momentum
(c) angular momentum (d) impulse

33 Which set of physical quantities has same dimensions?

(a) Force and power (b) Torque and energy
(c) Torque and power (d) Force and torque

34 Dimensions of force are ***JIPMER 2018***

(a) $[\text{M}^2\text{LT}^{-1}]$ (b) $[\text{MLT}^{-2}]$
(c) $[\text{M}^2\text{L}^{-1}\text{T}^{-2}]$ (d) $[\text{MLT}^{-1}]$

35 If mass M, distance L and time T are fundamental quantities, then dimensions of torque are ***JIPMER 2019***

(a) $[\text{ML}^2\text{T}^{-2}]$ (b) $[\text{MLT}^{-2}]$ (c) $[\text{MLT}]$ (d) $[\text{MLT}^2\text{T}]$

36 A quantity f is given by $f = \sqrt{\frac{hc^5}{G}}$, where c is speed of light, G universal gravitational constant and h is the Planck's constant. Dimension of f is that of ***JEE Main 2020***

(a) area (b) volume
(c) momentum (d) energy

37 Obtain the dimensional formula for universal gas constant.

(a) $[\text{M L}^2 \text{T}^{-2} \text{mol}^{-1} \text{K}^{-1}]$ (b) $[\text{ML}^3 \text{T}^{-1} \text{mol}^{-2} \text{K}^{-2}]$
(c) $[\text{M}^2 \text{LT}^{-1} \text{mol}^{-1} \text{K}^{-1}]$ (d) $[\text{M}^3 \text{LT}^{-2} \text{mol}^{-1} \text{K}^{-2}]$

38 The dimension of stopping potential V_0 in photoelectric effect in units of Planck's constant h, speed of light c and gravitational constant G and ampere A is ***JEE Main 2020***

(a) $h^{-2/3}c^{-1/3}G^{4/3}A^{-1}$ (b) $h^{1/3}G^{2/3}c^{1/3}A^{-1}$
(c) $h^2G^{3/2}c^{1/3}A^{-1}$ (d) $h^{2/3}c^{5/3}G^{1/3}A^{-1}$

39 If speed (V), acceleration (A) and force (F) are considered as fundamental units, the dimension of Young's modulus will be ***JEE Main 2019***

(a) $[\text{V}^{-4}\text{A}^{-2}\text{F}]$ (b) $[\text{V}^{-2}\text{A}^2\text{F}^2]$
(c) $[\text{V}^{-2}\text{A}^2\text{F}^{-2}]$ (d) $[\text{V}^{-4}\text{A}^2\text{F}]$

40 If surface tension (S), moment of inertia (I) and Planck's constant (h), were to be taken as the fundamental units, the dimensional formula for linear momentum would be ***JEE Main 2019***

(a) $S^{1/2}I^{1/2}h^{-1}$ (b) $S^{3/2}I^{1/2}h^0$
(c) $S^{1/2}I^{1/2}h^0$ (d) $S^{1/2}I^{3/2}h^{-1}$

41 The force of interaction between two atoms is given by $F = \alpha\beta \exp\left(-\frac{x^2}{\alpha kT}\right)$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimension of β is **JEE Main 2019**

(a) $[MLT^{-2}]$ (b) $[M^0L^2T^{-4}]$
(c) $[M^2LT^{-4}]$ (d) $[M^2L^2T^{-2}]$

42 The potential energy of a particle varies with distance x from a fixed origin as $U = \frac{A\sqrt{x}}{x+B}$, where A and B are constants. The dimensions of AB are

(a) $[ML^{5/2}\ T^{-2}]$ (b) $[ML^2\ T^{-2}]$
(c) $[M^{3/2}L^3\ T^{-2}]$ (d) $[ML^{7/2}\ T^{-2}]$

43 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 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) $\frac{1}{c^2}\left[\frac{e^2}{G\,4\pi\varepsilon_0}\right]^{1/2}$ (d) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$

44 In the formula, $X = 3YZ^2$, X and Z have dimensions of capacitance and magnetic induction. The dimensions of Y in MKSQ system are **AIIMS 2018**

(a) $[M^{-3}L^{-2}T^4Q^4]$ (b) $[ML^2T^8Q^4]$
(c) $[M^{-2}L^{-3}T^2Q^4]$ (d) $[M^{-2}L^{-2}TQ^2]$

45 If energy E, velocity v and time T are chosen as the fundamental quantities, the dimensional formula of surface tension will be **CBSE AIPMT 2015**

(a) $[Ev^{-2}T^{-1}]$ (b) $[Ev^{-1}T^{-2}]$
(c) $[Ev^{-2}T^{-2}]$ (d) $[E^2v^{-1}T^{-3}]$

46 The expression for viscous force F acting on a tiny steel ball of radius r moving in a viscous liquid of viscosity η with a constant speed v with the help of the method of dimensional analysis is

(a) $kr\eta v$ (b) $kr^2\eta v$
(c) $kr\eta v^{3/2}$ (d) $kr\eta^2 v$

47 If dimensions of critical velocity v_c of a liquid flowing through a tube are expressed as $[\eta^x\rho^y r^z]$, 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 **CBSE AIPMT 2015**

(a) $1, -1, -1$ (b) $-1, -1, 1$
(c) $-1, -1, -1$ (d) $1, 1, 1$

48 Given that the amplitude of the scattered light is
(i) directly proportional to amplitude of incident light
(ii) directly proportional to the volume of the scattering dust particle
(iii) inversely proportional to its distance from the scattering particle and
(iv) dependent upon the wavelength λ of the light.
Then, the relation of intensity of scattered light with the wavelength is

(a) $\frac{1}{\lambda^2}$ (b) $\frac{1}{\lambda^4}$
(c) $\frac{1}{\lambda^6}$ (d) $\frac{1}{\lambda^7}$

49 The density of a material in CGS system is $10\ \text{g cm}^{-3}$. If unit of length becomes 10 cm and unit of mass becomes 100 g, the new value of density will be

(a) 10 units (b) 100 units
(c) 1000 units (d) 1 unit

50 Find the value of power of 60 J per min on a system that has 100 g, 100 cm and 1 min as the base units.

(a) 2.16×10^4 units
(b) 2.16×10^6 units
(c) 3×10^4 units
(d) 4×10^7 units

51 When 1 m, 1 kg and 1 min are taken as the fundamental units, the magnitude of the force is 36 units. What will be the value of this force in CGS system?

(a) 10^5 dyne (b) 10^3 dyne
(c) 10^8 dyne (d) 10^4 dyne

52 In a new system of units, unit of mass is α kg, unit of length is β metre and unit of time is γ second. In this system, 10 J will be represented as

(a) $10\alpha^{-1}\beta^2\gamma^2$ (b) $10\alpha^{-2}\beta^{-1}\gamma^{-2}$
(c) $10\alpha^{-1}\beta^{-2}\gamma^2$ (d) $10\alpha\beta^2\gamma^{-2}$

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

- **Direction** (Q. Nos. 53-59) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

53 **Assertion** The unit used for measuring nuclear cross-section is 'barn'.

Reason 1 barn = 10^{-14} m^2.

54 **Assertion** Parallax method is used for measuring distances of nearby stars only.

Reason With increase in the distance of star from earth, the parallactic angle becomes too small to be measured accurately.

55 **Assertion** When we look at the pencil first through our left eye and then through the right eye, we will notice that the position of pencil seems to be changed.

Reason The distance between the two points of observation is called the basis.

56 **Assertion** Random errors arise due to random and unpredictable fluctuations in experimental conditions.

Reason Random errors occurred due to irregularly with respect to sign and size.

57 **Assertion** When a quantity appears with a power n greater than one in an expression, its error contribution to the final result decreases n times.

Reason In all mathematical operations, the errors are of additive in nature.

58 **Assertion** The method of dimensions analysis cannot validate the exact relationship between physical quantities in any equation.

Reason It does not distinguish between the physical quantities having same dimensions.

59 **Assertion** Special functions such as trigonometric, logarithmic and exponential functions are dimensionless.

Reason A pure number, ratio of similar physical quantities, such as angle and refractive index, has no dimensions.

II. Statement Based Questions

60 I. Unit should be of suitable size.
II. Unit should not be easily reproducible.
III. Unit should not change with the changing physical conditions like temperature, pressure, etc.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and III
(c) Only II (d) I, II and III

61 Consider the following rules of significant figures.
I. All the non-zero digits are significant.
II. All the zeros between two non-zero digits are significant.
III. The terminal or trailing zero(s) in a number without a decimal point are significant.

Which of the above statement(s) is/are correct?

(a) Both I and II (b) Both II and III
(c) Both I and III (d) I, II and III

62 I. Volumetric strain and coefficient of friction are dimensionless quantities.
II. Disintegration constant of a radioactive substance and frequency of light wave both have same dimensions .
III. Heat capacity and gravitational potential both have different dimensions.

Which of the following statement(s) is/are correct?

(a) Both I and II (b) Both I and III
(c) I, II and III (d) Both II and III

63 Which amongst the following statement is incorrect regarding mass?

(a) Its SI unit is kilogram.
(b) It does not depend on the location of the object in space.
(c) It is the basic property of matter.
(d) While dealing with atoms, kilogram is a convenient unit for measuring mass.

64 Choose the correct statement.

(a) The smaller the least count, greater is the precision.
(b) The greater the least count, greater is the precision.
(c) The smaller the least count, smaller is the precision.
(d) Precision does not depend upon least count.

65 Choose the correct statement.

(a) Error in a measurement is equal to the sum of true value and measured value of the quantity.
(b) Systematic errors occur in both directions, positive and negative.
(c) Random errors occur irregularly and at random, in magnitude and direction.
(d) In constant errors, errors affect each observation by the different amount.

66 Choose the incorrect statement.
(a) Change in unit does not change the number of significant figure.
(b) In 4.700 m = 4700 mm a change of significant figure occur from 4 to 2 due to change in unit.
(c) In 4.700 m = 4.700×10^3 cm, there is no change in the number of significant figures.
(d) None of the above

III. Matching Type

67 Match the Column I (physical quantity) with Column II (unit) and select the correct answer from the codes given below.

Column I		Column II
A. Capacitance	1.	Am^2
B. Inductance	2.	Wb
C. Magnetic flux	3.	Coulomb $(volt)^{-1}$
D. Magnetic moment	4.	Ohm-second

	A	B	C	D
(a)	3	4	2	1
(b)	1	2	4	3
(c)	3	2	1	4
(d)	4	1	3	2

68 Match the Column I (unit) with Column II (value) and select the correct answer from the codes given below.

Column I		Column II
A. 1 barn	1.	200 mg
B. 1 are	2.	1.013×10^5 Pa
C. 1 bar	3.	10^2 m^2
D. 1 carat	4.	10^{-28} m^2

	A	B	C	D
(a)	3	2	1	4
(b)	3	4	2	1
(c)	4	3	2	1
(d)	4	3	1	2

69 Match the Column I (type of errors) with Column II (cause) and select the correct answer from the codes given below.

Column I		Column II
A. Instrumental errors	1.	External conditions such as change in temperature, humidity, etc.
B. Imperfection in experimental technique	2.	Person's carelessness
C. Personal errors	3.	Either positive or negative in one direction.
D. Systematic errors	4.	Imperfect design or calibration of the measuring instruments.

	A	B	C	D
(a)	4	1	2	3
(b)	4	2	3	1
(c)	2	1	4	3
(d)	4	1	3	2

70 Match the Column I (number) with Column II (number of significant figures) and select the correct answer from the codes given below.

Column I		Column II
A. 0.004608	1.	3
B. 8.9000	2.	5
C. 186	3.	6
D. 2.00891	4.	4

	A	B	C	D
(a)	1	4	2	3
(b)	4	2	1	3
(c)	3	4	1	2
(d)	4	2	1	3

71 Match the Column I (physical quantity) with Column II (dimension) and select the correct answer from the codes given be low.

Column I		Column II
A. Boltzmann constant (k)	1.	$[ML^2 T^{-1}]$
B. Coefficient of viscosity (η)	2.	$[ML^{-1} T^{-1}]$
C. Planck constant (h)	3.	$[MLT^{-3} K^{-1}]$
D. Thermal conductivity (K)	4.	$[ML^2 T^{-2} K^{-1}]$

	A	B	C	D
(a)	3	2	1	4
(b)	4	2	1	3
(c)	4	1	3	2
(d)	1	4	2	4

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

72 If $G = 6.67 \times 10^{-11}$ N-m^2 kg^{-2}, then the value of G in CGS system of units is

(a) 6.67×10^{-8} (b) 6.67×10^{-9}
(c) 6.67×10^{-10} (d) 6.67×10^{-11}

73 A new unit of length is chosen in which length is equals to the speed of light in vacuum is taken as unity. If light takes 8 min 20 s to reach from the surface of the sun to the earth, find the distance in terms of new unit.

(a) 200 units (b) 300 units (c) 400 units (d) 500 units

74 Which of the following is the most precise device for measuring length?

(a) A vernier callipers with 20 divisions on the sliding scale
(b) A screw gauge of pitch 1 mm and 100 divisions on the circular scale
(c) An optical instrument that can measure length to within a wavelength of visible light
(d) Both (b) and (c)

75 The number of significant figures in 0.007 m^2, 0.2370 g cm^{-3} and 6.032 Nm^{-2} respectively are

(a) 3, 4, 4 (b) 1, 4, 4 (c) 4, 5, 4 (d) 1, 3, 4

76 The length, breadth and thickness of a rectangular sheet of metal are 4.234 m, 1.005 m and 2.01 cm, respectively. Give the area and volume of the sheet to correct significant figures.

(a) 8.7 m^2, 0.092 m^3 (b) 8.4 m^2, 0.095 m^3
(c) 9.2 m^2, 0.001^3 (d) 8.72 m^2, 0.0855 m^3

77 The mass of a box measured by a grocer's balance is 2.3 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is (i) the total mass of the box (ii) and the difference in the mass of the pieces to correct significant figures?

(a) 2.8 kg, 0.08 g (b) 2.9 kg, 0.02 g
(c) 2.3 kg, 0.02 g (d) 3.0 kg, 0.02 g

78 A physical quantity P is related to four observations a, b, c and d as follows : $P = a^3 b^2 / \sqrt{c} \cdot d$

The percentage errors of measurement in a, b, c and d are 1%, 3%, 4% and 2%, respectively. What is the percentage error in the quantity P? If the value of P calculated using the above relation turns out to be 3.763, to what value should you round off the result?

(a) 10%, 3.76 (b) 13%, 3.87
(c) 10%, 3.8 (d) 13%, 3.8

79 A book with many printing errors contains four different formulae for the displacement y of a particle under going a certain periodic motion.

I. $y = a \sin \dfrac{2\pi t}{T}$

II. $y = a \sin vt$

III. $y = \left(\dfrac{a}{T}\right) \sin (t/a)$

IV. $y = \left(\dfrac{a}{\sqrt{2}}\right)\left(\sin \dfrac{2\pi t}{T} + \cos \dfrac{2\pi t}{T}\right)$

where, a = maximum displacement of the particle, v = speed of the particle, T = time period of motion. Which are the correct formulae on dimensional grounds?

(a) I, II and III (b) Both III and II
(c) Both I and IV (d) Both II and I

80 A parsec is a convenient unit of length on the astronomical scale. It is the distance of an object that will show a parallax of 1″(second of arc) from opposite ends of a base line equal to the distance from the earth to the sun. How much is parsec in terms of metres?

(a) 1.495×10^{11} m (b) 3.08×10^{16} m
(c) 4.85×10^{-6} m (d) 2.05×10^{16} m

81 The sun is a hot plasma (ionised matter) with its inner core at a temperature according 10^7 K and its outer surface at a temperature of about 6000 K. At these high temperatures, no substance remains in a solid or liquid phase. In what range do you expect the mass density of the sun to be? (Take, mass of the sun $= 2.0 \times 10^{30}$ kg and radius of the sun $= 7.0 \times 10^8$ m)

(a) 1.4×10^3 kg m^{-3} (b) 1.6×10^3 kg m^{-3}
(c) 2×10^3 kg m^{-3} (d) 4×10^3 kg m^{-3}

82 When the planet jupiter is at a distance of 824.7 million kilometres from the earth, its angular diameter is measured to be 35.72 s of arc. The diameter of jupiter is

(a) 3.5×10^6 km (b) 2.7×10^6 km
(c) 1.4×10^5 km (d) 1.7×10^7 km

83 It is claimed that two cesium clocks, if allowed to run for 100 years without any disturbance may differ by only about 0.02 s. What is the accuracy of the clock in measuring a time interval of 1s?

(a) 10^{-10} (b) 10^{-11} (c) 10^{-5} (d) 10^{-8}

NCERT Exemplar

84 The number of significant figures in 0.06900 is
(a) 5 (b) 4 (c) 2 (d) 3

85 The sum of the numbers 436.32, 227.2 and 0.301 in appropriate significant figures is
(a) 663.821 (b) 664
(c) 663.8 (d) 663.82

86 The mass and volume of a body are 4.237 g and 2.5 cm^3, respectively. The density of the material of the body in correct significant figures is
(a) 1.6048 g cm^{-3} (b) 1.69 g cm^{-3}
(c) 1.7 g cm^{-3} (d) 1.695 g cm^{-3}

87 The numbers 2.745 and 2.735 on rounding off to 3 significant figures will give
(a) 2.75 and 2.74 (b) 2.74 and 2.73
(c) 2.75 and 2.73 (d) 2.74 and 2.74

88 The length and breadth of a rectangular sheet are (16.2 ± 0.1) cm and (10.1 ± 0.1) cm, respectively. The area of the sheet in appropriate significant figures and error is
(a) $(164 \pm 3) \text{ cm}^2$
(b) $(163.62 \pm 2.6) \text{ cm}^2$
(c) $(163.6 \pm 2.6) \text{ cm}^2$
(d) $(163.62 \pm 3) \text{ cm}^2$

89 Which of the following pairs of physical quantities does not have same dimensional formula?
(a) Work and torque
(b) Angular momentum and Planck constant
(c) Tension and surface tension
(d) Impulse and linear momentum

90 Measure of two quantities alongwith the precision of respective measuring instrument is
$A = 2.5 \text{ ms}^{-1} \pm 0.5 \text{ ms}^{-1}$ and $B = 0.10 \text{ s} \pm 0.01$ s. The value of AB will be
(a) (0.25 ± 0.08) m (b) (0.25 ± 0.5) m
(c) (0.25 ± 0.05) m (d) (0.25 ± 0.135) m

91 You measure two quantities as $A = 1.0 \text{ m} \pm 0.2$ m, $B = 2.0 \text{ m} \pm 0.2$ m. We should report correct value for $\sqrt{AB}$ as
(a) (1.4 ± 0.4) m (b) (1.41 ± 0.15) m
(c) (1.4 ± 0.3) m (d) (1.4 ± 0.2) m

92 Which of the following measurement is most precise?
(a) 5.00 mm (b) 5.00 cm (c) 5.00 m (d) 5.00 km

93 The mean length of an object is 5 cm. Which of the following measurements is most accurate?
(a) 4.9 cm (b) 4.805 cm (c) 5.25 cm (d) 5.4 cm

94 Young's modulus of steel is $1.9 \times 10^{11} \text{ Nm}^{-2}$. When it is expressed in CGS units of dyne cm^{-2}, it will be equal to ($1\text{N} = 10^5$ dyne and $1 \text{ m}^2 = 10^4 \text{cm}^2$)
(a) 1.9×10^{10} (b) 1.9×10^{11} (c) 1.9×10^{12} (d) 1.9×10^{13}

95 If momentum p, area A and time T are taken to be fundamental quantities, then energy has the dimensional formula **JIPMER 2019**
(a) $[pA^{-1}T^1]$ (b) $[p^2AT]$ (c) $[pA^{-1/2}T]$ (d) $[pA^{1/2}T^{-1}]$

96 In the expression $P = EL^2 m^{-5} G^{-2}$, where E, m, l and G denote energy, mass, angular momentum and gravitational constant, respectively.
The dimensions of P are
(a) $[MLT^0]$ (b) $[M^2LT^{-1}]$
(c) $[M^0L^0T^0]$ (d) $[M^0LT^{-2}]$

Answers

> Mastering NCERT with MCQs

1 (c)	2 (b)	3 (d)	4 (c)	5 (c)	6 (b)	7 (a)	8 (c)	9 (c)	10 (a)
11 (c)	12 (b)	13 (a)	14 (a)	15 (b)	16 (b)	17 (c)	18 (a)	19 (c)	20 (b)
21 (b)	22 (a)	23 (a)	24 (a)	25 (b)	26 (b)	27 (c)	28 (b)	29 (b)	30 (d)
31 (c)	32 (c)	33 (b)	34 (b)	35 (a)	36 (d)	37 (a)	38 (*)	39 (d)	40 (c)
41 (c)	42 (d)	43 (a)	44 (a)	45 (c)	46 (a)	47 (a)	48 (b)	49 (b)	50 (b)
51 (b)	52 (c)								

> Special Types Questions

53 (c)	54 (a)	55 (b)	56 (b)	57 (d)	58 (a)	59 (b)	60 (b)	61 (a)	62 (a)
63 (d)	64 (a)	65 (c)	66 (b)	67 (a)	68 (c)	69 (a)	70 (b)	71 (b)	

> NCERT & NCERT Exemplar MCQs

72 (a)	73 (d)	74 (c)	75 (b)	76 (d)	77 (c)	78 (d)	79 (c)	80 (b)	81 (a)
82 (c)	83 (b)	84 (b)	85 (c)	86 (c)	87 (d)	88 (a)	89 (c)	90 (a)	91 (d)
92 (a)	93 (a)	94 (c)	95 (d)	96 (c)					

Hints & Explanations

2 (*b*) Given, $dA = 1\,\text{cm}^2$ and $r = 5\,\text{cm}$

$\therefore$ Solid angle, $d\Omega = \dfrac{dA}{r^2} = \dfrac{1}{(5)^2}$

$= 0.04\,\text{sr} = 4 \times 10^{-2}\,\text{sr}$

3 (*d*) Given, work done, $W = 10^{10}\,\text{gcm}^2\text{s}^{-2}$ which is in CGS system of units.

In SI unit, $W = 10^{10}\,\dfrac{\text{g}}{\text{s}^2}\text{cm}^2 = 10^{10}\,\dfrac{(10^{-3}\,\text{kg})(10^{-4}\,\text{m}^2)}{1\,\text{s}^2}$

$= 10^3\,\text{kg-m}^2\text{s}^{-2}$

4 (*c*) The coefficient of thermal conductivity is given by

$$K = \frac{L}{A\Delta T}\frac{dQ}{dt}$$

where, L = length of conductor, A = area of conductor, ΔT = change in temperature

and $\dfrac{dQ}{dt}$ = rate of flow of heat.

$\therefore$ Unit of $K = \dfrac{\text{metre}}{(\text{metre})^2 \times (\text{kelvin})} \times \text{watt} = \text{Wm}^{-1}\text{K}^{-1}$

5 (*c*) Given, damping force $\propto$ velocity

$$F \propto v \Rightarrow F = kv$$

where, k = constant of proportionality.

$\Rightarrow \qquad k = \dfrac{F}{v}$

$\therefore \qquad$ Unit of $k = \dfrac{\text{Unit of } F}{\text{Unit of } v} = \dfrac{\text{kg-ms}^{-2}}{\text{ms}^{-1}} = \text{kg s}^{-1}$

6 (*b*) We have, $\theta = 1°54' = (60 + 54)' = 114' = (114 \times 60)''$

Since, $\quad 1'' = 4.85 \times 10^{-6}$ rad

$= (114 \times 60)'' \times (4.85 \times 10^{-6})$ rad

$= 3.33 \times 10^{-2}$ rad

Also, diameter of earth, $b = 1.276 \times 10^7$ m

Hence, the earth-moon distance is given as

$$D = b/\theta = \frac{1.276 \times 10^7}{3.33 \times 10^{-2}} = 3.83 \times 10^8\ \text{m}$$

7 (*a*) We know that, radius of atom, $r_a = 10^{-10}$ m

Radius of nucleus, $r_n = 10^{-15}$ m

$\therefore \qquad$ Ratio, $\dfrac{r_a}{r_n} = \dfrac{10^{-10}}{10^{-15}} = 10^5$

Ratio of volume $= \dfrac{\frac{4}{3}\pi r_a^3}{\frac{4}{3}\pi r_n^3} = \left(\dfrac{r_a}{r_n}\right)^3 = (10^5)^3 = 10^{15}$

8 (*c*) Since, frequency of spring oscillator is smallest among all the given options, hence small time interval cannot be measured with **spring oscillator.**

9 (*c*) Given, age of mankind $= 10^6$ yr

and age of universe $= 10^{10}$ yr

Magnification in time $= \dfrac{\text{Age of mankind}}{\text{Age of universe}} = \dfrac{10^6}{10^{10}} = 10^{-4}$

$\therefore$ Apparent age of mankind

$= 10^{-4} \times 1\,\text{day} = 10^{-4} \times 86400\,\text{s}$

$= 8.64\,\text{s} \approx 8.6\,\text{s}$

12 (*b*) The range of variation of time over the seven days of observations is 162 s for clock 1 and 31 s for clock 2.

The average reading of clock 1 is much closer to the standard time than the average reading of clock 2. The important point is that a clock's zero error is not as significant for precision work as its variation. It is because the zero error can be easily corrected.

Hence, clock 2 is to be preferred over clock 1.

13 (*a*) The mean period of oscillation of the pendulum,

$$T_{\text{mean}} = \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5}$$

$$= \frac{13.12}{5} = 2.624 = 2.62\,\text{s}$$

The absolute errors in the measurements are

$\Delta T_1 = 2.63\,\text{s} - 2.62\,\text{s} = 0.01\,\text{s}$

$\Delta T_2 = 2.56\,\text{s} - 2.62\,\text{s} = -0.06\,\text{s}$

$\Delta T_3 = 2.42\,\text{s} - 2.62\,\text{s} = -0.20\,\text{s}$

$\Delta T_4 = 2.71\,\text{s} - 2.62\,\text{s} = 0.09\,\text{s}$

$\Delta T_5 = 2.80\,\text{s} - 2.62\,\text{s} = 0.18\,\text{s}$

The arithmetic mean of all the absolute errors is

$$\Delta T_{\text{mean}} = \sum_{i=1}^{5} \frac{|\Delta T_i|}{5}$$

$= [(0.01 + 0.06 + 0.20 + 0.09 + 0.18)]/5$

$= 0.54/5 = 0.108 \simeq 0.11\,\text{s}$

14 (*a*) Mean of five observations,

$$O_{\text{mean}} = \mu = \frac{80.0 + 80.5 + 81.0 + 81.5 + 82}{5} = \frac{405.0}{5} = 81$$

Absolute errors in the observations are

$\Delta O_1 = 80.0 - \mu \qquad \Delta O_2 = 80.5 - \mu$

$\Delta O_3 = 81.0 - \mu \qquad \Delta O_4 = 81.5 - \mu$

$\Delta O_5 = 82 - \mu$

$\therefore$ Arithmetic mean of all the absolute errors,

$$\Delta O_{\text{mean}} = \sum_{i=1}^{5} \frac{|\Delta O_i|}{n}$$

$$= \frac{|80.0 - \mu| + |80.5 - \mu| + |81.0 - \mu| + |81.5 - \mu| + |82 - \mu|}{5}$$

Substituting the value of μ, we get

$$\Delta O_{\text{mean}} = \frac{|80.0 - 81| + |80.5 - 81| + |81.0 - 81| + |81.5 - 81| + |82 - 81|}{5}$$

$$= \frac{1 + 0.5 + 0 + 0.5 + 1}{5} = \frac{3}{5} = 0.6$$

$\therefore$ Mean percentage error $= \dfrac{\Delta O_{\text{mean}}}{O_{\text{mean}}} \times 100\%$

$= \dfrac{0.6}{81} \times 100\% = 0.74\%$

15 (*b*) As we know, time period of oscillation is $T = 2\pi\sqrt{\dfrac{L}{g}}$.

So, $g = 4\pi^2 L/T^2$

Therefore, relative error in g is

$$(\Delta g/g) = (\Delta L/L) + 2(\Delta T/T)$$

Given, $\Delta L = 1\,\text{mm} = 0.1\,\text{cm}$, $L = 20\,\text{cm}$, $\Delta T = 1\,\text{s}$ and $T = 90\,\text{s}$

$$\Rightarrow \quad \frac{\Delta g}{g} = \frac{0.1}{20} + 2\left(\frac{1}{90}\right) = 0.027$$

Thus, the percentage error in g is

$$= \frac{\Delta g}{g} \times 100\% = 0.027 \times 100\% = 2.7\% \simeq 3\%$$

16 (*b*) The error in the measurement of mass 1.02 g is ± 0.01 g,
whereas that of another measurement 9.89 g is also ± 0.01 g.

∴ The relative error in 1.02 g

$$= [\pm 0.01/1.02) \times 100\% = \pm 0.98\% \cong \pm 1\%$$

Similarly, the relative error in 9.89 g

$$= (\pm 0.01/9.89) \times 100\% = \pm 0.1\%$$

The relative errors in measurement of two masses are ± 1% and ± 0.1%.

17 (*c*) ∵ Density, $\rho = \dfrac{\text{Mass}}{\text{Volume}} = \dfrac{M}{L^3}$ or $\rho = \dfrac{M}{L^3}$

$$\Rightarrow \text{Error in density } \frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta L}{L}$$

So, maximum % error in measurement of ρ is

$$\frac{\Delta\rho}{\rho} \times 100 = \frac{\Delta M}{M} \times 100 + \frac{3\Delta L}{L} \times 100$$

or % error in density $= 1.5 + 3 \times 1$

% error = 4.5%

18 (*a*) By ascent formula, we have surface tension

$$T = \frac{rhg}{2} \times 10^3 \frac{\text{N}}{\text{m}} = \frac{dhg}{4} \times 10^3 \frac{\text{N}}{\text{m}} \quad \left(\because r = \frac{d}{2}\right)$$

$$\Rightarrow \frac{\Delta T}{T} = \frac{\Delta d}{d} + \frac{\Delta h}{h} \quad \text{[given, } g \text{ is constant]}$$

$$\text{So, percentage} = \frac{\Delta T}{T} \times 100 = \left(\frac{\Delta d}{d} + \frac{\Delta h}{h}\right) \times 100$$

$$= \left(\frac{0.01 \times 10^{-2}}{1.25 \times 10^{-2}} + \frac{0.01 \times 10^{-2}}{1.45 \times 10^{-2}}\right) \times 100$$

$$= 1.5\%$$

$$\therefore \quad \frac{\Delta T}{T} \times 100 = 1.5\%$$

19 (*c*) Given, length of pendulum, $l = 25.0$ cm So, there is an uncertainty of 0.1 cm in measurement of length.
Resolution of stopwatch is 1s. So, uncertainty in measurement of time is 1s.

Now using, $T = 2\pi\sqrt{\dfrac{l}{g}}$ or $g = \dfrac{4\pi^2 l}{T^2}$

We have, $\dfrac{\Delta g}{g} = \dfrac{\Delta l}{l} + \dfrac{2\Delta T}{T}$

$$\Rightarrow \quad \frac{\Delta g}{g} \times 100\% = \left(\frac{\Delta l}{l} + \frac{2\Delta T}{T}\right) \times 100\%$$

Accuracy in measurement of g is

$$\frac{\Delta g}{g} \times 100\% = \left(\frac{0.1}{25} + \frac{2 \times 1}{50}\right) \times 100\%$$

$$= (0.004 + 0.04) \times 100\%$$

$$= 4.40\ \%$$

20 (*b*) Given, $R_1 = 100\ \&\ \Delta R_1 = 3\Omega$,
and $R_2 = 200\ \&\ \Delta R_2 = 4\Omega$

The equivalent resistance of parallel combination,

$$\frac{1}{R'} = \frac{1}{R_1} + \frac{1}{R_2} \quad \ldots\text{(i)}$$

$$R' = \frac{R_1 R_2}{R_1 + R_2} = \frac{100 \times 200}{100 + 200}$$

$$= \frac{20000}{300} = \frac{200}{3} = 66.7\Omega$$

Then from Eq. (i), we get

$$\frac{\Delta R'}{R'^2} = \frac{\Delta R_1}{R_1^2} + \frac{\Delta R_2}{R_2^2}$$

$$\Rightarrow \quad \Delta R' = (R'^2)\frac{\Delta R_1}{R_1^2} + (R'^2)\frac{\Delta R_2}{R_2^2}$$

$$= \left(\frac{66.7}{100}\right)^2 \times 3 + \left(\frac{66.7}{200}\right)^2 \times 4 = 1.78 \cong 1.8$$

∴ Equivalent resistance, $R' = (66.7 \pm 1.8)\Omega$

21 (*b*) Given, $R = 65\ \Omega$, $\Delta R = 1\Omega$, $l = 5\text{mm} = 5 \times 10^{-3}$ m,
$\Delta l = 0.1\text{mm} = 0.1 \times 10^{-3}$ m, $d = 10\text{mm} = 10 \times 10^{-3}$ m,
$\Delta d = 0.5\text{mm} = 0.5 \times 10^{-3}$ m

$$\therefore \text{ Resistivity, } \rho = \frac{RA}{l} \Rightarrow \rho = \frac{R\pi\,(d/2)^2}{l} = \frac{\pi R d^2}{4l}$$

$$\therefore \quad \frac{\Delta\rho}{\rho} = \frac{\Delta R}{R} + 2\frac{\Delta d}{d} + \frac{\Delta l}{l}$$

Substituting the given values, we get

$$\frac{\Delta\rho}{\rho} = \frac{1}{65} + 2\left(\frac{0.5 \times 10^{-3}}{10 \times 10^{-3}}\right) + \frac{0.1 \times 10^{-3}}{5 \times 10^{-3}}$$

$$\Rightarrow \quad \frac{\Delta\rho}{\rho} = 0.0154 + 0.1 + 0.02 \Rightarrow \frac{\Delta\rho}{\rho} = 0.1354$$

So, % error in calculation of resistivity $= 0.1354 \times 100\%$
$= 13.5\% \approx 13\%$.

22 (*a*) Given, $X = \dfrac{A^2 B^{1/2}}{C^{1/3} D^3}$

The percentage error in X is given by

$$\frac{\Delta X}{X} \times 100\% = 2\left(\frac{\Delta A}{A}\right) \times 100\% + \frac{1}{2}\left(\frac{\Delta B}{B}\right) \times 100\%$$

$$+ \frac{1}{3}\left(\frac{\Delta C}{C}\right) \times 100\% + 3\left(\frac{\Delta D}{D}\right) \times 100\% \quad \ldots\text{(i)}$$

Given, $\frac{\Delta A}{A} \times 100\% = 1\%, \frac{\Delta B}{B} \times 100\% = 2\%,$

$\frac{\Delta C}{C} \times 100\% = 3\%$ and $\frac{\Delta D}{D} \times 100\% = 4\%$

Substituting these values in Eq. (i), we get

$$\frac{\Delta X}{X} \times 100\% = 2(1\%) + \frac{1}{2}(2\%) + \frac{1}{3}(3\%) + 3(4\%)$$
$$= 2\% + 1\% + 1\% + 12\% = 16\%$$

Thus, maximum percentage error in X is 16%.

23 (*a*) Given, $P = \frac{a^3 b^2}{cd}$, $\frac{\Delta a}{a} \times 100\% = 1\%$,

$\frac{\Delta b}{b} \times 100\% = 2\%$, $\frac{\Delta c}{c} \times 100\% = 3\%$

and $\frac{\Delta d}{d} \times 100\% = 4\%$

$\therefore$ % error in P

$$= \left(\frac{\Delta P}{P} \times 100\right)\% = \left(\frac{3\Delta a}{a} + \frac{2\Delta b}{b} + \frac{\Delta c}{c} + \frac{\Delta d}{d}\right) \times 100\%$$

$$= \left(3\frac{\Delta a}{a} \times 100\% + 2\frac{\Delta b}{b} \times 100\% + \frac{\Delta c}{c} \times 100\% + \frac{\Delta d}{d} \times 100\%\right)$$

$= 3 \times 1\% + 2 \times 2\% + 3\% + 4\% = 14\%$

24 (*a*) As we know that, the terminal or trailing zero(s) in a number without a decimal point are not significant.
So, 4700 m has two significant figures.

25 (*b*) The power of 10 is irrelevant to the determination of significant figures. However, all the zeroes appearing in the base number in the scientific notation are significant.
So, 4.8000×10^4 has 4, 8, 0, 0, 0 $\Rightarrow$ 5 significant digits.

For a number greater than 1, with a decimal, the trailing zero(s) are significant.
So, 48000.50 has 4, 8, 0, 0, 0, 5, 0 $\Rightarrow$ 7 significant digits.

26 (*b*) According to the rule for arithmetic operations with significant figures, in multiplication, the final result should retain as many significant figures as there are in the original number with the least significant figures.

Given, length of each side of cube, $l = 7.203$ m.

As the number of significant figures in the measured length is 4.

So, the calculated area and the volume should therefore be rounded off to 4 significant figures.

Surface area of the cube $= 6l^2 = 6\,(7.203)^2$
$= 311.299254 = 311.3\ \text{m}^2$

Volume of the cube $= l^3 = (7.203)^3$
$= 373.714754 = 373.7\ \text{m}^3$

27 (*c*) Given, mass of the substance, $m = 5.74$ g

and volume of the substance, $V = 1.2\ \text{cm}^3$.

There are 3 significant figures in the measured mass, whereas there are only 2 significant figures in the measured volume.

Hence, the density should be expressed to only 2 significant figures.

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{5.74}{1.2} = 4.783 = 4.8\ \text{gcm}^{-3}$$

28 (*b*) In addition and subtraction, the uncertainty of result is determined by the smallest number of decimal places rather than the number of significant figures. Therefore, the correct value of $12.9 - 7.06 = 5.84$ g $= 5.8$ g.

29 (*b*) The addition of given values is

$$3.8 \times 10^{-6} + 4.2 \times 10^{-5} = 0.38 \times 10^{-5} + 4.2 \times 10^{-5}$$
$$= 4.58 \times 10^{-5}$$

As per the rule for arithmetic operations with significant figures, in addition the final result should retain as many decimal places as there are in the number with the least decimal places.

Since, here the least decimal place in the given numbers is 1. So, the result should be rounded off upto 1 decimal place.

Thus, the addition of the given numbers is 4.6×10^{-5}.

30 (*d*) The number 5.355 rounded off to three significant figures becomes 5.36, since preceding digit of 5 is odd, hence it is raised by 1.

On other hand, the number 5.345 rounded off to three significant figures becomes 5.34. Since, the preceding digit of 5 is even.

32 (*c*) Planck's constant $h = \frac{E}{\nu}$

So, dimension of h is $= \left[\frac{\text{ML}^2\text{T}^{-2}}{\text{T}^{-1}}\right] = [\text{ML}^2\text{T}^{-1}]$

Angular momentum, $L = mvr$

Dimension of L is $= [\text{M}][\text{LT}^{-1}][\text{L}] = [\text{ML}^2\text{T}^{-1}]$

Work, W = Force × Displacement

$\therefore$ Dimensions of $W = [\text{MLT}^{-2}] \times [\text{L}] = [\text{ML}^2\text{T}^{-2}]$

Linear momentum p = Mass × Velocity

Dimensions of $p = [\text{M}][\text{LT}^{-1}] = [\text{MLT}^{-1}]$

Impulse, $I = \frac{\text{Force}}{\text{Time}}$

The dimensions of $I = \frac{[\text{MLT}^{-2}]}{[\text{T}]} = [\text{MLT}^{-3}]$

Hence, only angular momentum has same dimensions as that of Planck's constant.

33 (*b*) $\because$ Force = Mass × Acceleration

$\therefore$ Dimensions of force $= [\text{M}]\,[\text{LT}^{-2}] = [\text{MLT}^{-2}]$

$\because$ Power $= \frac{\text{Work}}{\text{Time}}$

$\therefore$ Dimensions of power $= \frac{[\text{ML}^2\text{T}^{-2}]}{[\text{T}]} = [\text{ML}^2\text{T}^{-3}]$

$\because$ Torque = Force × Displacement

$\therefore$ Dimensions of torque $= [\text{MLT}^{-2}]\,[\text{L}] = [\text{ML}^2\text{T}^{-2}]$

and dimensions of energy $= [\text{ML}^2\text{T}^{-2}]$

Hence, torque and energy have same dimensions.

35 (*a*) Dimensions of torque, τ = Dimension of force, F

$\times$ Dimensions of displacement, r

$$= [MLT^{-2}][L] = [ML^2T^{-2}]$$

36 (*d*) Dimensions of quantity f are

$$[f] = \frac{[h]^{\frac{1}{2}}[c]^{\frac{5}{2}}}{[G]^{\frac{1}{2}}} \quad \text{...(i)}$$

As, $\quad h = \dfrac{E}{\nu}$;

$$[h] = [ML^2T^{-2}][T] = [ML^2T^{-1}]$$

$$c = [LT^{-1}]$$

and $\quad G = \dfrac{F \cdot r^2}{m^2}$

$$\Rightarrow \quad [G] = \frac{[MLT^{-2}][L^2]}{[M^2]} = [M^{-1}L^3T^{-2}]$$

So, dimensions of f using Eq. (i),

$$[f] = \frac{[ML^2T^{-1}]^{\frac{1}{2}}[LT^{-1}]^{\frac{5}{2}}}{[M^{-1}L^3T^{-2}]^{\frac{1}{2}}}$$

$$= \left[M^{\frac{1}{2}+\frac{1}{2}}, L^{\frac{5}{2}-\frac{3}{2}+1}, T^{-\frac{1}{2}-\frac{5}{2}+\frac{2}{2}}\right] = [ML^2T^{-2}]$$

Thus, it is the dimensions of energy.

37 (*a*) According to ideal gas equation, i.e. $pV = nRT$, where n is the number of moles of gases.

$\therefore$ Universal gas constant, $R = \dfrac{(p)(V)}{(n)(T)}$

Dimensional formula of $R = \dfrac{[ML^{-1}T^{-2}][L^3]}{[mol][K]}$

$$= [ML^2T^{-2}\,mol^{-1}K^{-1}]$$

38 (*) Let $V_0 = (h)^a \cdot (c)^b \cdot (G)^c \cdot (A)^d$ $\quad$ ...(i)

Then, $[V_0] = [\text{potential}] = \left[\dfrac{\text{potential energy}}{\text{charge}}\right]$

$$= \frac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$$

$$[h] = \left[\frac{\text{Energy}}{\text{Frequency}}\right] = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$$

$$[c] = [\text{Speed}] = [LT^{-1}]$$

$$[G] = \left[\frac{\text{Force} \times (\text{Distance})^2}{(\text{Mass})^2}\right] = \frac{[MLT^{-2}][L^2]}{[M^2]}$$

$$= [M^{-1}L^3T^{-2}]$$

Substituting the dimensions of $V_0 h, C, G$ and A in Eq. (i) and equating dimension on both sides, we get

$$[ML^2T^{-3}A^{-1}] = [ML^2T^{-1}]^a \times [LT^{-1}]^b \times [M^{-1}L^3T^{-2}]^c \times [A]^d$$

$$\Rightarrow \quad a - c = 1 \quad \text{...(ii)}$$

$$2a + b + 3c = 2 \quad \text{...(iii)}$$

$$-a - b - 2c = -3 \quad \text{...(iv)}$$

$$d = -1 \quad \text{...(v)}$$

On solving above equations, we get

$$a = 0, b = 5, c = -1, d = -1$$

Substituting these values in Eq. (i), we get

$$V_0 = h^0 \cdot c^5 \cdot G^{-1} \cdot A^{-1}$$

None of the given options matches with the result.

39 (*d*) Dimensions of speed are $[V] = [LT^{-1}]$

Dimensions of acceleration are $[A] = [LT^{-2}]$

Dimensions of force are $[F] = [MLT^{-2}]$

Dimension of Young modulus is $[Y] = [ML^{-1}T^{-2}]$

Let dimensions of Young's modulus is expressed in terms of speed, acceleration and force as;

$$[Y] = [V]^\alpha [A]^\beta [F]^\gamma \quad \text{...(i)}$$

Then substituting dimensions in terms of M, L and T we get,

$$[ML^{-1}T^{-2}] = [LT^{-1}]^\alpha [LT^{-2}]^\beta [MLT^{-2}]^\gamma$$

$$= [M^\gamma L^{\alpha+\beta+\gamma}\, T^{-\alpha-2\beta-2\gamma}]$$

Now comparing powers of basic quantities on both sides we get,

$$\gamma = 1$$

$$\alpha + \beta + \gamma = -1$$

and $\quad -\alpha - 2\beta - 2\gamma = -2$

Solving these we get; $\quad \alpha = -4, \; \beta = 2, \gamma = 1$

Substituting $\alpha, \beta, \& \; \gamma$ in (i) we get;

$$[Y] = [V^{-4}A^2F^1]$$

40 (*c*) Suppose, linear momentum (p) depends upon the Planck's constant (h) raised to the power (a), surface tension(S) raised to the power (b) and moment of inertia (I) raised to the power (c).

Then, $\quad p \propto (h)^a (S)^b (I)^c$ or $p = kh^a S^b I^c$

where, k is a dimensionless proportionality constant.

Thus, $\quad [p] = [h]^a [S]^b [I]^c \quad$ ...(i)

Then, the respective dimensions of the given physical quantities, i.e.

$[p] = [\text{mass} \times \text{velocity}] = [MLT^{-1}]$

$[I] = [\text{mass} \times \text{distance}^2] = [ML^2T^0]$

$[S] = [\text{force} \times \text{length}] = [ML^0T^{-2}]$

$[h] = [ML^2T^{-1}]$

Then, substituting these dimensions in Eq. (i), we get

$$[MLT^{-1}] = [ML^2T^{-1}]^a [MT^{-2}]^b [ML^{+2}]^c$$

For dimensional balance, the dimensions on both sides should be same.

Thus, equating dimensions, we have

$$a + b + c = 1$$

$$2(a + c) = 1 \quad \text{or} \quad a + c = \frac{1}{2}$$

$$-a - 2b = -1 \quad \text{or} \quad a + 2b = 1$$

Solving these three equations, we get

$$a = 0, b = \frac{1}{2}, c = \frac{1}{2}$$

$\therefore \quad p = h^0 S^{\frac{1}{2}} I^{\frac{1}{2}}$ or $p = S^{\frac{1}{2}} I^{\frac{1}{2}} h^0$

41 (*c*) Force of interaction between two atoms is given as

$$F = \alpha\beta \exp(-x^2/\alpha kT)$$

As we know, exponential terms are always dimensionless, so

dimensions of $\left(\frac{-x^2}{\alpha\, kT}\right) = [M^0L^0T^0]$

$\Rightarrow$ Dimensions of α = Dimension of (x^2/kT)

Now, substituting the dimensions of individual term in the given equation, we get

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

{$\because$ Dimensions of kT equivalent to the dimensions of energy $= [M^1L^2T^{-2}]$}

$$= [M^{-1}L^0T^2] \quad ...(i)$$

Now from given equation, we have dimensions of

F = dimensions of $\alpha \times$ dimensions of β

$\Rightarrow$ Dimensions of β = Dimensions of $\left(\frac{F}{\alpha}\right)$

$$= \frac{[M^1L^1T^{-2}]}{[M^{-1}L^0T^2]} \quad [\because \text{using Eq. (i)}]$$

$$= [M^2L^1T^{-4}]$$

42 (*d*) Given, $U = \frac{A\sqrt{x}}{x+B}$

Dimensions of U = Dimensions of potential energy $= [ML^2T^{-2}]$

According to the principle of homogeneity,

Dimensions of B = Dimensions of $x = [M^0LT^0]$

$\therefore$ Dimensions of A

$$= \frac{\text{Dimensions of } U \times \text{Dimensions of } (x+B)}{\text{Dimensions of } \sqrt{x}}$$

$$= \frac{[ML^2T^{-2}][M^0LT^0]}{[M^0L^{1/2}T^0]} = [ML^{5/2}T^{-2}]$$

Hence, dimensions of $AB = [ML^{5/2}T^{-2}][M^0LT^0]$

$$= [ML^{7/2}T^{-2}]$$

43 (*a*) As force between two charges,

$$F = \frac{e^2}{4\pi\varepsilon_0 r^2} \Rightarrow \frac{\varepsilon^2}{4\pi\varepsilon_0} = \rho^2 \cdot \Phi$$

Putting dimensions of r and F, we get

$$\left[\frac{e^2}{4\pi\varepsilon_0}\right] = [L^2][MLT^{-2}] \quad ...(i)$$

Also, force between two masses, $F = \frac{Gm^2}{r^2}$

$$\Rightarrow G = \frac{Fr^2}{m^2} \Rightarrow [G] = \frac{[MLT^{-2}][L^2]}{[M^2]}$$

$$\Rightarrow [G] = [M^{-1}L^3T^{-2}] \quad ...(ii)$$

and $\left[\frac{1}{c^2}\right] = \frac{1}{[L^2T^{-2}]} = [L^{-2}T^2] \quad ...(iii)$

Now, checking optionwise for option (a)

$$= \frac{1}{c^2}\left(\frac{Ge^2}{4\pi\varepsilon_0}\right)^{1/2}$$

$$= [L^{-2}T^2]\{[M^{-1}L^3T^{-2}][L^2][MLT^{-2}]\}^{1/2}$$

$$= [L^{-2}T^2][L^6T^{-4}]^{1/2} = [L]$$

For option (b),

$$c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2} = [L^{-2}T^2]^{-1}[L^6T^{-4}]^{1/2} = [L^5T^{-4}]$$

For option (c),

$$\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{1/2} = [L^{-2}T^2]\left\{\frac{[L^2][MLT^{-2}]}{[M^{-1}L^3T^{-2}]}\right\}^{1/2}$$

$$= [L^{-2}T^2][M^2]^{1/2} = [ML^{-2}T^2]$$

For option (d),

$$\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0} = [L^{-2}T^2][M^{-1}L^3T^{-2}][L^2][MLT^{-2}]$$

$$= [L^4T^{-2}]$$

$\therefore$ Physical quantity $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ has the dimensions of length.

Hence, option (a) is correct.

44 (*a*) According to question, $[X]$ = Dimensions of capacitance $= [M^{-1}L^{-2}T^2Q^2]$

and $[Z]$ = Dimensions of magnetic induction.

$$= [MT^{-1}Q^{-1}]$$

Given, $X = 3YZ^2$,

$$\therefore \quad [Y] = \frac{[X]}{[Z^2]}$$

$$\Rightarrow [Y] = \frac{[M^{-1}L^{-2}T^2Q^2]}{[M^2T^{-2}Q^{-2}]} = [M^{-3}L^{-2}T^4Q^4]$$

45 (*c*) We know that, Surface tension, $S = \frac{\text{Force } [F]}{\text{Length } [L]}$

So, $[S] = \frac{[MLT^{-2}]}{[L]} = [ML^0T^{-2}]$

Energy, E = Force $\times$ Displacement

$$\Rightarrow [E] = [MLT^{-2}][L] = [ML^2T^{-2}]$$

Velocity, $v = \frac{\text{Displacement}}{\text{Time}} \Rightarrow [v] = [LT^{-1}]$

As, $S \propto E^a v^b T^c$, where, a, b and c are constants.

From the principle of homogeneity,

$$[LHS] = [RHS]$$