Notes and exercises

by

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Physical World

- **Science** means organized knowledge.

It is human nature to observe things and happenings around in the nature and then to relate them. This knowledge is organized so that it become well connected and logical. Then it is known as Science. It is a systematic attempt to understand natural phenomenon and use this knowledge to predict, modify and control phenomena.

Scientific Method

Scientific methods are used to observe things and natural phenomena. It includes several steps :

- Observations
- Controlled experiments,
- Qualitative and quantitative reasoning,
- Mathematical modeling,
- Prediction and
- Verification or falsification of theories.

There is no 'final' theory in science and no unquestioned authority in science.

- Observations and experiments need theories to support them. Sometimes the existing theory is unable to explain the new observations, hence either new theories are formed or modification is done in the existing theories.
- For example to explain different phenomena in light, theories are changed. To explain bending of light a new Wave-theory was formed, and then to explain photoelectric effect help of quantum mechanics was taken.

Natural Sciences can be broadly divided in three branches namely Physics, Chemistry and biology

- **Physics** is a study of basic laws of nature and their manifestation in different phenomenas.

Principal thrusts in Physics

- There are two principal thrusts in Physics;
- 1.Unification 2. reduction

Unification

- Efforts are made to explain different phenomena in nature on the basis of one or minimum laws. This is principle of Unification.

Example: Phenomena of apple falling to ground, moon revolving around earth and weightlessness in the rocket, all these phenomena are explained with help of *one* Law that is, Newtons Law of Gravitation.

Reductionism

- To understand or to derive the properties of a bigger or more complex system the properties of its simpler constituents are taken into account. This approach is called reductionism.

It is supposed to be the heart of Physics.

For example a complex thermo dynamical system can be understood by the properties of its constituent like kinetic energy of molecules and atoms.

- ***The scope of Physics*** can be divided in to two domains; Macroscopic and Microscopic.
- Macroscopic domain includes phenomena at the level of Laboratory, terrestrial and astronomical scales.
- Microscopic domain I ncludes atomic, molecular and nuclear phenomena.
- Recently third domain in between is also thought of with name Mesoscopic Physics. This deals with group of Hundreds of atoms
  - Scope of physics is very wide and exciting because it deals with objects of size as large as Universe (10^{25}m) and as small as 10^{-14} m, the size of a nucleus.

The excitement of Physics is experienced in many fields Like:
- Live transmissions through television.
- Computers with high speed and memory,
- Use of Robots,
- Lasers and their applications

Physics in relation to other branches of Science
Physics in relation to Chemistry.
- Chemical bonding, atomic number and complex structure can be explained by physics phenomena of Electrostatic forces,
- taking help of X-ray diffraction.

Physics in relation to other Science
- Physics in relation to Biological Sciences: Physics helps in study of Biology through its inventions. Optical microscope helps to study bio-samples, electron microscope helps to study biological cells. X-rays have many applications in biological sciences. Radio isotopes are used in cancer.
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Physics in relation with Astronomy:
- Giant astronomical telescope developed in physics are used for observing planets. Radio telescopes have enabled astronomers to observe distant limits of universe.
- Physics related to other sciences: Laws of Physics are used to study different phenomenas in other sciences like Biophysics, oceanography, seismology etc.

Fundamental Forces in Nature

There is a large number of forces experienced or applied. These may be macroscopic forces like gravitation, friction, contact forces and microscopic forces like electromagnetic and inter-atomic forces. But all these forces arise from some basic forces called Fundamental Forces.

Fundamental Forces in Nature..

1. Gravitational force.

- *It is due to Mass of the two bodies.*
- *It is always attractive.*
- *It operates in all objects of universe.*
- *Its range is infinite*

It's a weak force. 10^{-38} times compared to strong Nuclear force

2.Electromagnetic Forces:

- It's due to stationery or moving Electrical charge
- It may be attractive or repulsive.
- It operates on charged particles
- Its range is infinite
- Its stronger 10^{36} times than gravitational force but 10^{-2} times of strong Nuclear force.

3. Strong nuclear force:

- Operate between Nucleons
- It may be attractive or repulsive
- Its range is very short, within nuclear size (10^{-15} m).
- Its strongest force in nature

4.Weak Nuclear force:

- Operate within nucleons I.e. elementary particles like electron and neutrino.
- It appears during radioactive b decay.
- Has very short range 10^{-15}m.
- 10^{-13} times than Strong nuclear force.

Conservation Laws

- In any physical phenomenon governed by different forces, several quantities do not change with time. These special quantities are conserved quantities of nature.

1. For motion under conservative force, the total mechanical Energy of a body is constant.
2. Total energy of a system is conserved, and it is valid across all domains of nature from microscopic to macroscopic. Total energy of the universe is believed to be constant.
3. Conservation of Mass was considered another conservation law, till advent of Einstein. Then it was converted to law of conservation of mass plus energy. Because mass is converted into energy and vice-versa according to equation $E = mc^2$ The examples are annihilation and pair production.
4. Momentum is another quantity which is preserved. Similar is angular momentum of an isolated system.
5. Conservation of Electric charge is a fundamental law of nature.
6. Later there was development of law of conservation of attributes called baryon number, lepton number and so on.

The laws of nature do not change with change of space and time. This is known as symmetry of space and time. This and some other symmetries play a central role in modern physics. Conservation laws are connected to this.

Laws of Physics related to technology :

Principal of Physics	***Technology***
Electromagnetic Induction	Electricity Generation
Laws of Thermodynamics	Steam, petrol, or diesel Engine
Electromagnetic Waves propagation	Radio, TV, Phones
Nuclear chain reaction	Nuclear reactor for power
Newtons Second & Third Law	Rocket propulsion
Bernoulli's theorem	Aero planes
Population inversion	Lasers
X-rays	Medical Diagnosis
Ultra high magnetic fields	Superconductors
Digital electronics	Computers and calculators
Electromagnetic Induction	Electricity Generation

Physicist and their contributions

Name	***Contribution***	***country***
Isaac Newton	Law of Gravitation, Laws of Motion, Reflecting telescope	U.K.
Galileo Galilei	Law of Inertia	Italy
Archimedes	Principle of Buoyancy, Principle of Lever	Greece
James Clerk Maxwell	Electromagnetic theory, light is an e/m wave.	U.K.
W.K.Roentgen	X-rays	Germany
Marie S. Curie	Discovery of Radium, Polonium, study of Radioactivity	Poland
Albert Einstein	Law of Photo electricity, Theory of Relativity	Germany
S.N.Bose	Quantum Statistics	India
James Chadwick	Neutron	U.K.
Niels Bohr	Quantum model of Hydrogen atom	Denmark
Earnest Rutherford	Nuclear model of Atom	New Zealand
C.V.Raman	Inelastic Scattering of light by molecules	India
Christian Huygens	Wave theory of Light	Holland
Michael Faraday	Laws of Electromagnetic Induction	U.K.
Edvin Hubble	Expanding Universe	U.S.A.
H.J.Bhabha	Cascade process in cosmic radiation	India
Abdus Salam	Unification of week and e/m interactions	Pakistan
R.A.Milikan	Measurement of Electronic Charge	U.S.A.
E.O.Lawrence	Cyclotron	U.S.A.
Wolfgong Pauli	Quantum Exclusion principle	Austria
Louis de Broglie	Wave nature of matter	France
J.J.Thomson	Electron	U.K.
S.Chandrashekhar	Chandrashekhar limit, structure of stars	India
Christian Huygens	Wave theory of Light	Holland
Michael Faraday	Laws of Electromagnetic Induction	U.K.

Edvin Hubble	Expanding Universe	U.S.A.
Henrick Hertz	Electromagnetic Waves	Germany
J.C.Bose	Ultra short radio waves	India
Hideki Yukava	Theory of Nuclear Forces	Japan
W.Heisenberg	Quantum mechanics, Uncertainty principle	Germany
M.N.Saha	Thermal Ionization	India
G.N.Ramachandran	Triple Helical structure of proteins	india

1.1 Physical Quantity

A quantity which can be measured and by which various physical happenings can be explained and expressed in form of laws is called a physical quantity. For example length, mass, time, force *etc*.

On the other hand various happenings in life *e.g.*, happiness, sorrow *etc*. are not physical quantities because these can not be measured.

Measurement is necessary to determine magnitude of a physical quantity, to compare two similar physical quantities and to prove physical laws or equations.

A physical quantity is represented completely by its magnitude and unit. For example, 10 *metre* means a length which is ten times the unit of length 1 *kg*. Here 10 represents the numerical value of the given quantity and *metre* represents the unit of quantity under consideration. Thus in expressing a physical quantity we choose a unit and then find that how many times that unit is contained in the given physical quantity, *i.e.*

$$\text{Physical quantity } (Q) = \text{Magnitude} \times \text{Unit} = n \times u$$

Where, n represents the numerical value and u represents the unit. Thus while expressing definite amount of physical quantity, it is clear that as the unit(u) changes, the magnitude(n) will also change but product 'nu' will remain same.

i.e. $n\,u$ = constant, or $n_1u_1 = n_2u_2 = \text{constar}$; $\therefore$ $n \propto \frac{1}{u}$

i.e. magnitude of a physical quantity and units are inversely proportional to each other .Larger the unit, smaller will be the magnitude.

1.2 Types of Physical Quantity

(1) **Ratio (numerical value only) :** When a physical quantity is a ratio of two similar quantities, it has no unit.

e.g. Relative density = Density of object/Density of water at $4^{o}C$

Refractive index = Velocity of light in air/Velocity of light in medium

Strain = Change in dimension/Original dimension

Note : ❑ Angle is exceptional physical quantity, which though is a ratio of two similar physical quantities (angle = arc / radius) but still requires a unit (degrees or radians) to specify it along with its numerical value.

(2) **Scalar (Magnitude only) :** These quantities do not have any direction *e.g*. Length, time, work, energy *etc*.

Magnitude of a physical quantity can be negative. In that case negative sign indicates that the numerical value of the quantity under consideration is negative. It does not specify the direction.

Scalar quantities can be added or subtracted with the help of following ordinary laws of addition or subtraction.

(3) **Vector (magnitude and direction) :** *e.g.* displacement, velocity, acceleration, force *etc*.

Vector physical quantities can be added or subtracted according to vector laws of addition. These laws are different from laws of ordinary addition.

Note : ❑ There are certain physical quantities which behave neither as scalar nor as vector. For example, moment of inertia is not a vector as by changing the sense of rotation its value is not changed. It is also not a scalar as it has different values in different directions (*i.e.* about different axes). Such physical quantities are called Tensors.

1.3 Fundamental and Derived Quantities

(1) **Fundamental quantities :** Out of large number of physical quantities which exist in nature, there are only few quantities which are independent of all other quantities and do not require the help of any other physical quantity for their definition, therefore these are called absolute quantities. These quantities are also called fundamental or base quantities, as all other quantities are based upon and can be expressed in terms of these quantities.

(2) **Derived quantities :** All other physical quantities can be derived by suitable multiplication or division of different powers of fundamental quantities. These are therefore called derived quantities.

If length is defined as a fundamental quantity then area and volume are derived from length and are expressed in term of length with power 2 and 3 over the term of length.

Note : ❑ In mechanics Length, Mass and time are arbitrarily chosen as fundamental quantities. However this set of fundamental quantities is not a unique choice. In fact any three quantities in mechanics can be termed as fundamental as all other quantities in mechanics can be expressed in terms of these. *e.g.* if speed and time are taken as fundamental quantities, length will become a derived quantity because then length will be expressed as Speed × Time. and if force and acceleration are taken as fundamental quantities, then mass will be defined as Force / acceleration and will be termed as a derived quantity.

1.4 Fundamental and Derived Units

Normally each physical quantity requires a unit or standard for its specification so it appears that there must be as many units as there are physical quantities. However, it is not so. It has been found that if in *mechanics* we choose arbitrarily units of any *three* physical quantities we can express the units of all other physical quantities in mechanics in terms of these. Arbitrarily the physical quantities *mass*, *length* and *time* are choosen for this purpose. *So any unit of mass, length and time in mechanics is called a* **fundamental, absolute or base unit.** *Other units which can be expressed in terms of fundamental units, are called derived units.* For example light year or *km* is a fundamental units as it is a unit of length while s^{-1}, m^2 or *kg*/*m* are derived units as these are derived from units of time, mass and length respectively.

System of units : A complete set of units, both fundamental and derived for all kinds of physical quantities is called system of units. The common systems are given below –

(1) **CGS system :** The system is also called Gaussian system of units. In it length, mass and time have been chosen as the fundamental quantities and corresponding fundamental units are centimetre (*cm*), gram (*g*) and second (*s*) respectively.

(2) **MKS system :** The system is also called Giorgi system. In this system also length, mass and time have been taken as fundamental quantities, and the corresponding fundamental units are *metre*, kilogram and second.

(3) **FPS system :** In this system foot, pound and second are used respectively for measurements of length, mass and time. In this system force is a derived quantity with unit poundal.

(4) **S. I. system :** It is known as International system of units, and is infact extended system of units applied to whole physics. There are seven fundamental quantities in this system. These quantities and their units are given in the following table

Quantity	Name of Unit	Symbol

Length	metre	*m*
Mass	kilogram	*kg*
Time	second	*s*
Electric Current	ampere	*A*
Temperature	Kelvin	*K*
Amount of Substance	mole	*mol*
Luminous Intensity	candela	*cd*

Besides the above seven fundamental units two supplementary units are also defined –

Radian (*rad*) for plane angle and Steradian (*sr*) for solid angle.

Note : ❑ Apart from fundamental and derived units we also use very frequently practical units. These may be fundamental or derived units

e.g., light year is a practical unit (fundamental) of distance while horse power is a practical unit (derived) of power.

❑ Practical units may or may not belong to a system but can be expressed in any system of units

e.g., 1 mile = 1.6 *km* = 1.6×10^3 *m*.

1.5 S.I. Prefixes

In physics we have to deal from very small (*micro*) to very large (*macro*) magnitudes as one side we talk about the atom while on the other side of universe, *e.g.*, the mass of an electron is 9.1×10^{-31} *kg* while that of the sun is 2×10^{30} *kg*. To express such large or small magnitudes simultaneously we use the following prefixes :

Power of 10	Prefix	Symbol
10^{18}	exa	*E*
10^{15}	peta	*P*
10^{12}	tera	*T*
10^{9}	giga	*G*
10^{6}	mega	*M*
10^{3}	kilo	*k*
10^{2}	hecto	*h*
10^{1}	deca	*da*

10^{-1}	deci	*d*
10^{-1}	centi	*c*
10^{-3}	milli	*m*
10^{-6}	micro	*μ*
10^{-9}	nano	*n*
10^{-12}	pico	*p*
10^{-15}	femto	*f*
10^{-18}	atto	*a*

1.6 Standards of Length, Mass and Time

(1) **Length :** Standard metre is defined in terms of wavelength of light and is called atomic standard of length.

The metre is the distance containing 1650763.73 wavelength in vacuum of the radiation corresponding to orange red light emitted by an atom of krypton-86.

Now a days metre is defined as length of the path travelled by light in vacuum in 1/299,7792, 458 part of a second.

(2) **Mass :** The mass of a cylinder made of platinum-iridium alloy kept at International Bureau of Weights and Measures is defined as 1 *kg*.

On atomic scale, 1 *kilogram* is equivalent to the mass of 5.0188×10^{25} atoms of ${}_6C^{12}$ (an isotope of carbon).

(3) **Time :** 1 *second* is defined as the time interval of 9192631770 vibrations of radiation in *Cs*-133 atom. This radiation corresponds to the transition between two hyperfine level of the ground state of *Cs*-133.

1.7 Practical Units

(1) **Length :**

(i) 1 fermi = 1 *fm* = 10^{-15} *m*

(ii) 1 *X*-ray unit = 1*XU* = 10^{-13} *m*

(iii) 1 angstrom = 1Å = 10^{-10} *m* = 10^{-8} *cm* = 10^{-7} *mm* = 0.1 *μmm*

(iv) 1 micron = *μm* = 10^{-6} *m*

(v) 1 astronomical unit = 1 *A.U.* = 1.49×10^{11} *m* ≈ 1.5×10^{11} *m* ≈ 10^{8} *km*

(vi) 1 Light year = 1 *ly* = 9.46×10^{15} *m*

(vii) 1 *Parsec* = 1*pc* = 3.26 light year

(2) **Mass :**

(i) Chandra Shekhar unit : 1 *CSU* = 1.4 times the mass of sun = 2.8×10^{30} *kg*

(ii) Metric tonne : 1 Metric tonne = 1000 *kg*

(iii) Quintal : 1 Quintal = 100 *kg*

(iv) Atomic mass unit (*amu*) : *amu* = 1.67×10^{-27} *kg* mass of proton or neutron is of the order of 1 *amu*

(3) **Time :**

(i) Year : It is the time taken by earth to complete 1 revolution around the sun in its orbit.

(ii) Lunar month : It is the time taken by moon to complete 1 revolution around the earth in its orbit.

1 *L.M.* = 27.3 days

(iii) Solar day : It is the time taken by earth to complete one rotation about its axis with respect to sun. Since this time varies from day to day, average solar day is calculated by taking average of the duration of all the days in a year and this is called Average Solar day.

1 Solar year = 365.25 average solar day

or average solar day $= \frac{1}{365.25}$ the part of solar year

(iv) Sedrial day : It is the time taken by earth to complete one rotation about its axis with respect to a distant star.

1 Solar year = 366.25 Sedrial day = 365.25 average solar day

Thus 1 Sedrial day is less than 1 solar day.

(v) Shake : It is an obsolete and practical unit of time.

1 Shake = 10^{-8} *sec*

1.8 Dimensions of a Physical Quantity

When a derived quantity is expressed in terms of fundamental quantities, it is written as a product of different powers of the fundamental quantities. The powers to which fundamental quantities must be raised in order to express the given physical quantity are called its dimensions.

To make it more clear, consider the physical quantity force

Force = mass × acceleration $= \frac{\text{mass} \times \text{velocity}}{\text{time}} = \frac{\text{mass} \times \text{length/time}}{\text{time}}$ = mass × length × $(\text{time})^{-2}$ .... (i)

Thus, the dimensions of force are 1 in mass, 1 in length and – 2 in time.

Here the physical quantity that is expressed in terms of the base quantities is enclosed in square brackets to indicate that the equation is among the dimensions and not among the magnitudes.

Thus equation (i) can be written as [force] = $[MLT^{-2}]$.

Such an expression for a physical quantity in terms of the fundamental quantities is called the dimensional equation. If we consider only the R.H.S. of the equation, the expression is termed as dimensional formula.

Thus, dimensional formula for force is, $[MLT^{-2}]$.

1.9 Important Dimensions of Complete Physics

Mechanics

S. N.	Quantity	Unit	Dimension
(1)	Velocity or speed (v)	*m/s*	$[M^0L^1T^{-1}]$
(2)	Acceleration (a)	*m/s*^{2}	$[M^0LT^{-2}]$
(3)	Momentum (P)	*kg-m/s*	$[M^1L^1T^{-1}]$
(4)	Impulse (I)	*Newton-sec* or *kg-m/s*	$[M^1L^1T^{-1}]$
(5)	Force (F)	*Newton*	$[M^1L^1T^{-2}]$
(6)	Pressure (P)	*Pascal*	$[M^1L^{-1}T^{-2}]$
(7)	Kinetic energy (E_K)	*Joule*	$[M^1L^2T^{-2}]$
(8)	Power (P)	*Watt* or *Joule/s*	$[M^1L^2T^{-3}]$
(9)	Density (d)	*kg/m*^{3}	$[M^1L^{-3}T^0]$
(10)	Angular displacement (θ)	*Radian* (*rad.*)	$[M^0L^0T^0]$
(11)	Angular velocity (ω)	*Radian*/sec	$[M^0L^0T^{-1}]$
(12)	Angular acceleration (α)	*Radian*/*sec*^{2}	$[M^0L^0T^{-2}]$
(13)	Moment of inertia (I)	*kg-m*^{2}	$[M^1L^2T^0]$
(14)	Torque (τ)	*Newton-meter*	$[M^1L^2T^{-2}]$
(15)	Angular momentum (L)	*Joule-sec*	$[M^1L^2T^{-1}]$
(16)	Force constant or spring constant (k)	*Newton/m*	$[M^1L^0T^{-2}]$
(17)	Gravitational constant (G)	*N-m*^{2}/*kg*^{2}	$[M^{-1}L^3T^{-2}]$
(18)	Intensity of gravitational field (E_g)	*N/kg*	$[M^0L^1T^{-2}]$
(19)	Gravitational potential (V_g)	*Joule/kg*	$[M^0L^2T^{-2}]$
(20)	Surface tension (T)	*N/m* or *Joule/m*^{2}	$[M^1L^0T^{-2}]$
(21)	Velocity gradient (V_g)	*Second*$^{-1}$	$[M^0L^0T^{-1}]$
(22)	Coefficient of viscosity (η)	*kg/m-s*	$[M^1L^{-1}T^{-1}]$
(23)	Stress	*N/m*^{2}	$[M^1L^{-1}T^{-2}]$
(24)	Strain	No unit	$[M^0L^0T^0]$

(25)	Modulus of elasticity (E)	N/m^2	$[M^1L^{-1}T^{-2}]$
(26)	Poisson Ratio (σ)	No unit	$[M^0L^0T^0]$
(27)	Time period (T)	*Second*	$[M^0L^0T^1]$
(28)	Frequency (n)	*Hz*	$[M^0L^0T^{-1}]$

Heat

S. N.	Quantity	Unit	Dimension
(1)	Temperature (T)	*Kelvin*	$[M^0L^0T^0\theta^1]$
(2)	Heat (Q)	*Joule*	$[ML^2T^{-2}]$
(3)	Specific Heat (c)	*Joule/kg-K*	$[M^0L^2T^{-2}\theta^{-1}]$
(4)	Thermal capacity	*Joule/K*	$[M^1L^2T^{-2}\theta^{-1}]$
(5)	Latent heat (L)	*Joule/kg*	$[M^0L^2T^{-2}]$
(6)	Gas constant (R)	*Joule/mol-K*	$[M^1L^2T^{-2}\theta^{-1}]$
(7)	Boltzmann constant (k)	*Joule/K*	$[M^1L^2T^{-2}\theta^{-1}]$
(8)	Coefficient of thermal conductivity (K)	*Joule/m-s-K*	$[M^1L^1T^{-3}\theta^{-1}]$
(9)	Stefan's constant (σ)	*Watt/m^2-K^4*	$[M^1L^0T^{-3}\theta^{-4}]$
(10)	Wien's constant (b)	*Meter-K*	$[M^0L^1T^0\theta^1]$
(11)	Planck's constant (h)	*Joule-s*	$[M^1L^2T^{-1}]$
(12)	Coefficient of Linear Expansion (α)	*Kelvin^{-1}*	$[M^0L^0T^0\theta^{-1}]$
(13)	Mechanical eq. of Heat (J)	*Joule/Calorie*	$[M^0L^0T^0]$
(14)	Vander wall's constant (a)	*Newton-m^4*	$[ML^5T^{-2}]$
(15)	Vander wall's constant (b)	m^3	$[M^0L^3T^0]$

Electricity

S. N.	Quantity	Unit	Dimension
(1)	Electric charge (q)	*Coulomb*	$[M^0L^0T^1A^1]$
(2)	Electric current (I)	*Ampere*	$[M^0L^0T^0A^1]$
(3)	Capacitance (C)	*Coulomb/volt or Farad*	$[M^{-1}L^{-2}T^4A^2]$
(4)	Electric potential (V)	*Joule/coulomb*	$M^1L^2T^{-3}A^{-1}$
(5)	Permittivity of free space (ε_0)	$\frac{Coulomb^2}{Newton\text{-}meter^2}$	$[M^{-1}L^{-3}T^4A^2]$
(6)	Dielectric constant (K)	Unitless	$[M^0L^0T^0]$
(7)	Resistance (R)	*Volt/Ampere* or *ohm*	$[M^1L^2T^{-3}A^{-2}]$
(8)	Resistivity or Specific resistance (ρ)	*Ohm-meter*	$[M^1L^3T^{-3}A^{-2}]$

(9)	Coefficient of Self-induction (L)	$\frac{volt-second}{ampere}$ or *henery or ohm-second*	$[M^1L^2T^{-2}A^{-2}]$
(10)	Magnetic flux (φ)	*Volt-second* or *weber*	$[M^1L^2T^{-2}A^{-1}]$
(11)	Magnetic induction (B)	$\frac{newton}{ampere-meter}$ $\frac{Joule}{ampere-meter^2}$ $\frac{volt-second}{meter^2}$ or *Tesla*	$[M^1L^0T^{-2}A^{-1}]$
(12)	Magnetic Intensity (H)	*Ampere/meter*	$[M^0L^{-1}T^0A^1]$
(13)	Magnetic Dipole Moment (M)	*Ampere-meter*^{2}	$[M^0L^2T^0A^1]$
(14)	Permeability of Free Space (μ_0)	$\frac{Newton}{ampere^2}$ or $\frac{Joule}{ampere^2-meter}$ or $\frac{Volt-second}{ampere-meter}$ or $\frac{Ohm-second}{meter}$ or $\frac{henery}{meter}$	$[M^1L^1T^{-2}A^{-2}]$
(15)	Surface charge density (σ)	$Coulomb\ metre^{-2}$	$[M^0L^{-2}T^1A^1]$
(16)	Electric dipole moment (p)	$Coulomb-meter$	$[M^0L^1T^1A^1]$
(17)	Conductance (G) (1/R)	ohm^{-1}	$[M^{-1}L^{-2}T^3A^2]$
(18)	Conductivity (σ) (1/ρ)	$ohm^{-1}meter^{-1}$	$[M^{-1}L^{-3}T^3A^2]$
(19)	Current density (J)	*Ampere/m*^{2}	$M^0L^{-2}T^0A^1$
(20)	Intensity of electric field (E)	*Volt/meter*, *Newton/coulomb*	$M^1L^1T^{-3}A^{-1}$
(21)	Rydberg constant (R)	m^{-1}	$M^0L^{-1}T^0$

1.10 Quantities Having Same Dimensions

S. N.	Dimension	Quantity
(1)	$[M^0L^0T^{-1}]$	Frequency, angular frequency, angular velocity, velocity gradient and decay constant
(2)	$[M^1L^2T^{-2}]$	Work, internal energy, potential energy, kinetic energy, torque, moment of force
(3)	$[M^1L^{-1}T^{-2}]$	Pressure, stress, Young's modulus, bulk modulus, modulus of rigidity, energy density
(4)	$[M^1L^1T^{-1}]$	Momentum, impulse
(5)	$[M^0L^1T^{-2}]$	Acceleration due to gravity, gravitational field intensity
(6)	$[M^1L^1T^{-2}]$	Thrust, force, weight, energy gradient
(7)	$[M^1L^2T^{-1}]$	Angular momentum and Planck's constant
(8)	$[M^1L^0T^{-2}]$	Surface tension, Surface energy (energy per unit area)
(9)	$[M^0L^0T^0]$	Strain, refractive index, relative density, angle, solid angle, distance gradient, relative permittivity (dielectric constant), relative permeability etc.
(10)	$[M^0L^2T^{-2}]$	Latent heat and gravitational potential

(11)	$[M^0L^2T^{-2}\theta^{-1}]$	Thermal capacity, gas constant, Boltzmann constant and entropy
(12)	$[M^0L^0T^1]$	$\sqrt{l/g}, \sqrt{m/k}, \sqrt{R/g}$, where l = length g = acceleration due to gravity, m = mass, k = spring constant
(13)	$[M^0L^0T^1]$	L/R, $\sqrt{LC}$, RC where L = inductance, R = resistance, C = capacitance
(14)	$[ML^2T^{-2}]$	$I^2Rt, \frac{V^2}{R}t, VIt, qV, LI^2, \frac{q^2}{C}, CV^2$ where I = current, t = time, q = charge, L = inductance, C = capacitance, R = resistance

1.11 Application of Dimensional Analysis

(1) **To find the unit of a physical quantity in a given system of units** : Writing the definition or formula for the physical quantity we find its dimensions. Now in the dimensional formula replacing M, L and T by the fundamental units of the required system we get the unit of physical quantity. However, sometimes to this unit we further assign a specific name, *e.g.*, Work = Force × Displacement

So $[W] = [MLT^{-2}] \times [L] = [ML^2T^{-2}]$

So its units in C.G.S. system will be $g\ cm^2/s^2$ which is called *erg* while in M.K.S. system will be $kg\ m^2/s^2$ which is called *joule*.

Sample problems based on unit finding

***Problem* 1.** The equation $\left(P + \frac{a}{V^2}\right)(V - b)$ = constant. The units of a is **[MNR 1995; AFMC 1995]**

(a) $Dyne \times cm^5$ (b) $Dyne \times cm^4$ (c) $Dyne / cm^3$ (d) $Dyne / cm^2$

Solution : (b) According to the principle of dimensional homogenity $[P] = \left[\frac{a}{V^2}\right]$

$\Rightarrow [a] = [P]\,[V^2] = [ML^{-1}T^{-2}][L^6] = [ML^5T^{-2}]$

or unit of a = $gm \times cm^5 \times sec^{-2}$ = Dyne × cm^4

***Problem* 2.** If $x = at + bt^2$, where x is the distance travelled by the body in *kilometre* while t the time in seconds, then the units of b are **[CBSE 1993]**

(a) km/s (b) $km\text{-}s$ (c) km/s^2 (d) $km\text{-}s^2$

Solution : (c) From the principle of dimensional homogenity $[x] = [bt^2] \Rightarrow [b] = \left[\frac{x}{t^2}\right]$ ∴ Unit of b = km/s^2.

Problem 3. The unit of absolute permittivity is **[EAMCET (Med.) 1995; Pb. PMT 2001]**

(a) *Farad - meter* (b) *Farad / meter* (c) $Farad/meter^2$ (d) *Farad*

Solution : (b) From the formula $C = 4\pi\varepsilon_0 R$ $\therefore$ $\varepsilon_0 = \frac{C}{4\pi R}$

By substituting the unit of capacitance and radius : unit of $\varepsilon_0 =$ *Farad/ meter*.

Problem 4. Unit of Stefan's constant is **[MP PMT 1989]**

(a) Js^{-1} (b) $Jm^{-2}s^{-1}K^{-4}$ (c) Jm^{-2} (d) Js

Solution : (b) Stefan's formula $\frac{Q}{At} = \sigma T^4$ $\therefore$ $\sigma = \frac{Q}{AtT^4}$ $\therefore$ Unit of $\sigma = \frac{Joule}{m^2 \times sec \times K^4} = Jm^{-2}s^{-1}K^{-4}$

Problem 5. The unit of surface tension in SI system is

[MP PMT 1984; AFMC 1986; CPMT 1985, 87; CBSE 1993; Karnataka CET (Engg/Med.) 1999; DCE 2000, 01]

(a) $Dyne/cm^2$ (b) *Newton/m* (c) *Dyne/cm* (d) $Newton/m^2$

Solution : (b) From the formula of surface tension $T = \frac{F}{l}$

By substituting the S.I. units of force and length, we will get the unit of surface tension = *Newton/m*

Problem 6. A suitable unit for gravitational constant is **[MNR 1988]**

(a) $kg\ metre\ sec^{-1}$ (b) $Newton\ metre^{-1}\ sec$ (c) $Newton\ metre^2 kg^{-2}$ (d) $kg\ metre\ sec^{-1}$

Solution : (c) As $F = \frac{Gm_1m_2}{r^2}$ $\therefore$ $G = \frac{Fr^2}{m_1m_2}$

Substituting the unit of above quantities unit of G = $Newton\ metre^2 kg^{-2}$.

Problem 7. The SI unit of universal gas constant (R) is

[MP Board 1988; JIPMER 1993; AFMC 1996; MP PMT 1987, 94; CPMT 1984, 87; UPSEAT 1999]

(a) $Watt\ K^{-1}mol^{-1}$ (b) $Newton\ K^{-1}mol^{-1}$ (c) $Joule\ K^{-1}mol^{-1}$ (d) $Erg\ K^{-1}mol^{-1}$

Solution : (c) Ideal gas equation $PV = nRT$ $\therefore$ $[R] = \frac{[P][V]}{[nT]} = \frac{[ML^{-1}T^{-2}][L^3]}{[mole][K]} = \frac{[ML^2T^{-2}]}{[mole]\times[K]}$

So the unit will be $Joule\ K^{-1}mol^{-1}$.

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(2) **To find dimensions of physical constant or coefficients** : As dimensions of a physical quantity are unique, we write any formula or equation incorporating the given constant and then by substituting the

dimensional formulae of all other quantities, we can find the dimensions of the required constant or coefficient.

(i) Gravitational constant : According to Newton's law of gravitation $F = G\frac{m_1 m_2}{r^2}$ or $G = \frac{Fr^2}{m_1 m_2}$

Substituting the dimensions of all physical quantities $[G] = \frac{[MLT^{-2}][L^2]}{[M][M]} = [M^{-1}L^3T^{-2}]$

(ii) Plank constant : According to Planck $E = h\nu$ or $h = \frac{E}{\nu}$

Substituting the dimensions of all physical quantities $[h] = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$

(iii) Coefficient of viscosity : According to Poiseuille's formula $\frac{dV}{dt} = \frac{\pi pr^4}{8\eta l}$ or $\eta = \frac{\pi pr^4}{8l(dV/dt)}$

Substituting the dimensions of all physical quantities $[\eta] = \frac{[ML^{-1}T^{-2}][L^4]}{[L][L^3/T]} = [ML^{-1}T^{-1}]$

Sample problems based on dimension finding

Problem **8.** $X = 3YZ^2$ find dimension of Y in (MKSA) system, if X and Z are the dimension of capacity and magnetic field respectively **[MP PMT 2003]**

(a) $M^{-3}L^{-2}T^{-4}A^{-1}$ (b) ML^{-2} (c) $M^{-3}L^{-2}T^4A^4$ (d) $M^{-3}L^{-2}T^8A^4$

Solution : (d) $X = 3YZ^2$ $\therefore$ $[Y] = \frac{[X]}{[Z^2]} = \frac{[M^{-1}L^{-2}T^4A^2]}{[MT^{-2}A^{-1}]^2} = [M^{-3}L^{-2}T^8A^4]$.

Problem **9.** Dimensions of $\frac{1}{\mu_0\varepsilon_0}$, where symbols have their usual meaning, are **[AIEEE 2003]**

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

Solution : (d) We know that velocity of light $C = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$ $\therefore$ $\frac{1}{\mu_0\varepsilon_0} = C^2$

$\therefore$ So $\left[\frac{1}{\mu_0\varepsilon_0}\right] = [LT^{-1}]^2 = [L^2T^{-2}]$.

Problem **10.** If *L*, *C* and *R* denote the inductance, capacitance and resistance respectively, the dimensional formula for C^2LR is **[UPSEAT 2002]**

(a) $[ML^{-2}T^{-1}I^0]$ (b) $[M^0L^0T^3I^0]$ (c) $[M^{-1}L^{-2}T^6I^2]$ (d) $[M^0L^0T^2I^0]$

Solution : (b) $[C^2LR] = \left[C^2L^2\frac{R}{L}\right] = \left[(LC)^2\left(\frac{R}{L}\right)\right]$

and we know that frequency of LC circuits is given by $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$ *i.e.*, the dimension of LC is equal to $[T^2]$

and $\left[\frac{L}{R}\right]$ gives the time constant of $L-R$ circuit so the dimension of $\frac{L}{R}$ is equal to [*T*].

By substituting the above dimensions in the given formula $\left[(LC)^2\left(\frac{R}{L}\right)\right] = [T^2]^2[T^{-1}] = [T^3]$.

Problem **11.** A force *F* is given by $F = at + bt^2$, where t is time. What are the dimensions of *a* and *b* **[BHU 1998; AFMC 2001]**

(a) MLT^{-3} and ML^2T^{-4} (b) MLT^{-3} and MLT^{-4} (c) MLT^{-1} and MLT^0 (d) MLT^{-4} and MLT^1

Solution : (b) From the principle of dimensional homogenity $[F] = [at]$ $\therefore$ $[a] = \left[\frac{F}{t}\right] = \left[\frac{MLT^{-2}}{T}\right] = [MLT^{-3}]$

Similarly $[F] = [bt^2]$ $\therefore$ $[b] = \left[\frac{F}{t^2}\right] = \left[\frac{MLT^{-2}}{T^2}\right] = [MLT^{-4}]$.

Problem **12.** The position of a particle at time *t* is given by the relation $x(t) = \left(\frac{v_0}{\alpha}\right)(1 - c^{-\alpha t})$, where v_0 is a constant and $\alpha > 0$. The dimensions of v_0 and α are respectively **[CBSE 1995]**

(a) $M^0L^1T^{-1}$ and T^{-1} (b) $M^0L^1T^0$ and T^{-1} (c) $M^0L^1T^{-1}$ and LT^{-2} (d) $M^0L^1T^{-1}$ and T

Solution : (a) From the principle of dimensional homogeneity $[\alpha t]$ = dimensionless $\therefore$ $[\alpha] = \left[\frac{1}{t}\right] = [T^{-1}]$

Similarly $[x]=\frac{[v_0]}{[\alpha]}$ $\therefore$ $[v_0]=[x][\alpha]=[L][T^{-1}]=[LT^{-1}]$.

<u>P</u>roblem **13.** The dimensions of physical quantity X in the equation Force $=\frac{X}{\text{Density}}$ is given by **[DCE 1993]**

(a) $M^1L^4T^{-2}$ (b) $M^2L^{-2}T^{-1}$ (c) $M^2L^{-2}T^{-2}$ (d) $M^1L^{-2}T^{-1}$

Solution : (c) [*X*] = [Force] × [Density] = $[MLT^{-2}]\times[ML^{-3}]$ = $[M^2L^{-2}T^{-2}]$.

<u>P</u>roblem **14.** Number of particles is given by $n=-D\frac{n_2-n_1}{x_2-x_1}$ crossing a unit area perpendicular to *X*- axis in unit time, where n_1 and n_2 are number of particles per unit volume for the value of *x* meant to x_2 and x_1. Find dimensions of *D* called as diffusion constant **[CPMT 1979]**

(a) M^0LT^2 (b) $M^0L^2T^{-4}$ (c) M^0LT^{-3} (d) $M^0L^2T^{-1}$

Solution : (d) (*n*) = Number of particle passing from unit area in unit time = $\frac{\text{No.of particle}}{A\times t}=\frac{[M^0L^0T^0]}{[L^2][T]}$ = $[L^{-2}T^{-1}]$

$[n_1]=[n_2]=$ No. of particle in unit volume = $[L^{-3}]$

Now from the given formula $[D]=\frac{[n][x_2-x_1]}{[n_2-n_1]}=\frac{[L^{-2}T^{-1}][L]}{[L^{-3}]}=[L^2T^{-1}]$.

<u>P</u>roblem **15.** *E*, *m*, *l* and *G* denote energy, mass, angular momentum and gravitational constant respectively, then the dimension of $\frac{El^2}{m^5G^2}$ are **[AIIMS 1985]**

(a) Angle (b) Length (c) Mass (d) Time

Solution : (a) $[E]$ = energy = $[ML^2T^{-2}]$, [*m*] = mass = [*M*], [*l*] = Angular momentum = $[ML^2T^{-1}]$

[*G*] = Gravitational constant = $[M^{-1}L^3T^{-2}]$

Now substituting dimensions of above quantities in $\frac{El^2}{m^5G^2}=\frac{[ML^2T^{-2}]\times[ML^2T^{-1}]^2}{[M^5]\times[M^{-1}L^3T^{-2}]^2}=[M^0L^0T^0]$

i.e., the quantity should be angle.

<u>P</u>roblem **16.** The equation of a wave is given by $Y=A\sin\omega\left(\frac{x}{v}-k\right)$ where ω is the angular velocity and v is the linear velocity. The dimension of *k* is **[MP PMT 1993]**

(a) LT (b) T (c) T^{-1} (d) T^2

Solution : (b) According to principle of dimensional homogeneity $[k]=\left[\frac{x}{v}\right]=\left[\frac{L}{LT^{-1}}\right]=[T]$.

***P**roblem* **17.** The potential energy of a particle varies with distance *x* from a fixed origin as $U=\frac{A\sqrt{x}}{x^2+B}$, where *A* and *B* are dimensional constants then dimensional formula for *AB* is

(a) $ML^{7/2}T^{-2}$ (b) $ML^{11/2}T^{-2}$ (c) $M^2L^{9/2}T^{-2}$ (d) $ML^{13/2}T^{-3}$

Solution : (b) From the dimensional homogeneity $[x^2]=[B]$ $\therefore$ $[B]=[L^2]$

As well as $[U]=\frac{[A][x^{1/2}]}{[x^2]+[B]}$ $\Rightarrow$ $[ML^2T^{-2}]=\frac{[A][L^{1/2}]}{[L^2]}$ $\therefore [A]=[ML^{7/2}T^{-2}]$

Now $[AB]=[ML^{7/2}T^{-2}]\times[L^2]=[ML^{11/2}T^{-2}]$

***P**roblem* **18.** The dimensions of $\frac{1}{2}\varepsilon_0E^2$ (ε_0 = permittivity of free space ; *E* = electric field) is **[IIT-JEE 1999]**

(a) MLT^{-1} (b) ML^2T^{-2} (c) $ML^{-1}T^{-2}$ (d) ML^2T^{-1}

Solution : (c) Energy density = $\frac{1}{2}\varepsilon_0E^2=\frac{\text{Energy}}{\text{Volume}}=\left[\frac{ML^2T^{-2}}{L^3}\right]=[ML^{-1}T^{-2}]$

***P**roblem* **19.** You may not know integration. But using dimensional analysis you can check on some results. In the integral $\int\frac{dx}{(2ax-x^2)^{1/2}}=a^n\sin^{-1}\left(\frac{x}{a}-1\right)$ the value of *n* is

(a) 1 (b) – 1 (c) 0 (d) $\frac{1}{2}$

Solution : (c) Let *x* = length $\therefore [X]=[L]$ and $[dx]=[L]$

By principle of dimensional homogeneity $\left[\frac{x}{a}\right]=$ dimensionless $\therefore [a]=[x]=[L]$

By substituting dimension of each quantity in both sides: $\frac{[L]}{[L^2-L^2]^{1/2}}=[L^n]$ $\therefore n=0$

***P**roblem* **20.** A physical quantity $P=\frac{B^2l^2}{m}$ where *B*= magnetic induction, *l*= length and *m* = mass. The dimension of *P* is

(a) MLT^{-3} (b) $ML^2T^{-4}I^{-2}$ (c) $M^2L^2T^{-4}I$ (d) $MLT^{-2}I^{-2}$

Solution : (b) $F = BIL$ $\therefore$ Dimension of $[B] = \dfrac{[F]}{[I][L]} = \dfrac{[MLT^{-2}]}{[I][L]} = [MT^{-2}I^{-1}]$

Now dimension of $[P] = \dfrac{B^2l^2}{m} = \dfrac{[MT^{-2}I^{-1}]^2 \times [L^2]}{[M]} = [ML^2T^{-4}I^{-2}]$

***P**roblem* **21.** The equation of the stationary wave is $y = 2a\sin\left(\dfrac{2\pi ct}{\lambda}\right)\cos\left(\dfrac{2\pi x}{\lambda}\right)$, which of the following statements is wrong

(a) The unit of ct is same as that of λ (b) The unit of x is same as that of λ

(c) The unit of $2\pi c/\lambda$ is same as that of $2\pi x/\lambda t$ (d) The unit of c/λ is same as that of x/λ

Solution : (d) Here, $\dfrac{2\pi ct}{\lambda}$ as well as $\dfrac{2\pi x}{\lambda}$ are dimensionless (angle) *i.e.*

So (i) unit of $c\,t$ is same as that of λ (ii) unit of x is same as that of λ (iii)

and (iv) is unit less. It is not the case with

(3) **To convert a physical quantity from one system to the other** : The measure of a physical quantity is nu = constant

If a physical quantity X has dimensional formula $[M^aL^bT^c]$ and if (derived) units of that physical quantity in two systems are and respectively and n_1 and n_2 be the numerical values in the two systems respectively, then

⇒

⇒

where M_1, L_1 and T_1 are fundamental units of mass, length and time in the first (known) system and M_2, L_2 and T_2 are fundamental units of mass, length and time in the second (unknown) system. Thus knowing the values of fundamental units in two systems and numerical value in one system, the numerical value in other system may be evaluated.

Example : (1) conversion of *Newton* into *Dyne*.

The Newton is the S.I. unit of force and has dimensional formula $[MLT^{-2}]$.

So 1 N = 1 $kg\text{-}m/sec^2$

By using

∴ 1 $N = 10^5$ *Dyne*

(2) Conversion of gravitational constant (G) from C.G.S. to M.K.S. system

The value of G in C.G.S. system is 6.67×10^{-8} C.G.S. units while its dimensional formula is $[M^{-1}L^3T^{-2}]$

So $\quad G = 6.67 \times 10^{-8}\ cm^3/g\ s^2$

By using

∴ $\quad G = 6.67 \times 10^{-11}$ M.K.S. units

Sample problems based on conversion

***Problem* 22.** A physical quantity is measured and its value is found to be where numerical value and unit. Then which of the following relations is true **[RPET 2003]**

(a) (b) (c) (d)

Solution : (d) We know constant ∴ or .

***Problem* 23.** In C.G.S. system the magnitude of the force is 100 *dynes*. In another system where the fundamental physical quantities are *kilogram*, *metre* and *minute*, the magnitude of the force is **[EAMCET 2001]**

(a) 0.036 (b) 0.36 (c) 3.6 (d) 36

Solution : (c) , , , and , , , , ,

By substituting these values in the following conversion formula

Problem 24. The temperature of a body on Kelvin scale is found to be *X K*. When it is measured by a Fahrenheit thermometer, it is found to be *X F*. Then *X* is **[UPSEAT 200]**

(a) 301.25 (b) 574.25 (c) 313 (d) 40

Solution : (c) Relation between centigrade and Fahrenheit

According to problem ∴ .

Problem 25. Which relation is wrong **[RPMT 1997]**

(a) 1 *Calorie* = 4.18 *Joules* (b) 1$Å$ =10^{-10} *m*

(c) 1 *MeV* = 1.6 × 10^{-13} *Joules* (d) 1 *Newton* =10^{-5} *Dynes*

Solution : (d) Because 1 *Newton* = *Dyne*.

Problem 26. To determine the Young's modulus of a wire, the formula is where *L*= length, A= area of cross- section of the wire, Change in length of the wire when stretched with a force *F*. The conversion factor to change it from CGS to MKS system is

[MP PET 1983]

(a) 1 (b) 10 (c) 0.1 (d) 0.01

Solution : (c) We know that the dimension of young's modulus is

C.G.S. unit : *gm* and M.K.S. unit : *kg*. m^{-1} sec^{-2} .

By using the conversion formula:

∴ Conversion factor

Problem 27. Conversion of 1 MW power on a new system having basic units of mass, length and time as 10*kg*, 1*dm* and 1 *minute* respectively is

(a) (b) (c) (d)

Solution : (a)

Using the relation [As

]

unit

Problem **28.** In two systems of relations among velocity, acceleration and force are respectively

and If α and are constants then relations among mass, length and time in two systems are

(a) (b)

(c) (d)

Solution : (b) ......(i)

......(ii)

and ......(iii)

Dividing equation (iii) by equation (ii) we get

Squaring equation (i) and dividing by equation (ii) we get

Dividing equation (i) by equation (ii) we get

Problem **29.** If the present units of length, time and mass (m, s, kg) are changed to 100m, 100s, and kg then

(a) The new unit of velocity is increased 10 times (b) The new unit of force is decreased times
(c) The new unit of energy is increased 10 times (d) The new unit of pressure is increased 1000 times

Solution : (b) Unit of velocity = m/sec ; in new system = (same)

Unit of force ; in new system

Unit of energy ; in new system

Unit of pressure ; in new system

Problem **30.** Suppose we employ a system in which the unit of mass equals 100 kg, the unit of length equals 1 km and the unit of time 100 s and call the unit of energy *eluoj* (*joule* written in reverse order), then

(a) 1 *eluoj* = 10^4 *joule* (b) 1 *eluoj* = 10^{-3} *joule* (c) 1 *eluoj* = 10^{-4} *joule* (d) 1 *joule* = 10^3 *eluoj*

Solution : (a)

1 *eluoj*

Problem **31.** If 1$gm\ cms^{-1}$ = $x\ Ns$, then number x is equivalent to

(a) (b) (c) (d)

Solution : (d) = 10^{-5} Ns

(4) **To check the dimensional correctness of a given physical relation :** This is based on the '*principle of homogeneity*'. According to this principle the dimensions of each term on both sides of an equation must be the same.

If ,

then according to principle of homogeneity $[X] = [A] = [(BC)^2]$

If the dimensions of each term on both sides are same, the equation is dimensionally correct, otherwise not. A dimensionally correct equation may or may not be physically correct.

Example : (1)

By substituting dimension of the physical quantities in the above relation –

i.e.

As in the above equation dimensions of both sides are not same; this formula is not correct dimensionally, so can never be physically.

(2)

By substituting dimension of the physical quantities in the above relation –

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

i.e. $[L] = [L] - [L]$

As in the above equation dimensions of each term on both sides are same, so this equation is dimensionally correct. However, from equations of motion we know that

Sample problems based on formulae checking

***Problem* 32.** From the dimensional consideration, which of the following equation is correct **[CPMT 1983]**

(a) (b) (c) (d)

Solution : (a) [As $GM = gR^2$]

Now by substituting the dimension of each quantity in both sides.

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

***Problem* 33.** A highly rigid cubical block *A* of small mass *M* and side *L* is fixed rigidly onto another cubical block *B* of the same dimensions and of low modulus of rigidity such that the lower face of A completely covers the upper face of *B*. The lower face of B is rigidly held on a horizontal surface. A small force *F* is applied perpendicular to one of the side faces of *A*. After the force is withdrawn block *A* executes small oscillations. The time period of which is given by

[IIT-JEE 1992]

(a) (b) (c) (d)

Solution : (d) Given *m* = mass = [*M*], = coefficient of rigidity = , *L* = length = [*L*]

By substituting the dimension of these quantity we can check the accuracy of the given formulae

= = [*T*].

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

***Problem* 34.** A small steel ball of radius r is allowed to fall under gravity through a column of a viscous liquid of coefficient of viscosity. After some time the velocity of the ball attains a constant value known as terminal velocity The terminal velocity depends on (i) the mass of the ball. (ii) (iii) *r* and (iv) acceleration due to gravity *g*. which of the following relations is dimensionally correct

[CPMT 1992; CBSE 1992; NCERT 1983; MP PMT 2001]

(a) (b) (c) (d)

Solution : (a) Given = terminal velocity = $[LT^{-1}]$, *m* = Mass = [*M*], *g* = Acceleration due to gravity =

r = Radius = [*L*], = Coefficient of viscosity =

By substituting the dimension of each quantity we can check the accuracy of given formula

$\therefore$ = $[LT^{-1}]$

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

***Problem* 35.** A dimensionally consistent relation for the volume *V* of a liquid of coefficient of viscosity flowing per second through a tube of radius and length *l* and having a pressure difference p across its end, is

(a) (b) (c) (d)

Solution : (a) Given *V* = Rate of flow = , *P* = Pressure = , *r* = Radius = [*L*]

= Coefficient of viscosity = , *l* = Length = [*L*]

By substituting the dimension of each quantity we can check the accuracy of the formula

$\therefore$ =

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

Problem **36.** With the usual notations, the following equation is

(a) Only numerically correct (b) Only dimensionally correct

(c) Both numerically and dimensionally correct (d) Neither numerically nor dimensionally correct

Solution : (c) Given = distance travelled by the body in t^{th} *sec*.= , a = Acceleration = ,

v = velocity = , t = time = [T]

By substituting the dimension of each quantity we can check the accuracy of the formula

$\therefore$ $\Rightarrow$

Since the dimension of each terms are equal therefore this equation is dimensionally correct. And after deriving this equation from Kinematics we can also proof that this equation is correct numerically also.

Problem **37.** If velocity acceleration A and force F are chosen as fundamental quantities, then the dimensional formula of angular momentum in terms of and would be

(a) v (b) (c) (d)

Solution : (b) Given, v = velocity = , A = Acceleration = , F = force =

By substituting, the dimension of each quantity we can check the accuracy of the formula

[Angular momentum] =

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

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

Problem **38.** The largest mass (m) that can be moved by a flowing river depends on velocity (v), density ( ) of river water and acceleration due to gravity (g). The correct relation is

(a) (b) (c) (d)

Solution : (d) Given, m = mass = $[M]$, v = velocity = , ρ = density = , g = acceleration due to gravity = $[LT^{-2}]$

By substituting, the dimension of each quantity we can check the accuracy of the formula

= $[M]$

L.H.S. = R.H.S. *i.e.,* the above formula is Correct**.**

(5) **As a research tool to derive new relations :** If one knows the dependency of a physical quantity on other quantities and if the dependency is of the product type, then using the method of dimensional analysis, relation between the quantities can be derived.

Example : (i) Time period of a simple pendulum.

Let time period of a simple pendulum is a function of mass of the bob (m), effective length (l), acceleration due to gravity (g) then assuming the function to be product of power function of m, l and g

i.e., ; where K = dimensionless constant

If the above relation is dimensionally correct then by substituting the dimensions of quantities –

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

or $[M^0 L^0 T^1] = [M^x L^{y+z} T^{-2z}]$

Equating the exponents of similar quantities $x = 0$, $y = 1/2$ and $z = -1/2$

So the required physical relation becomes

The value of dimensionless constant is found (2π) through experiments so

(ii) Stoke's law : When a small sphere moves at low speed through a fluid, the viscous force F, opposing the motion, is found experimentally to depend on the radius r, the velocity of the sphere v and the viscosity η of the fluid.

So $F = f(\eta, r, v)$

If the function is product of power functions of η, r and v, ; where K is dimensionless constant.

If the above relation is dimensionally correct

or

Equating the exponents of similar quantities $x = 1$; $-x + y + z = 1$ and $-x - z = -2$

Solving these for x, y and z, we get $x = y = z = 1$

So eq^n (i) becomes $F = K\eta rv$

On experimental grounds, $K = 6\pi$; so $F = 6\pi\eta rv$

This is the famous Stoke's law.

***S**ample problem based on formulae derivation*

***Problem* 39.** If the velocity of light (c), gravitational constant (G) and Planck's constant (h) are chosen as fundamental units, then the dimensions of mass in new system is **[UPSEAT 2002]**

(a) (b) (c) (d)

Solution : (c) Let or

By substituting the dimension of each quantity in both sides

By equating the power of M, L and T in both sides : , ,

By solving above three equations , and .

$\therefore$

***Problem* 40.** If the time period (T) of vibration of a liquid drop depends on surface tension (S), radius (r) of the drop and density of the liquid, then the expression of T is **[AMU (Med.) 2000]**

(a) (b) (c) (d) None of these

Solution : (a) Let or $T =$

By substituting the dimension of each quantity in both sides

By equating the power of M, L and T in both sides , ,

By solving above three equations $\therefore$, , So the time period can be given as, .

***Problem* 41.** If *P* represents radiation pressure, *C* represents speed of light and *Q* represents radiation energy striking a unit area per second, then non-zero integers *x, y* and *z* such that is dimensionless, are

[AFMC 1991; CBSE 1992; CPMT 1981, 92; MP PMT 1992]

(a) (b) (c) (d)

Solution : (b)

By substituting the dimension of each quantity in the given expression

by equating the power of *M, L* and *T* in both sides: , and

by solving we get .

***Problem* 42.** The volume *V* of water passing through a point of a uniform tube during *t* seconds is related to the cross-sectional area *A* of the tube and velocity *u* of water by the relation , which one of the following will be true

(a) (b) (c) (d)

Solution : (b) Writing dimensions of both sides

By comparing powers of both sides and

Which give and *i.e.* .

***Problem* 43.** If velocity (*V*), force (*F*) and energy (*E*) are taken as fundamental units, then dimensional formula for mass will be

(a) (b) (c) (d)

Solution : (d) Let

Putting dimensions of each quantities in both side

Equating powers of dimensions. We have and

Solving these equations, $b = 0$ and $c = 1$

So

***Problem* 44.** Given that the amplitude A of scattered light is :

(i) Directly proportional to the amplitude (A_0) of incident light.

(ii) Directly proportional to the volume (V) of the scattering particle

(iii) Inversely proportional to the distance (r) from the scattered particle

(iv) Depend upon the wavelength ( ) of the scattered light. then:

(a) (b) (c) (d)

Solution : (b) Let

By substituting the dimension of each quantity in both sides

; or

1.12 Limitations of Dimensional Analysis

Although dimensional analysis is very useful it cannot lead us too far as,

(1) If dimensions are given, physical quantity may not be unique as many physical quantities have same dimensions. For example if the dimensional formula of a physical quantity is it may be work or energy or torque.

(2) Numerical constant having no dimensions [K] such as (1/2), 1 or 2π *etc*. cannot be deduced by the methods of dimensions.

(3) The method of dimensions can not be used to derive relations other than product of power functions. For example,

or

cannot be derived by using this theory (try if you can). However, the dimensional correctness of these can be checked.

(4) The method of dimensions cannot be applied to derive formula if in mechanics a physical quantity depends on more than 3 physical quantities as then there will be less number (= 3) of equations than the unknowns (>3). However still we can check correctness of the given equation dimensionally. For example

can not be derived by theory of dimensions but its dimensional correctness can be checked.

(5) Even if a physical quantity depends on 3 physical quantities, out of which two have same dimensions, the formula cannot be derived by theory of dimensions, *e.g.*, formula for the frequency of a tuning fork cannot be derived by theory of dimensions but can be checked.

1.13 Significant Figures

Significant figures in the measured value of a physical quantity tell the number of digits in which we have confidence. Larger the number of significant figures obtained in a measurement, greater is the accuracy of the measurement. The reverse is also true.

The following rules are observed in counting the number of significant figures in a given measured quantity.

(1) All non-zero digits are significant.

Example : 42.3 has three significant figures.
243.4 has four significant figures.
24.123 has five significant figures.

(2) A zero becomes significant figure if it appears between to non-zero digits.

Example : 5.03 has three significant figures.
5.604 has four significant figures.
4.004 has four significant figures.

(3) Leading zeros or the zeros placed to the left of the number are never significant.

Example : 0.543 has three significant figures.
0.045 has two significant figures.
0.006 has one significant figures.

(4) Trailing zeros or the zeros placed to the right of the number are significant.

Example : 4.330 has four significant figures.
433.00 has five significant figures.
343.000 has six significant figures.

(5) In exponential notation, the numerical portion gives the number of significant figures.

Example : 1.32×10^{-2} has three significant figures.
1.32×10^{4} has three significant figures.

1.14 Rounding Off

While rounding off measurements, we use the following rules by convention:

(1) If the digit to be dropped is less than 5, then the preceding digit is left unchanged.

Example : is rounded off to 7.8, again is rounded off to 3.9.

(2) If the digit to be dropped is more than 5, then the preceding digit is raised by one.

Example : x = 6.87 is rounded off to 6.9, again x = *12.78* is rounded off to 12.8.

(3) If the digit to be dropped is 5 followed by digits other than zero, then the preceding digit is raised by one.

Example : x = 16.351 is rounded off to 16.4, again x = 6.758 is rounded off to 6.8.

(4) If digit to be dropped is 5 or 5 followed by zeros, then preceding digit is left unchanged, if it is even.

Example : x = 3.250 becomes 3.2 on rounding off, again x = 12.650 becomes 12.6 on rounding off.

(5) If digit to be dropped is 5 or 5 followed by zeros, then the preceding digit is raised by one, if it is odd.

Example : x = 3.750 is rounded off to 3.8, again x = 16.150 is rounded off to 16.2.

1.15 Significant Figures in Calculation

In most of the experiments, the observations of various measurements are to be combined mathematically, *i.e.*, added, subtracted, multiplied or divided as to achieve the final result. Since, all the observations in measurements do not have the same precision, it is natural that the final result cannot be more precise than the least precise measurement. The following two rules should be followed to obtain the proper number of significant figures in any calculation.

(1) The result of an addition or subtraction in the number having different precisions should be reported to the same number of decimal places as are present in the number having the least number of decimal places. The rule is illustrated by the following examples :

(i) 33.3 $\leftarrow$ (has only one decimal place)

3.11

+ 0.313

36.723 $\leftarrow$ (answer should be reported to one decimal place)

Answer = 36.7

(ii) 3.1421

0.241

+ 0.09 $\leftarrow$ (has 2 decimal places)

3.4731 $\leftarrow$ (answer should be reported to 2 decimal places)

Answer = 3.47

(iii) 62.831 $\leftarrow$ (has 3 decimal places)

– 24.5492

38.2818 ← (answer should be reported to 3 decimal places after rounding off)

Answer = 38.282

(2) The answer to a multiplication or division is rounded off to the same number of significant figures as is possessed by the least precise term used in the calculation. The rule is illustrated by the following examples :

(i) 142.06

× 0.23 ← (two significant figures)

32.6738 ← (answer should have two significant figures)

Answer = 33

(ii) 51.028

× 1.31 ← (three significant figures)

66.84668

Answer = 66.8

(iii)

Answer = 0.21

1.16 Order of Magnitude

In scientific notation the numbers are expressed as, Number . Where M is a number lies between 1 and 10 and *x* is integer. Order of magnitude of quantity is the power of 10 required to represent the quantity. For determining this power, the value of the quantity has to be rounded off. While rounding off, we ignore the last digit which is less than 5. If the last digit is 5 or more than five, the preceding digit is increased by one. For example,

(1) Speed of light in vacuum (ignoring 3 < 5)

(2) Mass of electron (as 9.1 > 5).

Sample problems based on significant figures

***Problem* 45.** Each side a cube is measured to be 7.203 *m*. The volume of the cube up to appropriate significant figures is

(a) 373.714 (b) 373.71 (c) 373.7 (d) 373

Solution : (c) Volume

In significant figures volume of cube will be because its side has four significant figures.

***Problem* 46.** The number of significant figures in 0.007 is

(a) 1 (b) 2 (c) 3 (d) 4

Solution : (a)

***Problem* 47.** The length, breadth and thickness of a block are measured as 125.5 *cm*, 5.0 *cm* and 0.32 *cm* respectively. Which one of the following measurements is most accurate

(a) Length (b) Breadth (c) Thickness (d) Height

Solution : (a) Relative error in measurement of length is minimum, so this measurement is most accurate.

***Problem* 48.** The mass of a box is 2.3 kg. Two marbles of masses 2.15 *g* and 12.39 *g* are added to it. The total mass of the box to the correct number of significant figures is

(a) 2.340 *kg* (b) 2.3145 *kg*. (c) 2.3 *kg* (d) 2.31 *kg*

Solution : (c) Total mass

Total mass in appropriate significant figures be 2.3 *kg*.

***Problem* 49.** The length of a rectangular sheet is 1.5 cm and breadth is 1.203 cm. The area of the face of rectangular sheet to the correct no. of significant figures is :

(a) 1.8045 (b) 1.804 (c) 1.805 (d) 1.8

Solution : (d) Area (Upto correct number of significant figure).

***Problem* 50.** Each side of a cube is measured to be 5.402 cm. The total surface area and the volume of the cube in appropriate significant figures are :

(a) 175.1 , 157 (b) 175.1 , 157.6

(c) 175 , 157 (d) 175.08 , 157.639

Solution : (b) Total surface area = (Upto correct number of significant figure)

Total volume (Upto correct number of significant figure).

***Problem* 51.** Taking into account the significant figures, what is the value of 9.99 *m* + 0.0099 *m*

(a) 10.00 *m* (b) 10 *m* (c) 9.9999 *m* (d) 10.0 *m*

Solution : (a) (In proper significant figures).

***Problem* 52.** The value of the multiplication 3.124 4.576 correct to three significant figures is

(a) 14.295 (b) 14.3 (c) 14.295424 (d) 14.305

Solution : (b) =14.3 (Correct to three significant figures).

***Problem* 53.** The number of the significant figures in 11.118 10 *V* is

(a) 3 (b) 4 (c) 5 (d) 6

Solution : (c) The number of significant figure is 5 as does not affect this number.

Problem **54.** If the value of resistance is 10.845 *ohms* and the value of current is 3.23 *amperes*, the potential difference is 35.02935 *volts*. Its value in significant number would be

[CPMT 1979]

(a) 35 V (b) 35.0 V (c) 35.03 V (d) 35.025 V

Solution : (b) Value of current (3.23 A) has minimum significant figure (3) so the value of potential difference have only 3 significant figure. Hence its value be 35.0 V.

1.17 Errors of Measurement

The measuring process is essentially a process of comparison. Inspite of our best efforts, the measured value of a quantity is always somewhat different from its actual value, or true value. This difference in the true value of a quantity is called error of measurement.

(1) **Absolute error :** Absolute error in the measurement of a physical quantity is the magnitude of the difference between the true value and the measured value of the quantity.

Let a physical quantity be measured n times. Let the measured value be a_1, a_2, a_3, ….. a_n. The arithmetic mean of these value is

Usually, a_m is taken as the true value of the quantity, if the same is unknown otherwise.

By definition, absolute errors in the measured values of the quantity are

…………

The absolute errors may be positive in certain cases and negative in certain other cases.

(2) **Mean absolute error :** It is the arithmetic mean of the magnitudes of absolute errors in all the measurements of the quantity. It is represented by Thus

Hence the final result of measurement may be written as

This implies that any measurement of the quantity is likely to lie between and

(3) **Relative error or Fractional error :** The relative error or fractional error of measurement is defined as the ratio of mean absolute error to the mean value of the quantity measured. Thus

Relative error or Fractional error

(4) **Percentage error :** When the relative/fractional error is expressed in percentage, we call it percentage error. Thus

Percentage error

1.18 Propagation of Errors

(1) **Error in sum of the quantities :** Suppose $x = a + b$

Let Δa = absolute error in measurement of a

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* sum of a and b.

The maximum absolute error in x is

Percentage error in the value of

(2) **Error in difference of the quantities :** Suppose $x = a - b$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* difference of a and b.

The maximum absolute error in x is

Percentage error in the value of

(3) **Error in product of quantities :** Suppose $x = a \times b$

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* product of a and b.

The maximum fractional error in x is

Percentage error in the value of x = (Percentage error in value of a) + (Percentage error in value of b)

(4) **Error in division of quantities :** Suppose

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x *i.e.* division of a and b.

The maximum fractional error in x is

Percentage error in the value of x = (Percentage error in value of a) + (Percentage error in value of b)

(5) **Error in quantity raised to some power :** Suppose

Let Δa = absolute error in measurement of a,

Δb = absolute error in measurement of b

Δx = absolute error in calculation of x

The maximum fractional error in x is

Percentage error in the value of x = n (Percentage error in value of a) + m (Percentage error in value of b)

Note : ❑ The quantity which have maximum power must be measured carefully because it's contribution to error is maximum.

Sample problems based on errors of measurement

***Problem* 55.** A physical parameter a can be determined by measuring the parameters b, c, d and e using the relation a = . If the maximum errors in the measurement of b, c, d and e are %, %, % and %, then the maximum error in the value of a determined by the experiment is **[CPMT 1981]**

(a) ( )% (b) ( )%

(c) ( )% (d) ( )%

Solution : (d)

So maximum error in a is given by

***Problem* 56.** The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate. If the maximum error in the measurement of force and length are respectively 4% and 2%, The maximum error in the measurement of pressure is

[CPMT 1993]

(a) 1% (b) 2% (c) 6% (d) 8%

Solution : (d) , so maximum error in pressure

= 4% + 2 × 2% = 8%

***Problem* 57.** The relative density of material of a body is found by weighing it first in air and then in water. If the weight in air is (5.00) *Newton* and weight in water is (4.00 0.05) *Newton*. Then the relative density along with the maximum permissible percentage error is

(a) 5.0 11% (b) 5.0 1% (c) 5.0 6% (d) 1.25 5%

Solution : (a) Weight in air

Weight in water

Loss of weight in water

Now relative density *i.e. R . D*

Now relative density with max permissible error

***Problem* 58.** The resistance *R* = where *V*= 100 5 volts and i = 10 0.2 *amperes*. What is the total error in *R*

(a) 5% (b) 7% (c) 5.2% (d) %

Solution : (b) $\therefore$ = 7%

***Problem* 59.** The period of oscillation of a simple pendulum in the experiment is recorded as 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s respectively. The average absolute error is

(a) 0.1 s (b) 0.11 s (c) 0.01 s (d) 1.0 s

Solution : (b) Average value

Now

Mean absolute error

***P**roblem* **60.** The length of a cylinder is measured with a meter rod having least count 0.1 *cm*. Its diameter is measured with venier calipers having least count 0.01 *cm*. Given that length is 5.0 *cm*. and radius is 2.0 *cm*. The percentage error in the calculated value of the volume will be

(a) 1% (b) 2% (c) 3% (d) 4%

Solution : (c) Volume of cylinder

Percentage error in volume

=

***P**roblem* **61.** In an experiment, the following observation's were recorded : L = 2.820 *m*, M = 3.00 *kg*, l = 0.087 *cm*,

Diameter D = 0.041 *cm* Taking g = 9.81 using the formula , Y= , the maximum permissible error in Y is

(a) 7.96% (b) 4.56% (c) 6.50% (d) 8.42%

Solution : (c) so maximum permissible error in Y =

***P**roblem* **62.** According to Joule's law of heating, heat produced Rt, where I is current, R is resistance and t is time. If the errors in the measurement of I, R and t are 3%, 4% and 6% respectively then error in the measurement of H is

(a) 17% (b) 16% (c) 19% (d) 25%

Solution : (b)

***P**roblem* **63.** If there is a positive error of 50% in the measurement of velocity of a body, then the error in the measurement of kinetic energy is

(a) 25% (b) 50% (c) 100% (d) 125%

Solution : (c) Kinetic energy

Here and

***P**roblem* **64.** A physical quantity P is given by P= . The quantity which brings in the maximum percentage error in P is

(a) A (b) B (c) C (d) D

Solution : (c) Quantity C has maximum power. So it brings maximum error in P.

Problems based on units and dimensions

1. Number of base SI units is **[MP PET 2003]**

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

2. The unit of Planck's constant is
[RPMT 1999; MP PET 2003]
(a) *Joule* (b) *Joule*/s (c) *Joule*/*m* (d) *Joule*- *s*

3. The unit of reactance is [MP PET 2003]
(a) *Ohm* (b) *Volt* (c) *Mho* (d) *Newton*

4. The dimension of are [MP PET 2003]
(a) (b) *T* (c) (d)

5. Dimensions of potential energy are [MP PET 2003]
(a) (b) (c) (d)

6. The dimensions of electric potential are [UPSEAT 2003]
(a) (b) (c) (d)

7. The physical quantities not having same dimensions are [AIEEE 2003]
(a) Speed and (b) Torque and work
(c) Momentum and Planck's constant (d) Stress and Young's modulus

8. The dimensional formula for Boltzmann's constant is [MP PET 2002]
(a)] (b) (c) (d)

9. Which of the following quantities is dimensionless [MP PET 2002]
(a) Gravitational constant (b) Planck's constant (c) Power of a convex lens (d) None of these

10. Which of the two have same dimensions [AIEEE 2002]
(a) Force and strain (b) Force and stress
(c) Angular velocity and frequency (d) Energy and strain

11. The dimensions of pressure is equal to [AIEEE 2002]
(a) Force per unit volume (b) Energy per unit volume (c) Force (d) Energy

12. Identify the pair whose dimensions are equal [AIEEE 2002]
(a) Torque and work (b) Stress and energy (c) Force and stress (d) Force and work

13. A physical quantity *x* depends on quantities *y* and *z* as follows: where and *C* are constants. Which of the following do not have the same dimensions [AMU (Eng.) 2001]
(a) *x* and *B* (b) *C* and (c) *y* and (d) *x* and *A*

14. is dimension of [RPET 2000]
(a) Resistivity (b) Conductivity (c) Resistance (d) None of these

15. Two quantities *A* and *B* have different dimensions. Which mathematical operation given below is physically meaningful [CPMT 1997]
(a) *A*/*B* (b) *A* + *B* (c) *A* – *B* (d) None of these

16. Let denotes the dimensional formula of the permittivity of the vacuum and that of the permeability of the vacuum. If *M* = mass, *L*= length, *T*= time and *I*= electric current, then

[IIT-JEE 1998]

(a) (b) (c) (d)

17. The dimension of quantity is **[Roorkee 1994]**

(a) [*A*] (b) (c) (d) None of these

18. The quantity here is the permittivity of free space, is length, *V* is potential difference and *t* is time. The dimensions of *X* are same as that of

[IIT-JEE (Screening) 2001]

(a) Resistance (b) Charge (c) Voltage (d) Current

19. The unit of permittivity of free space is **[MP PET 1993; MP PMT 2003]**

(a) *Coulomb*/*Newton-metre*

(b) *Newton-metre*^{2}/*Coulomb*^{2}

(c) *Coulomb*^{2}/(*Newton-metre*)^2

(d) *Coulomb*^{2}/*Newton-metre*^{2}

20. Dimensional formula of capacitance is **[CPMT 1978; MP PMT 1979; IIT-JEE 1983]**

(a) (b) (c) (d)

21. The dimensional formula for impulse is **[EAMCET 1981; CBSE PMT 1991; CPMT 1978; AFMC 1998; BCECE 2003]**

(a) (b) (c) (d)

22. The dimensions of universal gravitational constant are **[MP PMT 1984, 87, 97, 2000; CBSE PMT 1988, 92, 2004; MP PET 1984, 96, 99; MNR 1992; DPMT 1984; CPMT 1978, 84, 89, 90, 92, 96; AFMC 1999; NCERT 1975; DPET 1993; AIIMS 2002; RPET 2001; Pb. PMT 2002; UPSEAT 1999; BCECE 2003]**

(a) (b) (c) (d)

23. How many wavelength of are there in one *metre* **[MNR 1985; UPSEAT 2000]**

(a) 1553164.13 (b) 1650763.73 (c) 652189.63 (d) 2348123.73

24. Light year is a unit of **[MP PMT 1989; AFMC 1991; CPMT 1991]**

(a) Time (b) mass (c) Distance (d) Energy

25. *L*, *C* and *R* represent physical quantities inductance, capacitance and resistance respectively. The combination which has the dimensions of frequency is

[IIT-JEE 1984]

(a) 1/*RC* and *R*/*L* (b) and (c) (d)

26. In the relation , *P* is pressure, *z* is distance , *k* is Boltzmann constant and *θ* is temperature. The dimensional formula of *β* will be **[IIT-JEE (Screening) 2004]**

(a) (b) (c) (d)

27. If the acceleration due to gravity be taken as the unit of acceleration and the velocity generated in a falling body in one second as the unit of velocity then

(a) The new unit of length is *metre*
(b) The new unit of length is 1 *metre*
(c) The new unit of length is *metre*
(d) The new unit of time is *second*

28. The famous Stefan's law of radiation states that the rate of emission of thermal radiation per unit by a black body is proportional to area and fourth power of its absolute temperature that is where area, temperature and is a universal constant. In the 'energy- length- time temperature' (E-L-T-K) system the dimension of is

(a) (b) (c) (d) 2.

29. The resistive force acting on a body moving with a velocity *V* through a fluid at rest is given by where, = coefficient of drag, *A* = area of cross-section perpendicular to the direction of motion. The dimensions of are

(a) ML^3T^{-2} (b) $M^{-1}L^{-1}T^2$ (c) $M^{-1}L^{-1}T^{-2}$ (d) $M^0L^0T^0$

30. The dimensions of (angular momentum)/(magnetic moment) are :

(a) $[M^3LT^{-2}A^2]$ (b) $[MA^{-1}T^{-1}]$ (c) $[ML^2A^{-2}T]$ (d) $[M^2L^{-3}AT^2]$

31. The frequency *n* of vibrations of uniform string of length *l* and stretched with a force *F* is given by where *p* is the number of segments of the vibrating string and *m* is a constant of the string. What are the dimensions of *m*

(a) $ML^{-1}T^{-1}$ (b) $ML^{-3}T^0$ (c) $ML^{-2}T^0$ (d) $ML^{-1}T^0$

32. Choose the wrong statement(s)

(a) A dimensionally correct equation may be correct
(b) A dimensionally correct equation may be incorrect
(c) A dimensionally incorrect equation may be incorrect
(d) A dimensionally incorrect equation may be incorrect

33. A certain body of mass *M* moves under the action of a conservative force with potential energy *V* given by where *x* is the displacement and *a* is the amplitude. The units of *K* are

(a) *Watt* (b) *Joule* (c) *Joule-metre* (d) None of these.

34. The Richardson equation is given by . The dimensional formula for AB^2 is same as that for

(a) IT^2 (b) kT (c) IK^2 (d) IK^2/T

35. If the units of force, energy and velocity are 10 *N*, 100 *J* and 5 ms^{-1}, the units of length, mass and time will be

(a) 10*m*, 5*kg*, 1*s* (b) 10*m*, 4*kg*, 2*s* (c) 10*m*, 4*kg*, 0.5*s* (d) 20*m*, 5*kg*, 2*s*.

Problems based on error of measurement

36. The period of oscillation of a simple pendulum is given by where l is about 100 cm and is known to 1mm accuracy. The period is about 2s. The time of 100 oscillations is measured by a stop watch of least count 0.1 s. The percentage error in g is

(a) 0.1% (b) 1% (c) 0.2% (d) 0.8%

37. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimation of the kinetic energy obtained by measuring mass and speed **[NCERT 1990; Orissa JEE 1990]**

(a) 11% (b) 8% (c) 5% (d) 1%

38. While measuring the acceleration due to gravity by a simple pendulum, a student makes a positive error of 1% in the length of the pendulum and a negative error of 3% in the value of time period. His percentage error in the measurement of by the relation will be

(a) 2% (b) 4% (c) 7% (d) 10%

39. The random error in the arithmetic mean of 100 observations is x; then random error in the arithmetic mean of 400 observations would be

(a) 4x (b) (c) 2x (d)

40. What is the number of significant figures in 0.310×10^{3}

(a) 2 (b) 3 (c) 4 (d) 6

41. Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is

(a) 1% (b) 3% (c) 5% (d) 7%

42. The mean time period of second's pendulum is 2.00s and mean absolute error on the time period is 0.05s. To express maximum estimate of error, the time period should be written as

(a) $(2.00 \pm 0.01)\ s$ (b) $(2.00 + 0.025)\ s$ (c) $(2.00 \pm 0.05)\ s$ (d) $(2.00 \pm 0.10)\ s$

43. A body travels uniformly a distance of (13.8 ± 0.2) m in a time (4.0 ± 0.3) s. The velocity of the body within error limits is

(a) $(3.45 \pm 0.2)\ ms^{-1}$ (b) $(3.45 \pm 0.3)\ ms^{-1}$ (c) $(3.45 \pm 0.4)\ ms^{-1}$ (d) $(3.45 \pm 0.5)\ ms^{-1}$

44. The percentage error in the above problem is

(a) 7% (b) 5.95% (c) 8.95% (d) 9.85%

45. The unit of percentage error is

(a) Same as that of physical quantity

(b) Different from that of physical quantity

(c) Percentage error is unit less

(d) Errors have got their own units which are different from that of physical quantity measured

46. The decimal equivalent of 1/20 upto three significant figures is

(a) 0.0500 (b) 0.05000 (c) 0.0050 (d) 5.0×10^{-2}

47. If 97.52 is divided by 2.54, the correct result in terms of significant figures is

(a) 38.4 (b) 38.3937 (c) 38.394 (d) 38.39

48. Accuracy of measurement is determined by

(a) Absolute error (b) Percentage error (c) Both (d) None of these

49. The radius of a sphere is (5.3 ± 0.1) *cm*. The percentage error in its volume is

(a) (b) (c) (d)

50. A thin copper wire of length *l* metre increases in length by 2% when heated through 10ºC. What is the percentage increase in area when a square copper sheet of length *l* metre is heated through 10º*C*

(a) 4% (b) 8% (c) 16% (d) None of the above.

51. In the context of accuracy of measurement and significant figures in expressing results of experiment, which of the following is/are correct

(1) Out of the two measurements 50.14 *cm* and 0.00025 *ampere*, the first one has greater accuracy

(2) If one travels 478 *km* by rail and 397 *m*. by road, the total distance travelled is 478 *km*.

(a) Only (1) is correct (b) Only (2) is correct (c) Both are correct (d) None of them is correct.

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