**“**The only Place where Success comes before Work is in the dictionary…” - Vince Lombardi

**Physical World/ Units and Measurements**

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 phenomena.

-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. Its Sanskrit equivalent is *Bhautiki* that is used to refer to the study of the physical world.

The scope of physics can be described by **unification** and **reduction**.

Unification means attempts to unify different laws of physics.For example, the same law of gravitation (given by Newton)describes the fall of an apple to the ground, the motion of the moon around the earth and the

motion of planets around the sun.

**Reductionism** : is to derive the properties of a bigger, more complex, system from the properties and interactions of its constituent simpler parts.

**-Classical Physics** deals mainly with **macroscopic** phenomena and includes subjects like **Mechanics**, **Electrodynamics , Optics** and **Thermodynamics**.

- **Modern Physics** deals mainly with **microscopic** domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei (and even lower scales of length) and their interaction with different probes such as electrons, photons and other elementary particles.



**Mechanics**

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**

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

**Optics**

Optics deals with the phenomena involving light. The working of telescopes and microscopes, colours exhibited by thin films, etc., are topics in optics.

**Thermodynamics**

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.

**Modern Physics**

The **microscopic** domain of physics deals with the constitution and structure of matter at the minute scales of atoms and nuclei (and even lower scales of length) and their interaction with different probes such as electrons, photons and other elementary particles.

**Hypothesis, axioms and models**

A **hypothesis** is a supposition without assuming that it is true. It can be verified and substantiated by experiments and observations

for e.g It would not be fair to ask anybody to prove the universal law of gravitation, because it cannot be proved. It can be verified and substantiated by experiments and observations.

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

**Fundamental Forces In Nature**

At the present stage of our understanding, we know of four fundamental forces in nature,

* **Gravitational Force**
* **Electromagnetic Force**
* **Strong Nuclear Force**
* **Weak Nuclear Force**

**Gravitational Force**

The gravitational force is the force of mutual attraction between any two objects by virtue of their masses. It is a universal force.

**Electromagnetic Force**

Electromagnetic force is the force between charged particles. In the simpler case when charges are at rest, the force is given by Coulomb’s law : attractive for unlike charges and repulsive for like charges.

**Strong Nuclear Force**

The strong nuclear force binds protons and neutrons in a nucleus. It is evident that without some attractive force, a nucleus will be unstable due to the electric repulsion between its protons. This attractive force cannot be gravitational since force of gravity is negligible compared to the electric force.

**Weak Nuclear Force**

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.

The weak nuclear force is not as weak as the gravitational force, but much weaker than the strong nuclear and electromagnetic forces. The range of weak nuclear force is exceedingly small, of the order of 10-16 m.



**Conservation laws in physics**

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

**Physical Quantities:** Those quantities which can describe the laws of Physics and are possible to measure are called Physical Quantities. A Physical quantity is completely specified if it has

: Only numerical value (ratio ) e.g. refractive index ,relative density etc.

:If it has only magnitude i.e. Scalar quantities eg. Distance, speed etc.

:If it has both magnitude and direction i.e. Vector Quantities.

“ There are also some of the physical quantities which are not completely specified even by magnitude, unit and direction. These quantities are called **Tensors** eg. Moment of inertia .”

The Physical Quantities can be divided into (a) Fundamental Quantities and (b) Derived Quantities.

Fundamental Quantities: are those quantities which do not depend upon other Quantities. Following are the 7 fundamental quantities.

1.Length 2.Mass 3.Time 4.Electric Current 5.Thermodynamic Temperature 6.Amount of substance (mole) 7.Luminous Intensity

Besides these 7 fundamental Quantities two supplementary quantities are also used. They are for plane angle(unit-radian) and solid angle(unit steradian)

Unit : Measurement of any physical quantity involves comparison with a certain basic, arbitrarily chosen, internationally accepted reference standard called unit.

Properties of Unit :

* The Unit should be well defined
* The Unit should be of some suitable size
* The Unit should be easily reproducible
* The Unit should not change with time
* The Unit should not change with physical conditions like pressure, temperature etc.
* The Unit should be easily available

**Fundamental or base units** : The units for the fundamental or base quantities are called fundamental or base units.

**Derived units**: The units of all other physical quantities can be expressed as combinations of the base units. Such units obtained for the derived quantities are called derived units.

**System of units**: A complete set of these units, both the base units and derived units, is known as the system of units.

Some of the System of Units are : The CGS, the FPS (or British) system , the MKS and the Système Internationale’d. Unites (French for International System of Units) abbreviated as SI system.

The base units for length, mass and time in CGS, the FPS (or British) system , the MKS systems were as follows :

• In CGS system they were centimetre, gram and second respectively.

• In FPS system they were foot, pound and second respectively.

• In MKS system they were metre, kilogram and second respectively.

The system of units which is at present internationally accepted for measurement is the Système Internationale’d. Unites (French for International System of Units), abbreviated as SI. The SI, with standard scheme of symbols, units and abbreviations, was developed and recommended by General Conference on Weights and Measures in 1971 for international usage in scientific, technical, industrial and commercial work.

Because SI units used decimal system, conversions within the system are quite simple and convenient. We shall follow the SI units in this course.

In SI, there are seven base units as given in following Table

|  |  |  |
| --- | --- | --- |
| **Base quantity** | **Name** | **Symbol** |
| Length | metre | m |
| Mass | kilogram | kg |
| Time | second | s |
| Electric current | ampere | A |
| Thermodynamic temperature | Kelvin | K |
| Amount of substance | mole | mol |
| Luminous Intensity | Candela | cd |

Besides the seven base units, there are two more units that are defined for

(a) plane angle dθ as the ratio of length of arc ds to the radius r and

(b) solid angle dΩ as the ratio of the intercepted area dA of the spherical surface, described about the apex O as the centre, to the square of its radius r, as shown in Fig. 2.1(a) and (b) respectively.

-The unit for plane angle is radian with the symbol rad and the unit for the solid angle is steradian with the symbol sr. Both these are dimensionless quantities.

 Some points regarding SI system of units :

1. It is a coherent system of units, i.e., product or quotient of any two base

quantities results in a unit resultant quantity. For example, unit length

divided by unit time gives unit velocity.

2. It is a rationalized system of units. It clearly distinguishes between the units of mass and weight (force) which are expressed in kilogram and newton respectively.

3. All the units of the system can be derived from the base and supplementary units.

4. The decimal relationship between units of same quantity makes it possible to express any small or large quantity as power of 10.

5. For any quantity there is one and only one SI unit. For example, joule is the unit of energy of all forms such as mechanical, heat, chemical, electrical and nuclear. However, kWh also continues as unit of electrical energy.

Changing Units

We often need to change the units in which a physical quantity is expressed. We do so by a method called chain-link conversion. In this method, we multiply the original measurement by a conversion factor .

Now let’s review SI units of length ,mass and time in detail.

Calculation of Length.

In October 1983, the meter (m) was redefined as the distance travelled by light in vacuum during a time of 1/299 792 458 second.

We are already familiar with some direct methods for the measurement of length.

For example, a metre scale is used for lengths from 10-3 m to 10-2 m.

A vernier callipers is used for lengths to an accuracy of 10-4 m.

A screw gauge and a spherometer can be used to measure lengths as less as to 10-5 m.

To measure lengths beyond these ranges, we make use of some special indirect methods like parallax method to measure very large distances and an electron microscope to measure very small distances

(a)Measurement of large distances : Parallax Method :

Parallax, also called parallactic shift, the apparent displacement of the position of an object (preferably celestial object on the celestial sphere) when viewed from two different positions is known as Parallax.

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

To measure the distance D of a far away planet S by the parallax method, we observe it from two different positions (observatories) A and B on the Earth, separated by distance AB = b at the same time as shown in Fig. 2.2. We measure the angle between the two directions along which the planet is viewed at these two points. The ∠ASB in Fig. 2.2 represented by symbol θ is called the parallax angle or parallactic angle.

As the planet is very far away, b/D<<1,and therefore, θ is very small. Then we approximately take AB as an arc of length b of a circle with centre at S and the distance D as

the radius AS = BS so that AB = b = D θ where θ is in radians.

D =b/θ (2.1)

Hence in this way we can measure the distance ‘D’.

(b) Method to determine the size or angular diameter of the planet

If d is the diameter of the planet and α the angular size of the planet (the angle subtended by d at the earth),

we have α = d/D (2.2)

The angle α can be measured from the same location on the earth. It is the angle between the two directions when two diametrically opposite points of the planet are viewed through the telescope. Since D is known, the diameter d of the planet can be determined using Eq. (2.2)

Exercise : Do all solved numericals of NCERT Ex. 2.1 – 2.4 P.no. 19,20

(c) Estimation of Very Small Distances: Size of a Molecule/Atom

We need to use special methods to measure a very small size like that of a molecule (10-8 m to 10-10 m).

Use of an optical microscope :An optical microscope can be used to measure small lengths by using visible light at the system under investigation or. But it has certain limitations. An optical microscope uses visible light to look and as light has wave like features,the resolution to which an optical microscope can be used is the wavelength of light. For visible light the range of wavelengths is from about 4000 Å to 7000 Å

(1 angstrom = 1 Å = 10-10 m). Hence an optical microscope cannot resolve particles with sizes smaller than this

Use of an Electron microscope :Instead of visible light, we can use an electron beam. Electron beams can be focussed by properly designed electric and magnetic fields. The resolution of such an electron microscope is limited finally by the fact that electrons can also behave as waves.

But the wavelength of an electron can be as small as a fraction of an angstrom. Such electron microscopes with a resolution of 0.6 Å have been built. They can almost resolve atoms and molecules in a material. In recent times, tunnelling microscopy has been developed in which again the limit of resolution is better than an angstrom. It is possible to estimate the sizes of molecules.

Method to measure the molecular size of Oleic Acid : NCERT p.no. 20

Range of Lengths

The sizes of the objects we come across in the universe vary over a very wide range. These may vary from the size of the order of 10-14 m of the tiny nucleus of an atom to the size of the order of 1026 m of the extent of the observable universe.

We also use certain special length units for short and large lengths. These are

1 fermi = 1 f = 10-15 m 1 angstrom = 1 Å = 10-10 m

1 astronomical unit = 1 AU (average distance of the Sun from the Earth) = 1.496 × 1011 m

1 light year = 1 ly= 9.46 × 1015 m (distance that light travels with velocity of 3 × 108 m /s in 1 year)

1 parsec = 3.08 × 1016 m (Parsec is the distance at which average radius of earth’s orbit subtends an angle of 1 arc second)

Measurement of Mass

Mass is a basic property of matter. It does not depend on the temperature, pressure or location of the object in space. The SI unit of mass is kilogram (kg).

The basic SI unit of mass, the kilogram (kg), is defined as the mass of a specific platinum–iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sèvres, France. This mass standard was established in 1887 and has not been changed since that time because platinum–iridium is an unusually stable alloy

Another unit of mass while dealing with atoms and moles is “atomic mass unit ” or unified atomic mass unit (u), which has been established for expressing the mass of atoms as

1 unified atomic mass unit = 1u = 1amu = (1/12) of the mass of an atom of carbon-12 isotope including the mass of electrons= 1.66 x10-27 kg

Different methods to measure mass :

-Mass of commonly available objects can be determined by a common balance like the one used in a grocery shop.

- Large masses in the universe like planets, stars, etc., based on

Newton’s law of gravitation can be measured by using gravitational method

– For measurement of small masses of atomic/subatomic particles etc., we make use of mass spectrograph in which radius of the trajectory is proportional to the mass of a charged particle moving in uniform electric and magnetic field.

Measurement of time : In 1967 the SI unit of time, the second, was redefined using the characteristic frequency of a particular kind of cesium atom as the “reference clock.” The basic SI unit of time, the second (s), is defined as 9 192 631 770 times the period of vibration of radiation from the cesium-133 atom.

The cesium atomic clocks are very accurate. In principle they provide portable standard. The national standard of time interval ‘second’ as well as the frequency is maintained through four cesium atomic clocks. A cesium atomic clock is used at the National Physical Laboratory (NPL),New Delhi to maintain the Indian standard of time.

Accuracy ,Precision of Instruments and Errors in measurement.

Accuracy: The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity

-The accuracy in measurement may depend on several factors, including the limit or the resolution of the measuring instrument

Precision : Precision tells us to what resolution or limit the quantity is measured for e.g suppose the true value of a certain length is near 3.678 cm.

In one experiment, using a measuring instrument of resolution 0.1 cm, the measured value is found to be 3.5 cm, while in another experiment using a

measuring device of greater resolution, say 0.01 cm,the length is determined to be 3.38 cm.

The first measurement has more accuracy (because it is closer to the true value) but less precision (its resolution is only 0.1 cm), while the second measurement is less accurate but more precise.

Errors : The result of every measurement by any measuring instrument contains some uncertainty. This uncertainty is called error.

The errors in measurement can be broadly classified as

(a) Systematic errors (b) Random errors (c) Least Count errors

The other Categorisation of errors in measurements is as following:

(a) Absolute Error (b) Relative errors (c) Percentage errors

1. Systematic errors : The systematic errors are those errors that tend to be in one direction, either positive or negative. Some of the sources of systematic errors are :

(a) Instrumental errors

(b) Imperfection in experimental technique or procedure

(c) Personal errors

(a)Instrumental errors : Are those errors that arise from the errors due to imperfect design or calibration of the measuring instrument, zero error in the instrument, etc. For example, the temperature graduations of a thermometer may be inadequately calibrated (it may read 104 °C at the boiling point of water at STP whereas it should read 100 °C);

(b) Imperfection in experimental technique or procedure : arise from incorrect methods of measurement for e.g. To determine the temperature of a human body, a thermometer placed

under the armpit will always give a temperature lower than the actual value of the body temperature

(c) Personal errors : arise due to an individual’s bias, lack of proper setting of the apparatus or individual’s carelessness in taking observations without observing proper precautions. For example, if you,by habit, always hold your head a bit too far to the right while reading the position of a needle on the scale, you will introduce an error due to parallax.

How to reduce Systematic errors :

Systematic errors can be minimised by improving experimental techniques, selecting better instruments and removing personal bias as far as possible. For a given set-up, these errors may be estimated to a certain extent and the necessary corrections may be applied to the readings.

2. Random errors

The random errors are those errors, which occur irregularly and hence are random with respect to sign and size. These can arise due to random and unpredictable fluctuations in experimental conditions (e.g. unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc), personal (unbiased) errors by the observer taking readings, etc. For example, when the same person repeats the same observation, it is very likely that he may get different readings every time.

3 Least count error :

The smallest value that can be measured by the measuring instrument is called its least count.All the readings or measured values are good only up to this value.

The least count error is the error associated with the resolution of the instrument. For example, a vernier callipers has the least count as 0.01 cm.

Least count error belongs to the category of random errors but within a limited size; it occurs with both systematic and random errors.

How can we reduce Least count errors :

-Using instruments of higher precision ,improving experimental techniques--- Repeating the observations several times and taking the arithmetic mean of all the observations, the mean value would be very close to the true value.

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. This is denoted by |Δa|.

True Value – measured value =|Δa|.

Relative Error : The relative error is the ratio of the mean absolute error Δa to the true value a of the quantity measured.

Relative error = Δa / a (2.9)

Percentage Error : When the relative error is expressed in percent, it is called the percentage error (δa).

Thus, Percentage error δa = (Δa /a ) 100% (2.10)

Exercise : NCERT P.no. 25

Combination of errors :In an experiment involving several measurements the errors will combine with each other in different ways as explained below :

(a) Error of a sum or a difference (b) Error of a product or a quotient

(c) Error in case of a measured quantity raised to a power

(a) *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 errors in the individual quantities.

Suppose two physical quantities A and B have measured values A ± ΔA, B ± ΔB respectively where ΔA and ΔB are their absolute errors.

We wish to find the error ΔZ in the sum Z = A + B.; We have by addition, Z ± ΔZ = (A ± ΔA) + (B ± ΔB).

The maximum possible error in Z ΔZ = ΔA + ΔB

For the difference Z = A - B, we have Z ± Δ Z = (A ± ΔA) - (B ± ΔB) = (A- B) ± ΔA ± ΔB

or, ± ΔZ = ± ΔA ± ΔB

The maximum value of the error ΔZ is again ΔA + ΔB.

Hence When two quantities are added or subtracted, the absolute error in the final result is the sum of the absolute errors in the individual quantities.

*(b) 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.

Hence If Z=AB ; Then the maximum relative error ΔZ/ Z = (ΔA/A) + (ΔB/B).

(c) *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

Suppose Z = A2 ; Then, ΔZ/Z = (ΔA/A) + (ΔA/A) = 2 (ΔA/A).

Hence, the relative error in A2 is two times the error in A.

In general, if Z = Ap B q /C r Then, ΔZ/Z = p (ΔA/A) + q (ΔB/B) + r (ΔC/C).

Exercise : NCERT P.no. 27

**Significant Figures**

When physical quantities are measured, the measured values are known only to within the limits of the experimental uncertainty. The value of this uncertainty can depend on various factors, such as the quality of the apparatus, the skill of the experimenter, and the number of measurements performed.

*The reliable digits plus the first uncertain digit are known as significant digits or significant figures*

For e.g.

1. If we say the period of oscillation of a simple pendulum is 1.62 s, the digits 1 and 6 are reliable and certain, while the digit 2 is uncertain. Thus, the measured value has three significant figures.

2. The length of an object reported after measurement to be 287.5 cm has

four significant figures, the digits 2, 8, 7 are certain while the digit 5 is uncertain.

Do we need to report digits more than significant digits in the measurement ?

Clearly, reporting the result of measurement that includes more digits than the significant digits is superfluous and also misleading since it would give a wrong idea about the precision of measurement

*On what factor does the number of significant figures matter in a measurement ?*

Significant figures indicate, as already mentioned, the precision of measurement which depends on the least count of the measuring instrument

*Does the change of the system of units will change the number of significant figures ?*

No, A choice of change of different units does not change the number of significant digits or figures in a measurement. This important remark makes most of the following observations clear: For example, the length 2.308 cm has four significant figures. But in different units, the same value can be written as 0.02308 m or 23.08 mm or 23080 μm.

All these numbers have the same number of significant figures (digits 2, 3, 0, 8), namely four. This shows that the location of decimal point is of no consequence in determining the number of significant figures

Following are some of the rules for determining the number of significant figures in a measurement :

- All the non-zero digits are significant.

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

- If the number is less than 1, the zero(s) on the right of decimal point but to the left of the first non-zero digit are not significant. [In 0.00 2308, the underlined zeroes are not significant].

- The terminal or trailing zero(s) in a number without a decimal point are not significant.[Thus 123 m = 12300 cm = 123000 mm has three significant figures, the trailing zero(s) being not significant.]

However, you can also see the next observation

- The trailing zero(s) in a number with a decimal point are significant.

[The numbers 3.500 or 0.06900 have four significant figures each.]

(2) There can be some confusion regarding the trailing zero(s).

Suppose a length is reported to be 4.700 m. It is evident that the zeroes here

are meant to convey the precision of measurement and are, therefore, significant. [If these were not, it would be superfluous to write them explicitly, the reported measurement would have been simply 4.7 m].

Now suppose we change units, then

4.700 m = 470.0 cm = 4700 mm = 0.004700 km

Since the last number has trailing zero(s) in a number with no decimal, we would conclude erroneously from observation above that the number has two significant figures, while in fact, it has four significant figures and a mere change of units cannot change the number of significant figures.

(3) To remove such ambiguities in determining the number of significant figures, the best way is to report every measurement in scientific notation (in the power of 10).

In this notation, every number is expressed as a 10b, where a is a number between 1 and 10, and b is any positive or negative exponent (or power) of 10.

In order to get an approximate idea of the number, we may round off the number a to 1 (for a ≤ 5) and to 10 (for 5<a ≤ 10).

Then the number can be expressed approximately as 10b, in which the exponent (or power) b of 10 is called order of magnitude of the physical quantity.

When only an estimate is required, the quantity is of the order of 10b, For example, the diameter of the earth (1.28x107m) is of the order of 107m with the order of magnitude 7.

The diameter of hydrogen atom (1.06 x 10-10m) is of the order of 10-10m with the order of magnitude -10.

Thus, the diameter of the earth is 17 orders of magnitude larger than the hydrogen atom.

It is often customary to write the decimal after the first digit.

Now the confusion mentioned above disappears :

4.700 m = 4.700 x 102 cm = 4.700 x 103 mm = 4.700 10-3km

The power of 10 is irrelevant to the determination of significant figures.

However, all zeroes appearing in the base number in the scientific notation are significant. Each number in this case has four significant figures.

Thus, in the scientific notation, no confusion arises about the trailing zero(s) in the base number a. They are always significant.

(4) The scientific notation is ideal for reporting measurement. But if this is not adopted, we use the rules adopted in the preceding example :

i.e

- For a number greater than 1, without any decimal, the trailing zero(s) are not significant.

- For a number with a decimal, the trailing zero(s) are significant.

(5) The digit 0 conventionally put on the left of a decimal for a number less than 1 (like 0.1250) is never significant. However, the zeroes at the end of such number are significant in a measurement.

(6) The multiplying or dividing factors which are neither rounded numbers nor numbers representing measured values are exact and have infinite number of significant digits. For example in r =d/2 or s = 2π r , the factor 2 is an exact number and it can be written as 2.0, 2.00 or 2.0000 as required.

Similarly, in T = t/n , n is an exact number.

Rules for Arithmetic Operations with Significant Figures

The following rules for arithmetic operations with significant figures ensure that the final result of a calculation is shown with the precision that is consistent with the precision of the input measured values :

(1) 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.

Thus, in the example above, density should be reported to three significant figures. Density = 4.237g /2.51 cm3 =1.69 g cm-3

(2) In addition or subtraction, the final result should retain as many decimal places as are there in the number with the least decimal places.

For example, the sum of the numbers 436.32 g, 227.2 g and 0.301 g by mere arithmetic addition, is 663.821 g. But the least precise measurement (227.2 g) is correct to only one decimal place. The final result should, therefore, be rounded off to 663.8 g.

Similarly, the difference in length can be expressed as : 0.307 m - 0.304 m = 0.003 m = 3 x 10-3 m.

Rounding off the Uncertain Digits

The result of computation with approximate numbers, which contain more than one uncertain digit, should be rounded off. The rules for rounding off numbers to the appropriate significant figures are obvious in most cases.

A number 2.746 rounded off to three significant figures is 2.75, while the number 2.743 would be 2.74.

-The rule by convention is that the preceding digit is raised by 1 if the insignificant digit to be dropped (the underlined digit in this case) is more than 5, and is left unchanged if the latter is less than 5.

- But what if the number is 2.745 in which the insignificant digit is 5. Here, the convention is that if the preceding digit is even, the insignificant digit is simply dropped and, if it is odd, the preceding digit is raised by 1.

Then, the number 2.745 rounded off to three significant figures becomes 2.74. On the other hand, the number 2.735 rounded off to three significant figures becomes 2.74 since the preceding digit is odd.

Rules for Determining the Uncertainty in the Results of Arithmetic Calculations

The rules for determining the uncertainty or error in the number/measured quantity in arithmetic operations can be understood from the following examples.

(1) If the length and breadth of a thin rectangular sheet are measured, using a metre scale as 16.2 cm and, 10.1 cm respectively, there are three significant figures in each measurement.

It means that the length l may be written as

l = 16.2 ± 0.1 cm = 16.2 cm ± 0.6 %. Similarly, the breadth b may be written as

b = 10.1 ± 0.1 cm = 10.1 cm ± 1 %

Then, the error of the product of two (or more)experimental values, using the combination of errors rule, will be

l b = 163.62 cm2 + 1.6% = 163.62 + 2.6 cm2

This leads us to quote the final result as l b = 164 + 3 cm2

Here 3 cm2 is the uncertainty or error in the estimation of area of rectangular sheet.

(2) 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.

However, if data are subtracted, the number of significant figures can be reduced.

For example, 12.9 g . 7.06 g, both specified to three significant figures, cannot properly be evaluated as 5.84 g but only as 5.8 g, as uncertainties in subtraction or addition combine in a different fashion (smallest number of decimal places rather than the number of significant figures in any of the number added or subtracted).

(3) The relative error of a value of number specified to significant figures depends not only on n but also on the number itself.

For example, the accuracy in measurement of mass 1.02 g is ± 0.01 g whereas another measurement 9.89 g is also accurate to ± 0.01 g.

The relative error in 1.02 g is = (± 0.01/1.02) × 100 % = ± 1%

Similarly, the relative error in 9.89 g is = (± 0.01/9.89) × 100 % = ± 0.1 %

DIMENSIONAL ANALYSIS

The word dimension has a special meaning in physics. It usually denotes the physical nature of a quantity. Whether a distance is measured in the length unit feet or the length unit meters, it is still a distance. We say the dimension—the physical nature—of distance is length.

The symbols we will use to specify length, mass, and time are L, M,and T, respectively. We shall often use brackets [ ] to denote the dimensions of a

physical quantity. For example, the symbol we use for speed in this book is v, and in our notation the dimensions of speed are written as [v] = L/T.

As another example, the dimensions of area, for which we use the symbol A, are [A] = L2.

In solving problems in physics, there is a useful and powerful procedure called dimensional analysis. This procedure, which should always be used, will help minimize the need for rote memorization of equations.

Dimensional analysis makes use of the fact that dimensions can be treated as algebraic quantities. That is, quantities can be added or subtracted only if they have the same dimensions.

Furthermore, the terms on both sides of an equation must have the same dimensions.

By following these simple rules, you can use dimensional analysis to help determine whether an expression has the correct form. The relationship can be correct only if the dimensions are the same on both sides of the equation.

The principle of homogeneity of dimensions

The magnitudes of physical quantities may be added together or subtracted from one another only if they have the same dimensions. In other words, we can add or subtract similar physical quantities. Thus, velocity cannot be added to force, or an electric current cannot be subtracted from the thermodynamic temperature.

This simple principle called the principle of homogeneity of dimensions

This principle is extremely useful in checking the correctness of an equation. If the dimensions of all the terms are not same, the equation is wrong.

Dimensions are customarily used as a preliminary test of the consistency of an equation, when there is some doubt about the correctness of the equation.

However, the dimensional consistency does not guarantee correct equations. It is uncertain to the extent of dimensionless quantities or functions. The arguments of special functions, such as the trigonometric, logarithmic and exponential functions must be dimensionless. A pure number, ratio of similar physical quantities, such as angle as the ratio (length/length), refractive index as the ratio (speed of light in vacuum/speed of light in medium) etc., has no dimensions.

Checking the dimensional consistency or homogeneity of an equation

x = x0 + v0 t + 1/2 a t 2

for the distance x travelled by a particle or body in time t which starts from the position x0 with an initial velocity v0 at time t = 0 and has uniform acceleration a along the direction of motion.

The dimensions of each term may be written as

[x] = [L]

[x0 ] = [L]

[v0 t] = [L T-1] [T] = [L]

[(1/2) a t 2] = [L T-2] [T 2] = [L]

As each term on the right hand side of this equation has the same dimension, namely that of length, which is same as the dimension of left hand side of the equation, hence this equation is a dimensionally correct equation.

It may be noted that a test of consistency of dimensions tells us no more and no less than a test of consistency of units, but has the advantage that we need not commit ourselves to a particular choice of units, and we need not worry about conversions among multiples and sub-multiples of the units.

It may be borne in mind that if an equation fails this consistency test, it is proved wrong, but if it passes, it is not proved right. Thus, a dimensionally correct equation need not be actually an exact (correct) equation, but a dimensionally wrong (incorrect) or inconsistent equation must be wrong.

Deducing Relation among the Physical Quantities

The method of dimensions can sometimes be used to deduce relation among the physical quantities. For this we should know the dependence of the physical quantity on other quantities (upto three physical quantities or linearly independent variables) and consider it as a product type of the dependence.

Let us take an example.

Consider a simple pendulum, having a bob attached to a string, that oscillates under the action of the force of gravity. Suppose that the period of oscillation of the simple pendulum depends on its length (l), mass of the bob (m) and acceleration due to gravity (g).

Derive the expression for its time period using method of dimensions.

The dependence of time period T on the quantities l, g and m as a product may be written as :

T = k lx g y mz where k is dimensionless constant and x, y and z are the exponents.

By considering dimensions on both sides, we have

[LoMoT1 ]= [L1 ]x [L1 T–2 ]y [M1 ]z = Lx+y T-2y Mz

On equating the dimensions on both sides, we have

x + y = 0; - 2y = 1; and z = 0 So that x = 1/2 ; y = -1/2 ; z =0

Then, T = k Lx gy or, T = k √ (L/g)

Note that value of constant k cannot be obtained by the method of dimensions. Here it does not matter if some number multiplies the right side of this formula, because that does not affect its dimensions.

Actually, k = 2π so that T = 2π √ (L/g)

Conversion of one system of units into another

This is based on the fact that magnitude of any physical quantity remains the same whatever be the system of it’s measurement.

i.e. Q = n1 u1 = n2u2

Where u1 andu2 are two units of measurement of the quantity Q and n1 and n2 are their respective numerical values.

Suppose M1 , L1 , T1 are the fundamental units of mass , length and time in one system and M2 , L2 , T2 are the units of mass , length and time in another system of units.

If a ,b and c are the respective dimensions then

u1 = [ M1aL1bT1c] and u2 = [ M2aL2bT2c] ------ 1

from equation 1 n2 = n1 u1/ u2

or  n2 = n1 [ M1aL1bT1c] or n2 = n1 [ M1/ M2]a[ L1/ L2]b [ T1/ T2]c

[ M2aL2bT2c]

(Always take absolute units of mass, length and time in conversion )

Convert 1 Newton into dyne

Solution : One newton is absolute unit of force in MKS system and dyne is absolute unit of force in CGS system of units.

Dimensional formula of force is F = M1L1T-2 therefore a=1 , b=1 and c=-2

We have to convert MKS into CGS so, M1 = 1 kg , L1 = 1 m and T1 = 1 sec

n1 = 1 newton , n2 = (number of dynes) = ?

as n2 = n1 [ M1/ M2]a[ L1/ L2]b [ T1/ T2]c therefore ,

n2 = n1 [ 1kg/ 1gm]1[ 1m/ 1cm]1 [ 1 sec/ 1 sec]-2

= n1 [ 1000 gm/ 1gm]1[ 100cm/ 1cm]1 [ 1 sec/ 1 sec]-2

=n1 103 x 102 = 1 x 105 Hence 1 newton = 105 dyne

Convert an energy of 1 Joule into ergs

Solution : One joule is an absolute unit of energy in MKS system and ergs is absolute unit of energy in CGS system of units.

Dimensional formula of Energy is = M1L2T-2 therefore a=1 , b=2 and c= -2

We have to convert MKS into CGS so, M1 = 1 kg , L1 = 1 m and T1 = 1 sec

n1 = 1 joule , n2 = (number of ergs) = ?

as n2 = n1 [ M1/ M2]a[ L1/ L2]b [ T1/ T2]c therefore ,

n2 = n1 [ 1kg/ 1gm]1[ 1m/ 1cm]2 [ 1 sec/ 1 sec]-2

= n1 [ 1000 gm/ 1gm]1[ 100cm/ 1cm]2 [ 1 sec/ 1 sec]-2

=n1 103 x 104 = 1 x 107 Hence 1 Joule = 107 ergs

Dimensional analysis is very useful in deducing relations among the interdependent physical quantities.

However, dimensionless constants cannot be obtained by this method.

The method of dimensions can only test the dimensional validity, but not the exact relationship between physical quantities in any equation.

It does not distinguish between the physical quantities having same dimensions

Important points regarding Dimensions

-A physical Quantity may have a number of units but their dimensions would be same . For ex. Different units of velocity are m/s ,cm/s ,km/hr but for all of them the dimensional formula is M0L1T-1

Hence dimension doesn’t depend upon the unit of the physical quantity

-There might be physical quantities which have same dimensional formula but not the same units for e.g. Angular velocity and frequency.

- Pure number and pure ratio are dimensionless.

- Dimensionless quantities may have units for e.g. Angle and solid angle.

- The method of dimensions cannot be applied to derive the formula if a physical quantity depends on more than three physical quantities.

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Check Dimensional formulas in appendix

**Home Assignment- Units & Measurements**

**Notes**

1. What do you mean by a unit ?
2. Define physical Quantities?
3. Write the names and SI units of fundamental quantities ?
4. Convert the following into meters ? – 1 femto m , 1 pico m , 1 tera m , 1 giga m , 1μm & 1mm.
5. Convert the following into their SI untits ? 1 KwH , 1cal , 1eV , 1erg , 1 H.P. ?
6. Define 1 astronomical unit , 1 light year & 1 parsec ?
7. Define Accuracy & Precision ?
8. Define Error in a measurement ? Also define Absolute Error, Relative Error & Percentage Error ?
9. What do you mean by least count error ? Name least count errors of 3 common measuring instruments in day to day life ?
10. What are the rules for combination of errors for the following cases

-Error of a sum or a difference

-Error of a product or a quotient

-Error in case of a measured quantity raised to a power

1. Find the relative error in Z, if Z = A4B1/3/CD3/2.
2. Define Significant Figures ?
3. On what factor does the number of significant figures matter in a measurement?
4. Does the change of the system of units will change the number of significant figures?
5. Write the rules for determining the number of significant figures in a measurement?
6. Write the rules for Arithmetic Operations with Significant Figures?
7. Write the rules for Rounding off the Uncertain Digits?
8. What do you mean by dimension and Dimensional analysis ?
9. What is principle of homogeneity of dimensions?
10. Write 3 uses of Dimensional analysis ?

**NCERT**

1. Calculate the angle of (a) 10 (degree) (b) 1′ (minute of arc or arcmin) and (c) 1″ (second of arc or arc second) in radians.
2. 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 10 54′ . Given the diameter of the Earth to be about 1.276 × 107 m, compute the distance of the moon from the Earth.( Answer : 3.84 ×108m)
3. The Sun’s angular diameter is measured to be 1920′′(secs). The distance D of the Sun from the Earth is 1.496 × 1011 m. What is the diameter of the Sun ?(Ans: 1.39 ×109m)
4. When the planet Jupiter is at a distance of 824.7 million kilometers from the Earth, its angular diameter is measured to be 35.72” of arc. Calculate the diameter of Jupiter.
5. The temperatures of two bodies measured by a thermometer are t1 = 200C ± 0.50C and t2 = 500C ± 0.50C.

Calculate the temperature difference and the error their in .

1. A calorie is a unit of heat or energy and it equals about 4.2 J where 1J = 1 kg m2 s–2.Suppose we employ a system of units in which the unit of mass equals α kg, the unit of length equals β m, the unit of time is γ s. Show that a calorie has a magnitude 4.2 α–1 β –2 γ 2 in terms of the new units.
2. Explain this statement clearly :“To call a dimensional quantity ‘large’ or ‘small’ is meaningless without specifying a standard for comparison”. In view of this, reframe the following statements wherever necessary :
   * 1. atoms are very small objects
     2. a jet plane moves with great speed
     3. the mass of Jupiter is very large
     4. the air inside this room contains a large number of molecules
     5. a proton is much more massive than an electron
     6. the speed of sound is much smaller than the speed of light.
3. A new unit of length is chosen such that the speed of light in vacuum is unity. What is the distance between the Sun and the Earth in terms of the new unit if light takes 8 min and 20 s to cover this distance ?
4. If you are given a thread and a metre scale. How will you estimate the diameter of the thread ?
5. State the number of significant figures in the following :

(a) 0.007 (b) 2.64 × 1024 (c) 0.2370 (d) 6.320 (e) 6.032 (f) 0.0006032

1. 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.



1. A physical quantity P is related to four observables a, b, c and d as follows :

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 ?

1. The nearest star to our solar system is 4.29 light years away. How much is this distance in terms of parsecs? How much parallax would this star (named Alpha Centauri) show when viewed from two locations of the Earth six months apart in its orbit around the Sun ?

**Exemplar**

1. If P, Q, R are physical quantities, having different dimensions, which of the following combinations can never be a meaningful quantity? (a) (P – Q)/R (b) PQ – R (c) PQ/R (d) (PR – Q2)/R (e) (R + Q)/P
2. Why do we have different units for the same physical quantity?
3. Express unified atomic mass unit in kg.
4. Why length, mass and time are chosen as base quantities in mechanics?
5. The earth-moon distance is about 60 earth radius. What will be the diameter of the earth (approximately in degrees) as seen from the moon?
6. Moon is seen to be of (½)°diameter from the earth. What must be the relative size compared to the earth?
7. From parallax measurement, the sun is found to be at a distance of about 400 times the earth-moon distance. Estimate the ratio of sun-earth diameters
8. The distance of a galaxy is of the order of 1025 m. Calculate the order of magnitude of time taken by light to reach us from the galaxy.
9. During a total solar eclipse the moon almost entirely covers the sphere of the sun. Write the relation between the distances and sizes of the sun and moon.
10. If the unit of force is 100 N, unit of length is 10 m and unit of time is 100 s, what is the unit of mass in this system of units?
11. Calculate the length of the arc of a circle of radius 31.0 cm which subtends an angle of π /6 at the centre?
12. A new system of units is proposed in which unit of mass is α kg, unit of length β m and unit of time γ s. How much will 5 J measure in this new system?
13. A physical quantity X is related to four measurable quantities a, b, c and d as follows: X = a2 b3 c5/2 d–2. The percentage error in the measurement of a, b, c and d are 1%,2%, 3% and 4%, respectively. What is the percentage error in quantity X ? If the value of X calculated on the basis of the above relation is 2.763, to what value should you round off the result.
14. If velocity of light c, Planck’s constant h and gravitational constant G are taken as fundamental quantities then express mass, length and time in terms of dimensions of these quantities.
15. How many astronomical units (A.U.) make 1 parsec?

**Pardeep**

1. How many ergs are there in one kilowatt hour?
2. Can a quantity have units but still be dimensionless?
3. What is the difference between 5.0 & 5.00 ?
4. A substance weighing 5.74gm occupies volume of 1.2cm3.Calculate it’s density with due regard to significant digits?
5. What is the percentage error in R if V =100± 5 V and current I =10±0.2 A?
6. Which quantity in a given formula should be measured more accurately X = a2 b3 c5 ?

**Objective Questions- Units and Measurements/Physical world**

l. Einstein's name is associated with the discovery of:

(a) nuclear model of atom (b) neutron (c) theory of relativity (d) expansion of the universe

2. Who discovered the principle of inertia? (a) Newton (b) Galileo (c) Tycho Brahe (d) Kepler

3. Two India born American scientists who were awarded Nobel Prize are:.

(a) S. Bose and Narlikar (b) E.C.G. Sudarshan and Bhagwantam

(c) C.V. Raman and H'J' Bhabha (d) S. Chandrashekhar and A' Salam

4. Who invented wireless telegraphy? (a) Maxwell (b) Marconi (c) Hertz ' (d) Faraday

5. Who was awarded Nobel Prize for the theory of the unification of weak and electromagnetic interactions?

(a) Rutherford (b) A'Salam (c)H.J. Bhabha (d) S. chandrashekhar

6. Rocket propulsion is based on the principle of:

(a) nuclear fusion (b) nuclear fission (c)Newton's laws of motion (d) thermodynamics

7. In a hydroelectric power station: (a) thermal energy is converted into electrical energy

(b)) gravitational potential energy is converted into ' electrical energy

(c) kinetic energy is converted into potential energy (d)chemical energy is converted into electrical energy

8. In a thermal Power station(a) chemical energy of burning coal is converted into electrical energy

(b)gravitational energy is converted in to electrical energy

(c) potential energy is converted into kinetic energy (d) geothermal energy is converted into electrical energy

9. Two current areas in which physics and technology are closely interlinked, are:

(a) rocket propulsion and launching of satellites (b) nuclear fission and nuclear fusion

(c) lasers and microelectronics (d) none of the above

10. In superconductivity there is production of: (a) low magnetic fields (b) medium magnetic fields

(c) ultra high magnetic fields (d) none of these

ll.Give the nature of work for which Prof. Albert Einstein ,a physicist, was awarded the Nobel Prize in physics:(a) wave theory of light (b) theory of relativity ,(c) photoelectric equation (d) wave-particle duality

13. The unit of energy is: (a) J/s (b) watt-day (c) kilowatt (d) g-cm/s2

14. Which one of the following is not a unit of time?

(a) Lunar month (b) Leap Year (c) parallactic second (d) Solar day

(15) Which of the following is the name of a physical quantity?

(a) Parsec (b) Fermi (c) Energy (d) Light-Year

16. The ratio of the SI unit to the CGS unit of modulus of rigidity is:

(a) 102 (b) 10-2 (c) l0-1 (d) 10

17. If muscle times speed equals power ,what is the ratio of the SI unit and the CGS unit of muscle?

(a) 105 (b) 103 (c) 107 (d) 10-5

18. Which one of the following is not measured in units of energy?

(a) couple x angle turned through (b)moment of inertia x (angular velocity)2

(c) Force x distance (d) Impulse x time

19. Joule-sec is the unit of:(a) energy (b) momentum (c) angular momentum (d) power

(20)The density of mercury is 13600 kg/m3. Its value in CGS system will be

(a) 13.6 g/cm3 (b) 1360 gm/cm3 (c) 136 gm/cm3 (d) 1.36 gm/cm3

21. The value of G= 6.67x10-ll N-m2/kg2. Its value in CGS system will be:

(a) 6.67x 10-8 dynes-cm2-gm-2 (b) 6.67x 10-6 dynes-cm2-gm-2

(c) 6.67x 10-4 dynes-cm2-gm-2 (d) 6.67x 10-5 dynes-cm2-gm-2

22. Why is it wrong to express 106 km as Mkm?

(a) M is not the symbol for 106 b)Use of double prefixes is conventionally prohibited

(c) Symbols for the units other than commemorating great scientists are not written as capital letters

(d) Because of some reason other than mentioned above

23. The equation of a stationary wave is given by y=2Asin(2ct/λ) cos(2x/λ),which of the following statement 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 2c/λ is same as that of 2x/λt (d) the unit of c/λ is same as that of x/λ

24. Given that the displacement of the particle is given by x=A2 sin2kt , where t denotes the time. The unit of k is (a) hertz (b) metre (c) radian (d) second

25.The velocity of the particle is given by v=at2 +bt + c. If v is measured in m/s and t is measured in seconds then the unit of (a) a is m/s (b) b is m/s (c) c is m/s (d) a & b both are same but that of c is different

26. The dimensional ,representation of Planck's constant is identical to that, of,

(a) torque (b) work (c) stress (d) angular momentum

27. E, m ,J & G denote energy, mass angular momentum and gravitational constant respectively. Then the dimensions of EJ2/m5G2 are (a) angle (b) length (c) mass (d) time

28. Suppose the refractive index μ is given as : μ=A+ B/λ2 ,where A & B are constants and λ is the wavelength. The n dimensions of B are same as that of (a)Wavelength (b) Volume (c) Pressure (d) area

29. A student writes the escape velocity as V = [(GM)/R2]1/2 ,the equation is

(a)dimensionally incorrect (b) dimensionally correct (c)numerically correct (d) both (a) & (c)

30.If the speed of light(c) , acceleration due to gravity (g) and pressure (p) are taken as fundamental units, then dimensions of Gravitational constant G are : (a) cogp-3 (b) c2g3p-2 (c) cog2p-1 (d) c2g2p-2

31.What are the units of k in F = kq2/r2(a) C2N-1 m-2 (b) Nm2C-2  (c) N-m2C2 (d) unitless

32. If the velocity of light (c), gravitational constant (G) and Planck's constant (h) are chosen as fundamental units, then which of the following represents the dimensions of the mass

(a) c ½G ½h ½ (b) c ½ G -½ h -½ (c) c ½ G -½ h ½ (d) c -½ G ½ h ½

33. lf energy (E), velocity (v) and force (F) be taken as fundamental quantities, then what are the dimensions of mass? (a) Ev2 (b) Ev-2 (c) Fv-1 (d) Fv-2

34.lf the acceleration due to gravity is 10 m/s2 and the units of length and time are changed to kilometre and hour, respectively, the numerical value of the acceleration is:

(a) 360000 (b) 72000 (c) 36000 (d) 129600

35.If the acceleration due to gravity is represented by unity in a system of units and one second be the unit of time. Then the unit of length is: (a) 9.8 m (b)1m (c) 98 m (d) 0.98 m

36.It the force of attraction between two unit masses (1 kg each) kept I km apart is taken as unit force and the unit of energy in this system is called eluoj (joule written in the reverse order) then the relation of joule and eluoj is:(Given that;G -6.67x l0-ll N-m2kg-2)

(a) l joule =6.67 x 10-17 eluoj (b) 1 eluoj =6.67 x 10-14 joule

(c) 1 eluoj = 10-4 joule (d) l joule =6.67 x l0-9 eluoj

37. lf force (F ) , length (L) , current (I) and time (T ) are taken as bases then the dimensions of ∈o are:

(a) [F L2 I2 T-2 ] (b) [F-1 L2 I2 T2 ] (c) [F-1L-2 I2 T2] (d) [F2 L2 I2 T2 ]



38.The velocity of a particle depends upon the time r according to the

The physical quantities which are represented by a,b,c and d, are in the following order:

(a) distance, distance, acceleration, time (b) distance, acceleration, distance, time

(c) acceleration, distance, distance, time (d) none of the above

39. The velocity of water waves may depend on their wavelength λ, the density of water ρ and the acceleration due to gravity g. The method of dimensional analysis gives the following relation between these quantities: (a) v2=K λ-1 g-1 ρ-1 (b) v2=K λ g(c) v2=K λ ρ g (d) v2=K λ3 g-1 ρ-1

**Errors in Measurement**

40.A student measured the diameter of a wire using a screw gauge with least count 0.001 cm and listed the

measurements. The correct measurement is:

(a) 5.320 cm (b) 5.3 cm (c) 5.32cm (d) 5.3200cm

41.The mass of a body is 20.000 g and its volume is 10.00 cm3.If the measured values are expressed upto the correct significant figures, the maximum error in the value of density is:

(a) 0.001 g cm-3 (b) 0.010 g cm-3 (c) 0.100 g cm-3  (d) none of these

42.The least count of a stop watch is 0.1 sec. The time of 20 oscillations of the pendulum is found to be 20 sec. The percentage error in the time period is:

(a) 0.25% (b) 0.5% (c) 0.75% (d) 1.0%

43.An experiment measured quantities a, b,c and then x is calculated from x = ab2/c3. If the percentage errors in a, b, c are±1% , ±3% & ±2% respectively, then the percentage error in x is can be

(a) ± 13% (b) ± 7% (c) ± 4% (d) ± 1%

44.The length of a strip measured with a metre rod is 10.0 cm. Its width measured with a Vernier callipers is 1.00 cm. The least count of the metre rod is 0.1 cm and that of Vernier callipers 0.01 cm. What will be error in its area! (a) ± 0.01cm2 (b) ± 0.1cm2 (c) ± 0.11cm2 (d) ± 0.2cm2

45. The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with Vernier callipers having least count 0.01 cm. Given that length is 5.0 cm and radius is 2.0 cm. The percentage error in the calculated value of the volume will be:

(a) 1% (b2% (c) 3% (d) 4%

46. 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 above measurements is most accurate measurement of... ?

(a) length (b) breadth (c) thickness (d) height

47. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimate of the kinetic energy obtained by measuring mass and speed?

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

48. 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 g by the relation g = 4π2 (l/T2 )will be: (a) 2% (b) 4% (c) 7% (d) 10%

49. The best method to reduce random errors is:

(a) to change the instrument used for measurement (b) to take help of experienced observer

(c) to repeat the experiment many times and to take the average results (d) none of the above

50. 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) x/4 (c) 2x (d) x/2

51.The radius of a ball is (5.2 ± 0.2)cm. The percentage error in the volume of the ball is:

(a) 11% (b) 4% (c) 7% (d) 9%

52.Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is: (a) (a)1% (b) 3% (c) 5% (d) 7% **(DCE 2006)**

53. The density of a cube is measured by measuring its mass and length of its sides. If the maximum errors in the measurement of mass and length are 4% & 3% respectively, the maximum error in the measurement of density would be: (a)9% (b) 13% (c) 12% (d) 7%

54. A student performs experiment with simple pendulum and measures time for 10 vibrations. If he measures the time for 100 vibrations, the error in the measurement of time period will be reduced by a factor of: (a)10 (b) 90 (c) 100 (d) 1000

55. Which of the following readings taken by a microscope of least count 0.001 cm is correct?

(a) 3.28 (b) 3.00 (c) 3.000 (d) 0.02345

56. A wire has a mass 0.3 ±0.003 g, radius 0.5 ±0.005 mm and length 6 ± 0.06 cm. The maximum percentage error in the measurement of density is: (a) 1 (b) 2 (c) 3 (d)4 **(IIT 2004)**

57. 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 ± 0.2)m/s (a) (3.45 ± 0.3)m/s (a) (3.45 ± 0.4)m/s (a) (3.45 ± 0.5)m/s

58. In Q. 57, the percentage error, is: (a)7% (b) 5.95% (c) 8.95% (d) 9.85%

59. The length and breadth of a rectangle are (5.7± 0.1)cm and (3.4 ± 0.2) cm. The area of rectangle with error limits is approximately: (a) (19.4 ± 1)cm2 (b) (19.4 ± 2)cm2 (c) (19.4 ± 2.5)cm2 (d) (19.4 ± 1.5 )cm2

60. If x = an, then fractional error ∆x/x ,r equal to

(a) ± (∆a/a) n (b) ± n (∆ a/a) (c) ± n loge(∆ a/a) (d) ± n log (∆ a/a)

61. The heat dissipated in a resistance can be obtained by the measurement of resistance, the current and time. If the maximum error in the measurement of these quantities is l%, 2% and l% respectively, the maximum error in the determination of the dissipated heat is:(a)4% (b) 6% (c) 4/3 % (d) 2%

62. If physical quantity X is represented by X =MaLbT-c and the maximum percentage errors in M, L and T are α% ,β% and γ% respectively, then the total maximum percentage error in X is:

(a) (αa +βb – γc)% (b) (αa +βb + γc)% (c) (αa - βb – γc)% (d) none of these

63.While measuring acceleration due to gravity by a simple pendulum, a student makes a positive error of 2% in the length of the pendulum and a positive error of 1% in the value of time period. His actual percentage error in the measurement of the value of g will be: (a)3% (b) 0% (c) 4 % (d) 5%

64.If the error in the measurement of momentum of a particle is (+100%) then the error in the measurement of kinetic energy is: (a)100% (b) 200% (c) 300 % (d) 400%

65. Dimensional formula of a physical quantity X is M-1L3T-2.The errors in measuring the quantities M,L

and T respectively are 2%, 3% and 4%. The maximum percentage of error that occurs in measuring the quantity X is: (a)9% (b) 10% (c) 14 % (d) 19% **[EAMCIT (Engg.) 2002]**

66. The length and breadth of a metal sheet are 3.124 m and 3.002 m respectively. The area of this sheet upto four correct significant figures is: (a) 9.37 m2 (b) 9.378 m2 (c) 9.3782 m2 (d) 9.378248 m2

67. Dimensions of electrical resistance is:

(a) [ML2T-3A-1] (b) [ML2T-3A-2] (c) [ML3T-3A-2] (d)[ML-1T3A2] **(UPSEE 2007)**

68. In a system of units, if force (F) acceleration (A)and time (T) are taken as fundamental units then the dimensional formula for energy is (a) F1A2T1 (b) F1A1T2  (c) F2A1T1 (d) F1A1T1

69.If the wavelength of the green line of the visible spectrum is 546 nm, its value in metre is

(a) 546 × 10–10  (b) 546 × 10–19 (c) 54.6 × 10–8  (d) 54.6 × 109.

70. The speed of light (c), Planck’s constant (h) and gravitational constant (G) are taken as the fundamental units in a system. The dimensions of time in this system are

(a) h3/2 G2 C1/2 (b) G3/2 h1/3 C (c) C2 h G–2 (d) h1/2 G1/2 C–5/2.

71. Which one of the following has not been expressed in proper units?

(a) momentum → kg m/s (b) power → kg m2 s–3 (c) Energy/time → kg m2 s–3 (d) pressure → kg m–2 s–2.

72.What is the dimension of the physical quantity α in the equation, P =density/α, where P is the pressure?

(a) ML2T–1 (b) ML4T–2 (c) L–2 T2  (d) ML–2T2.

73. A watt is equal to

(a) 418 calorie per second (b) one joule per second (c) 4.18 joule per second (d)1/4.18 joule per second.

74.The intensity of the electric field has the unit

(a) newton/coulomb (b) newton/ampere (c) ampere/newton (d) volt/sec.

75. Planck’s constant has the dimensions of

(a) power (b) electric charge (c) angular momentum (d) linear momentum.

76. If C and R denote the capacity and resistance respectively the dimensions of CR are

(a) M0L2T (b) M0L0T (c) M0L0T0 (d) M0LT–1.

77. Which one of the following is a derived unit? (a) kg (b) m3 (c) rad (d) Ampere.

78.The time dependence of a physical quantity L is given by L = L0 eβt, where β is a constant and t is the time. The constant β

(a) has the dimension of L (b) has the dimension T-1 (c) is dimensionless (d) has the dimension of T2.

79. Which of the following is the smallest one in magnitude?

(a) one metre (b) one millimetre (c) one Fermi (d) one angstrom unit.

80. One torr is (a) 1 m of Hg (b) 1 atmosphere (c) 1 mm of Hg (d) 1 cm of Hg.

81. Joule /degree is the unit for

(a) solar constant (b) Boltzmann’s constant (c) Stefan’s constant (d) Planck’s constant.

82. The unit of thermal conductivity is

(a) J–1 m–1 s–1 K–2 (b) J m s K–1 (c) J2 m s K–1 (d) J m–1 s–1 K–1.

83. The unit of magnetic field is (a) weber/m2 (b) weber m (c) m2/weber (d) weber2/m2.

84. The dimension for the universal gas constant is

(a) ML2T–2 θ–1 (b) M2LT–2 θ–1 (c) MLT–1 θ–2 (d) ML2T–1θ–3.

85. Out of the following pairs, which one does not have identical dimensions, is:

(a) moment of inertia and moment of a force (b) work and torque

(c) angular momentum and Planck's constant (d) impulse and momentum **(AIEEE 2005)**

86. The density of a material in CGS system of units is 4 g cm-3. In a system of units in which unit of length is l0 cm and unit of mass is 100 g, the value of density of material will be:

a)0.04 (b) 0.4 (c) 40 (d) 400

87. Which of the following group have different dimension? **[IIT 2005]**

(a) Potential difference, emf, voltage (b) Pressure, stress, Young's modulus

(c) Heat, energy, work done (d) Dipole moment, electric flux, electric field

88. Which of the following units denotes the dimensions[ML2Q-2 ], where Q denotes the electric charge?

(a) Weber (Wb) (b)Wb/m2 (c)Henry(H) (d) H/m2 **(AIEEE 2006)**

89. Which of the following sets of quantities have same dimensional formulae?

(a) Frequency, angular frequency and angular momentum (b) Surface tension, stress and spring constant

(c) Acceleration, momentum and retardation (d) Thermal capacity, specific heat and entropy

(e) Work, energy and torque **[PET (Kerala) 2006]**

90. A physical quantity P = a1/2 b1/2 c d-3 e-1/3  is determined by measuring a,b,c,d & e separately with the percentage error of 2%,3%,2%,1% & 6% respectively. Minimum amount of error is contributed by the measurement of (a) b (b) a (c) d (d) e (e) c

91. If the units of mass, length and time are doubled, unit of angular momentum will be:

(a) doubled (b) tripled (c) quadrupled (d) 8 times the original value **[CET (J&K) 2006]**

92. If E =Energy, G = gravitational constant, I = impulse and M - mass, the dimensions of GIM2 /E2 are same as that of as that of: (a) time (b) mass (c) length (d) force

93. A new system of units is evolved in which the values of μo and ∈o are 2 and 8 respectively. Then the speed of light in this system will be (a) 0.25 (b) 0.5 (c) 0.75 (d) 1  **[VITEEE 2006]**

94. The dimensions of permittivity ∈o are :

(a) [M-1 L-3 A2 T4] (b) [M-1 L3 A-2 T-4] (c) [M-1 L-1 A2 T2] (d) [M-1 L-3 A2 T-4] [BV (pune) 2006]

95. If force is proportional to square of velocity, then the dimensions of proportionality constant is :

(a) [ML-1 T] (b) [ML-1T0] (c) [M LT0] (d) [M0 L T-1] [Orissa (JEE) 2007]

96. The speed (v)of ripples on the surface of water depends on surface tension (σ) density (ρ) and wavelength (λ) The square of speed (v)is proportional to: (a) σ / ρλ (b) ρ/σλ (a) λ/σρ (a) σρ λ [DCE 2007]

97. If 3.8 x 10-6 is added to 4.2 x l0-5 giving due regard to significant figures, then the result will be:

(a) 4.58 x l0-5 (b) 4.6 x 10-5 (c) 4.5 x 10-5 (d) none of these [UPSEE 2009]

98. If voltage V =(100 ± 5)V and current I =(10 ± 0.2)A, the percentage error in resistance R is:

(a) 5.2% (b) 25% (c) 7% (d) 10% (e) 2.5% [CET (Punjab) 2008]

99. The modulus of elasticity is dimensionally equivalent to

(a) strain (b) force (c) stress (d) coefficient of viscosity

100. The ratio of the dimensions of Planck's constant and that of the moment of inertia is the dimension of:

(a) frequency (b) velocity ' (c) angular momentum (d) time

**Previous year questions in JEE Main & AIEEE**

101.The respective number of significant figures for the numbers 23.023, 0.0003 and 21 x 10-3 are

(a) 5, 1,2 (b) 5, 1, 5 (c) 5, 5,2 (d) 4, 4,2 [AIEEE 2010]

102. In an experiment the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the Vernier scale. If the smallest division of the main scale is half-a-degree (: 0.5o), then the least count of the instrument is

(a) one minute (b) half minute (c) one degree (d) half degree [AIEEE 2009]

103. The dimensions of magnetic field in M, L, T and C (coulomb ) is given as: [AIEEE 2008]

(a) [MLT-1C-1] (b) [M T2 C-2] (c) [MT-1C-1] (d) [MT2C-1]

104. A body of mass m = 3.513kg is moving along the x-axis with a speed of 5.00 m/s. The magnitude of its momentum is recorded as [AIEEE 2008]

(a) 17.6 kg m/s (b) 17.565 kg m/s (c) 17.56 kg m/s (d) 17.57 kg m/s

105. Which of the following units denotes the dimensions [ML2 Q-2], where Q denotes the electric charge ?

(a) Weber/m2 (b) Henry (H) (c) H/m2 (d) Weber (Wb) [AIEEE 2006]

106. Identify the pair whose dimensions are equal. [AIEEE 2003]

(a) Torque and work (b) Stress and energy (c) Force and stress (d) Force and work

107. Out of the following pairs, which one does not have identical dimensions ? [AIEEE 2005]

(a) Angular momentum and planck's constant (b) Impulse and momentum

(c) Moment of inertia and moment of a force (d) Work and Torque

108. Which one of the following correct dimensions of the viscosity ? [AIEEE 2004]

(a) [ML-1T-2] (b) [MLT-l] (c) [ML-1 T-1] (d) [ML-2 T-2]

109. Dimensions of 1/μo∈o where symbols have their usual meaning are [AIEEE 2003]

(a) [L-1T] (b) [L2 T2] (c) [L2 T-2] (d) [LT-1]

110. The physical quantities not having same dimensions are (a)torque and work [AIEEE 2003]

(b) momentum and Planck’s constant(c) stress and Young's modulus (d) speed and 1/√(μo∈o )

**Answers Objective Questions- Units and Measurements**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 1. C | 1. B | 1. D | 1. B | 1. B |
| 1. C | 1. B | 1. A | 1. C | 1. C |
| 1. C | 1. C | 1. B | 1. C | 1. C |
| 1. D | 1. A | 1. D | 1. C | 1. A |
| 1. A | 1. B | 1. D | 1. A | 1. C |
| 1. D | 1. A | 1. D | 1. A | 1. C |
| 1. B | 1. C | 1. B | 1. D | 1. A |
| 1. B | 1. C | 1. B | 1. B | 1. A |
| 1. D | 1. B | 1. A | 1. D | 1. C |
| 1. C | 1. B | 1. C | 1. C | 1. B |
| 1. A | 1. B | 1. B | 1. A | 1. C |
| 1. D | 1. B | 1. C | 1. D | 1. B |
| 1. B | 1. B | 1. C | 1. C | 1. D |
| 1. B | 1. B | 1. B | 1. C | 1. D |
| 1. D | 1. C | 1. B | 1. A | 1. C |
| 1. B | 1. B | 1. B | 1. C | 1. C |
| 1. B | 1. D | 1. A | 1. A | 1. A |
| 1. C | 1. D | 1. C | 1. E | 1. B |
| 1. C | 1. A | 1. A | 1. A | 1. B |
| 1. A | 1. B | 1. C | 1. C | 1. A |
| 1. A | 1. A | 1. C | 1. A | 1. B |
| 1. A | 1. C | 1. C | 1. C | 1. B |

**Hints for difficult questions:**

30. Let G = cα gβ pδ ; substitute the dimensional formula’s on both sides and compare the powers of M,L & T on both sides .The solve for α,β & δ .

31.Coulomb’s law states that F= kq2/r2 , where q is the charge in coulomb.

32.same like q. 30

33. According to Einstein’s mass energy equivalence equation E =mc2 =mv2

Therefore m =E/v2 = Ev-2

34. 10m/s2 = n km/h2 or n = 129600

35. 1 L/s2 = 9.8 m/s2 or L =9.8m

36. 1 notwen = (G x 1kg x 1kg)/1km2 or G = 106 notwen m2kg-2

But G = 6.67 x 10 -11 Nm2 kg-2 therefore 1 notwen = 6.67 x 10-17 newton

1 elouj = 1 notwen x 1km = 6.67 x 10-17 newton x 103 m = 6.67 x 10-14 joule

37. F = q2/r24π∈o  therefore ∈o = q2/ r24πF now q = IT

∈o = [IT]2/FL2 = F-1L-2 I2 T2

40. As the least count is is 0.001cm , hence the measurement (a) is correct.

41. As ρ =M/V therefore ∆ ρ/ ρ = ∆M/M + ∆V/V = 0.001/20.000 + 0.01/10.00 = 1.05 x 10-3

Therefore ∆ ρ = ρ x 1.05 x 10-3  =( 20.000/10.00 ) x 1.05 x 10-3  = 0.002gm/cm3

Answer would be : none of these.

42. T = 20/20 =1 ∆T =0.1/20 =0.005 s ∆T/T = 0.005/1 =0.005 x 100% = 0.5%

43. ∆x/x = ∆a/a + 2∆b/b + 3∆c/c = ±1 ±2 x 3 ± 3 x 2 = ± 13%

44. ∆A/A = ∆L/L + ∆W/W = ±(0.1/10.0 +0.01/1.00) ; calculating ∆A = A (±(0.1/10.0 +0.01/1.00)) = ±0.2cm2

45. Percentage error ∆V/V x100 = [∆L/L + 2∆d/d] x 100 = [(0.1/5 + 2x0.01/2.00)]x100 = 3%

46.Thickness ,because measured upto 2 decimal places.

48. Given that ∆g/g x100 = [∆L/L + 2∆t/t] x 100 = 7%

50.When number of observations is made n times , then the random error reduces to 1/n times.

51.percentage error = 3∆r/r x100 =3 x 0.2/5.4 x 100 = 11%

54.Error in measurement remains the same. Hence ,when time is measured for 100 vibrations , instead of 10 vibrations, the relative error will reduce from ∆t/10 to ∆t/100, i.e. it will reduce by a factor of 10.

56. since ρ=m/πr2l

∆ ρ / ρ x100 = [∆m/m + 2∆r/r + ∆L/L] x 100 = [0.003/0.3 + 2x0.005/0.5 + 0.06/6]x100 = 4%

57.Here s= 13.8 ± 0.2 m and t = (4.0 ±0.3) s therefore V = s/t = 13.8 /4.0 = 3.45 m/s

Also ∆ V / V = ± [∆S/S + ∆t/t ] = ± [0.2/13.8 + 0.3/4.0 ] = ± 0.0895 ; ∆ V =± 0.0895 x V = ± 0.3 (rounding off)

60. if x =an then ∆ x / x =n ∆ a / a

62. Errors always add , never subtract !

63. T = 2π√(l/g) therefore g = 4 π2 L/T2

64.kinetic energy K is given in terms of momentum p as K = p2/2m.

If p is measured as p’, then K becomes K’ or K’ =p’2/2m

Therefore K’/K = (p’/p)2 ;now p’/p =(100+100)/100 =2 or K’/K =4

Therefore percentage error in K = (K’-K)/K x 100 = (4K-K)/K x 100 = 300%

68.Let unit of energy =Fx Ay Tz ; ML2T-2 = Fx Ay Tz substitute M,L & T for force etc. in RHS and equate powers to find x,y & z.

90. P = a1/2 b1/2 c d-3 e-1/3

∆P/P x100 = [∆a/2a + ∆b/2b + ∆c/c + 3∆d/d + ∆e/3e] x 100

= [ ½ x 2% + ½ x 3% + 2% + 3 x 1% + ⅓ x 6% ] = [ 1% + 1.5% + 2% + 3% + 2% ]

The minimum amount of error is contributed by the measurement of ‘a’ .

93. Now speed of light c =1/√(μo∈o) = 1/√(8 x2) =1/4 =0.25

94.Electrostatic force of attraction F = Q2/4π∈o r2  ,where Q is charge r is distance & A is unit of current Ampere.

96 let v α σx ρy λz put M,L & T on both sides and equate powers.

97. We will use the general rule of addition by making the powers same

i.e. 3.8 x 10-6 and 42 x 10-6 =45.8 x 10-6 = 4.58 x 10-5.

As there is only one number after decimal in given figures we round off the answer to 4.6 x 10-5

98.Given voltage V =(100 ± 5)V and current I =(10 ± 0.2)A

According to ohm’s law V=IR or R =V/I therefore ∆ R / R = ± [∆V/V + ∆I/I ]

therefore (∆ R / R ) x 100 = ± [5/100 + 0.2/10 ] x 100 = [ 5 + 2] =7%

99. modulus of elasticity = stress /strain , where strain = change in length/original length

100. E=hv and moment of inertia I = mr2

102.Least count =Value of main scale division / No. of divisions on Vernier scale

=1/30 Main scale division = 1/30 x 0.5o  = 1o/60 =1min

103. From F =qvB ; [MLT-2] = [C] [LT-1 ] [B] or [B] =[MC-1 T-1]

104. m = 3.513kg and v = 5.00m/s ; So, momentum, p=mv=17.565

As the number of significant digits in m is 4 and in v is 3, so, p must have 3 (minimum) significant digits. Hence, p=l7.6 kg m/s

105. Magnetic energy =½LI2 = LQ2/2T2 where L is inductance having units of Henry (H) and I is current.

Energy has the dimensions = [ML2T-2]

Equating the dimensions, we have [ML2T-2] = [H ] [Q2][T-2] therefore [H ] = [ ML2Q-2]

106. The dimensions of torque and work are=[ML2T-2]

107. I = mr2 therefore I = [ML2] and torque (τ)=rF = [ML2T-2]

108. By Newton's formula coefficient of viscosity η =F/A(∆vx/∆z)

Therefore dimensions of η= dimensions of force/(dimensions of area x dimensions of velocity gradient)

=[MLT-2]/[L2][LT-1][L-1] = [ML-1 T-1]

You can also use stokes’s law F =6πηrv

109. As we know that the formula for velocity is v =1/√(μo∈o) or 1/(μo∈o) =[L2T-2]

110. Planck's constant (in terms of unit) (h) = J-s =[ML2T-2][T] =[ML2T-1]

Momentum (p) = kg-m/s =[MLT-1]