

A Textbook of
Physics
For Grade **XI**

Test Edition



Khyber Pakhtunkhwa Textbook Board, Peshawar

Unit 1

Measurement



LEARNING OUTCOMES

After studying this unit the students will be able to

- ⊙ describe the scope of Physics in science, technology and society.
- ⊙ state SI base units, derived units, and supplementary units for various measurements.
- ⊙ express derived units as products or quotients of the base units.
- ⊙ state the conventions for indicating units as set out in the SI units.
- ⊙ explain why all measurements contain some uncertainty.
- ⊙ distinguish between systematic errors (including zero errors) and random errors.
- ⊙ identify that least count or resolution of a measuring instrument is the smallest increment measurable by it.
- ⊙ differentiate between precision and accuracy.
- ⊙ assess the uncertainty in a derived quantity by simple addition of actual, fractional or percentage uncertainties.
- ⊙ quote answers with correct scientific notation, number of significant figures and units in all numerical and practical work.
- ⊙ check the homogeneity of physical equations by using dimensionality and base units.
- ⊙ derive formulae in simple cases using dimensions.

1.1 PHYSICS AND ITS SCOPE

Physics is the branch of science that involves **the study of the physical world in specific and physical universe in general: energy, matter, and how they are related**. In physics modeling of the natural world is made with theory, and is usually expressed quantitatively with mathematical description.

Even if we do not study PHYSICS as a subject we depend on it for nearly everything. From walking to driving a car, from cooking to using a gadget, from cutting a tree to building a new house everything involves physics. Even as we read this sentence, physics is at work. Physicists investigate the motions of electrons and rockets, the energy in sound waves and electric circuits, the structure of the proton and that of the universe.

Physics is also called ‘the fundamental science’ because the subject of study of all branches of natural science like chemistry, astronomy, geology, and biology are constrained by laws of physics. We can say ‘*All other natural sciences stem from physics*. Chemistry is essentially applied physics and biology is applied chemistry’.

For technologies to develop physics is essential. Physics generates fundamental knowledge needed for the future technological advances that will continue to drive the economic engines of the world. So many pivotal discoveries of the 20th century - including the laser, television, radio, computer technology plus internet, DNA and nuclear weapons are all credited to advancement in physics.

Physics contributes to the technological infrastructure and provides trained personnel needed to take advantage of scientific advances and discoveries. It is important for improvement in health, telecommunication, transport and design of our future. Nearly all consumer goods we use at home have been developed from research in physics.

1.2 SYSTEM INTERNATIONAL (SI)

The International System of Units (abbreviated SI from *systeme internationale*, the French version of the name) is a scientific method of expressing the **magnitudes or quantities of important natural phenomena**.

Science require that quantities must be defined and measured. Things that cannot be measured like beauty, love, hate, are all not science.

On the other hand quantities like length, time, density, temperature, electric fluxes can be measured therefore they are called physical quantities.

A complete set of units for all physical quantities is called system of units.

However to form a system we does not need to define every quantity. We take only a few quantities (called base quantities) and base units to agree on accessible and invariable standards for measurement such that all other quantities and units are expressed in terms of those quantities.

In earlier times scientists around the world were using different systems of units for their liking. Three such systems, the MKS, the CGS and the FPS (or British) system were in use extensively till recently.

In 1960 an international committee agreed on a single system for whole world, the system's official name is the Syst' eme International, or SI, meaning International System. We can use other systems and its units (Fahrenheit, pounds, and miles) for our convenience but in science we must always use SI.

A. Base Units: In SI *SEVEN* physical quantities chosen arbitrarily as base and their corresponding units are defined and standardized and are called base units as shown in table 1.1. The definition of each base unit of the SI is carefully drawn up so that it is unique and provides a sound theoretical basis upon which the most accurate and reproducible measurements can be made.

Table 1.1: SI BASE QUANTITIES AND BASE UNITS			
Base Quantity		SI Base Unit	
Name	Symbol	Name	Symbol
Length	$l, x, r \text{ e.t.c}$	meter	m
Mass	m	kilogram	Kg
Time, duration	t	second	s
Electric current	I	ampere	A
Thermodynamic temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity	I_v	candela	cd

B. Derived Units: A quantity and its unit obtained and developed from base quantities and their respective units without giving any consideration to the directional properties are called derived quantities and its units. Units for all other physical quantities can be derived from the seven base units, table 1.2, list of few derived quantities.

TABLE 1.2: SI DERIVED QUANTITIES AND DERIVED UNITS

Derived Quantity		SI Coherent Derived Unit	
Name	Symbol	Name	Base terms
Area	A	square meter	m^2
Volume	V	cubic meter	m^3
Speed, velocity	v	meter per second	ms^{-1}
Acceleration	a	meter per second squared	ms^{-2}

The number of derived quantities of interest in science and technology has no limit. A large number of other derived units can also be formed by combining base units according to the algebraic relations of the corresponding quantities.

C. Supplementary units: Pure geometrical units (radian and the steradian) were classified by the System International (SI) as supplementary units. But this designation was abrogated in 20th CGPM (french words Conférence générale des poids et mesures abbreviated from General Conference on Weights and Measures) in 1995 and the units were grouped as derived units. These two units radian and steradian are discussed in this topic.

1. Radian: The most natural way to measure the angle θ is not in degrees, but in radians. *One radian (1 rad) is the angle subtended at the center of a circle by an arc with a length equal to the radius of the circle.*

The number of radians, in general is given by the arc length divided by radius of the circle.

$$\text{Number of radians } (q) = \frac{\text{ArcLength}}{\text{Radius of same circle}} = \frac{S}{r}$$

Relation radian measurement and degree measurement: In one complete rotation there are 360°

$$\text{Number of degrees in one revolution} = 360^\circ \quad \text{--- ①}$$

Where as the number of radians in one revolution is= $\frac{\text{Circumference of Circle}}{\text{Radius of same circle}}$

$$\text{Number of radians in one revolution} = \frac{2\pi r}{r} = 2\pi \text{ radians} \quad \text{--- ②}$$

Comparing Eq 1 & 2

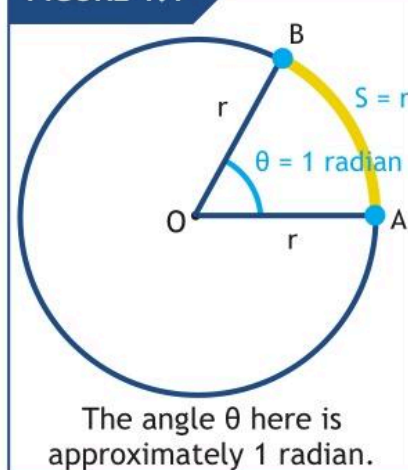
as Number of degrees in one revolution = Number of radians in one revolution

$$\text{Therefore } 2\pi \text{ rad} = 360^\circ$$

$$\text{or } 1 \text{ rad} = \frac{360^\circ}{2\pi} = \frac{360^\circ}{2 \times 3.14} = 57.3^\circ$$

An angle of approximately 57° corresponds to 1 radian. There are a little more than 6 radians in a full rotation (2π radians or 2×3.14 radians to be exact). This connection between the angle and the length measured along a circular arc is very useful in work on circular motion.

FIGURE 1.1



Example 1.1

GEARS

Two connected gears are rotating. The smaller gear has a radius of 0.4 m and the larger gear's radius is 0.7 m. What is the angle through which the larger gear has rotated when the smaller gear has made one complete rotation?

GIVEN

Larger gear's radius ' r_L ' = 0.7 m

Smaller gear's radius ' r_s ' = 0.4 m

REQUIRED

Angle of rotation for larger gear ' θ_L ' = ?

SOLUTION

The smaller gear performs one complete rotation ($\theta_s = 2\pi$), the length of the arc traveled is: $S = r_s \times \theta_s$

$$S = r_s \times \theta_s$$

Putting values $S = 0.4 \text{ m} \times 2\pi$

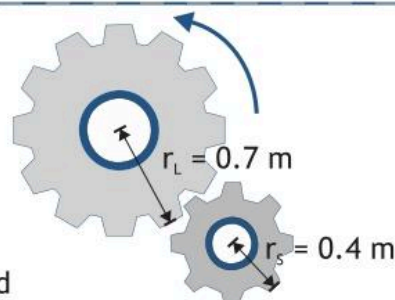
$$S = 0.8\pi \text{ m}$$

So, an 8π arc length on the larger circle would form an angle as follows:

$$\theta = \frac{S}{r_L} \quad \text{Putting values } \theta = \frac{0.8\pi \text{ m}}{0.7 \text{ m}}$$

$$\theta = 3.6 \text{ radians}$$

Answer



EXTENSION EXERCISE

What is the angle in degrees through which the larger gear has rotated?

Assignment 1.1

A pulley of radius 0.9 m is used to lift a bucket from the well. If it took 3.6 rotations for the pulley to take water out of the well, how deep is water in the well? (Answer = 20 m)

ii. Steradian: Steradian is the unit for solid angle. Steradian is defined as the solid angle subtended at the center of sphere by an area of its surface equal to the square of radius of that sphere as shown in Figure 1.2. Surface area of closed sphere of radius r is $4\pi r^2$.

Thus by definition of steradian the solid angle subtended by a closed sphere is

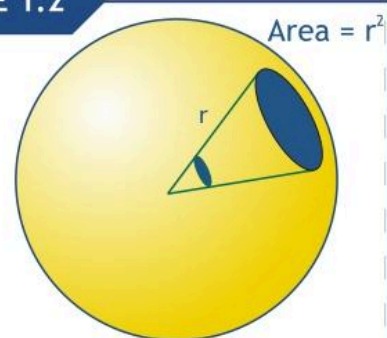
$$\begin{aligned} \text{Number of steradians in sphere} \\ = \frac{\text{Area of Sphere}}{r^2} \end{aligned}$$

Therefore

$$\text{Number of steradians in sphere} = \frac{4\pi r^2}{r^2}$$

Sphere or for that matter any closed surface subtends 4π (12.56) steradian at any of its interior point.

FIGURE 1.2



When the area on the surface of sphere become equal to the radius squared, then the angle subtended at the center is one steradian.

1.3 SCIENTIFIC NOTATION

Scientific notation is an easy way of writing numbers that are too big or too small to be written in decimal form. In scientific notation a big number is written as the product of a number greater than 1 and less than 10 (called the mantissa) and a power (or exponent) of 10:

$$\text{number} = \text{mantissa} \times 10^{\text{exponent}}$$

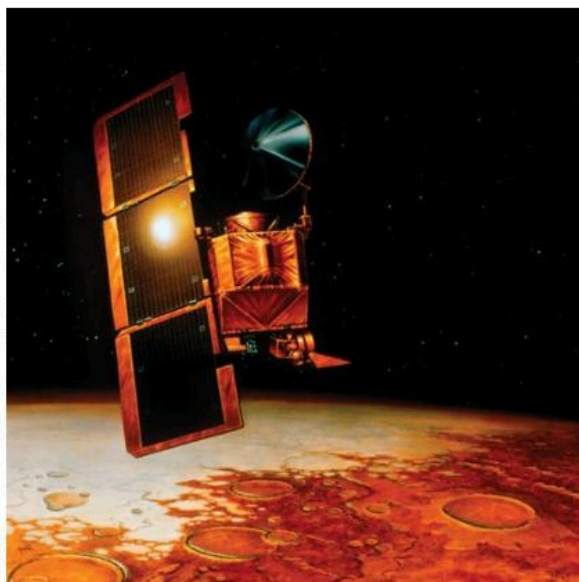
For example, if someone writes that human body contains approximately 7,000,000,000,000,000,000,000,000 atoms, it is not only time consuming and difficult to write this number but there is also a chance of error. The number of atoms in the human body can thus be written compactly as 7×10^{27} , where 7 is the mantissa and 27 is the exponent.

Another advantage of scientific notation is that it makes it easy to add, subtract, multiply and divide large numbers. For example, to multiply two numbers in scientific notation, we multiply their mantissas and then add their exponents.

POINT TO PONDER

Why is it important to have a standard system of units that is used by all scientists and engineers?

In December 1998, the NASA launched the Mars Climate Orbiter on a scientific mission to collect climate data from Mars. Nine months later, on September 23, 1999, the Orbiter disappeared while approaching Mars. The investigation showed that the orbital calculations were incorrect due to an error in the transfer of information between two teams working on the project. One team used English units such as feet and pounds, while the other group assumed the result of the calculation was being reported in SI.



If we wanted to estimate, as how many atoms are contained in the bodies of all the people on Earth, we could do this calculation easily. The population of earth is approximately 7 billion (or 7×10^9). To find our answer we have to multiply 7×10^{27} by 7×10^9 . We do this by multiplying the two mantissas and adding their exponents:

$$(7 \times 10^{27}) \times (7 \times 10^9) = (7 \times 7) \times 10^{27+9} = 49 \times 10^{36} = 4.9 \times 10^{37}.$$

In the last step, we follow the common convention of keeping only one digit in front of the decimal point of the mantissa and adjusting the exponent accordingly. (But be advised that we will have to further adjust this answer! read on – Significant Figures.

Prefixes to the power of TEN:

A mechanism through which a term in scientific notation is expressed by giving a proper name to its power of ten is called prefix to the power of ten.

A useful set of prefixes in SI replace given powers of 10, Prefixes makes standard form to be written even more easily.

For example, the length of a housefly, 5×10^{-3} m, is equivalent to 5 millimeters (mm), and the distance of a satellite 8.25×10^5 m from Earth's surface can be expressed as 825 kilometers (km).

Table 1.3: PREFIXES

Prefix	Decimal Multiplier	Symbol
yotta	10^{24}	Y
zetta	10^{21}	Z
Exa	10^{18}	E
Peta	10^{15}	P
Tera	10^{12}	T
giga	10^9	G
Mega	10^6	M
kilo	10^3	k
hecto	10^2	h
deca	10^1	da
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	μ
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f
atto	10^{-18}	a
zepto	10^{-21}	z
yocto	10^{-24}	y

DO YOU KNOW

There are some non-SI related units for distances extensively used around the world. Some of these units are discussed below.

A. Light Year: A light-year (ly), is a non-SI unit of length. It is defined as the distance that light travels in a vacuum in one year, which is 9.4607×10^{15} m. For example spiral galaxies like our own Milky Way measure approximately 2×10^5 light-years in diameter. Our nearest-neighbor galaxy is the great spiral galaxy Andromeda, which has been determined to be approximately 2.5 million ly away.

B. Angstrom: The angstrom or ångström (Å) is also a non-SI and internationally recognized unit of length equal to 1×10^{-10} meters (m) or 0.1 nanometer (nm). For example, a helium atom has a size of about 1 Ångström, while its nucleus is only 1 femtometer (10^{-15} meters) in diameter.

C. Micron: A micron (μ) is an obsolete name of a micrometer, which is a decimal fraction of the meter about 1×10^{-6} meters. For examples Red Blood Cells (RBCs) are approximately 10 microns in diameter. Human hair is between 10 and 100 microns in diameter.

1.4 WRITING UNIT SYMBOLS AND NAMES

Unit symbols

- * Unit symbols are printed in roman (upright) type regardless of the type used in the surrounding text. For example m for metre, s for second and Pa for pascal.
- * A multiple or sub-multiple prefix, if used, is part of the unit and precedes the unit symbol without a separator. A prefix is never used in isolation, and compound prefixes are never used. For example nm, not m μ m or pm not $\mu\mu$ m.
- * In forming products and quotients of unit symbols the normal rules of algebraic (multiplication or division) apply. Multiplication must be indicated by a space or a half-high (centred) dot ($\cdot$), since otherwise some prefixes could be misinterpreted as a unit symbol. Division is indicated by a horizontal line, by a solidus (oblique stroke, /) or by negative exponents. For example N m or N $\cdot$ m, for a newton metre and m/s or m s $^{-1}$ for metre per second
- * It is not permissible to use abbreviations for unit symbols or unit names, such as sec (for either s or second), sq. mm (for either mm 2 or square millimetre), cc (for either cm 3 or cubic centimetre), or mps (for either m/s or metre per second).

* When multiple of unit is raised to the power the power applies to the whole multiple not just the unit.

Unit names

* Unit names are normally printed in roman (upright) type, and they are treated like ordinary nouns. In English, the names of units start with a lower-case letter (even when the symbol for the unit begins with a capital letter), except at the beginning of a sentence or in capitalized material such as a title. For example joule J, hertz Hz, metre m, second s and ampere A.

* Although the values of quantities are normally expressed using symbols for numbers and symbols for units, if for some reason the unit name is more appropriate than the unit symbol, the unit name should be spelled out in full. For example 2.1 m/s, or 2.1 metres per second.

* When the name of a unit is combined with the name of a multiple or sub-multiple prefix, no space or hyphen is used between the prefix name and the unit name. The combination of prefix name plus unit name is a single word. For example milligram, but not milli-gram and kilopascal, but not kilo-pascal.

1.5 ERRORS

Error is the doubt that exists about the result of any measurement. For every measurement (even the most careful) there is always a margin of doubt which is called error.

Thus every measurement is approximate due to errors in measurement.

Types of Errors: The errors in measurement can be broadly classified as (a) systematic errors and (b) random errors.

A. 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** arise from the errors due to imperfect design or calibration of the measuring instrument, zero error in the instrument, etc.

(b) **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, etc.

Systematic errors can be minimized 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.

B. 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. changes in temperature, humidity, wind velocity, 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.

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; a spherometer may have a least count of 0.001 cm. Least count error belongs to the category of random errors but within a limited size; it occurs with both systematic and random errors. We can reduce the least count error by using instruments with higher resolution, improving experimental techniques, etc.

1.6 UNCERTAINTIES

The quantification or magnitude of error or doubt in measurement is called uncertainty. Uncertainty estimate how small or large the error is. Also we can state uncertainty as a *non-negative parameter characterizing the dispersion of the values attributed to a measured quantity.* As there is uncertainty to some extent in every measurement therefore every measurement need to be written in the form

$$\text{measurement} = \text{best estimate} \pm \text{uncertainty}$$

For example a measurement of $(5.07 \pm 0.02) \text{ g}$ means that the experimenter is confident that the actual value for the quantity being measured lies between 5.05 g i.e. $(5.07 - 0.02) \text{ g}$ and 5.09 g i.e. $(5.07 + 0.02) \text{ g}$. The uncertainty is the experimenter's best estimate of how far an experimental quantity might be from the "true value."

Types of Uncertainties: There are two main types of uncertainties

A. Absolute Uncertainty is denoted by the symbol ' Δ ' and has the same units as the quantity.

B. Relative or Percent Uncertainty is denoted by the symbol ' ϵ ' and has no units.

To convert back and forth between the two types of uncertainties consider the following

$$m = (3.3 \pm 0.2) \text{ kg} = (3.3 \text{ kg} \pm 6.1\%)$$

The Absolute Uncertainty is: $\Delta m = 0.2 \text{ kg} = (6.1/100) \times 3.3 \text{ kg}$

The Relative Uncertainty is: $\epsilon m = 6.1\% = (0.2/3.3) \times 100\%$

DO YOU KNOW

Technical specification data

Manufacturers of scientific instruments often supply data sheets that specify how accurate the instrument is. The instruments have been tested against very accurate standard instruments and the results are shown on the data sheet.

As you might expect, instruments that are guaranteed to be more accurate are usually more expensive.



Technical specifications
Voltage accuracy $\pm 0.2 \text{ V}$
Current accuracy $\pm 0.01 \text{ mA}$
Resistance $\pm 0.9 \%$

Indicating Uncertainty in calculation: A numeric measure of confidence in a measurement or result is known as uncertainty. A lower uncertainty indicates greater confidence. Uncertainties are usually expressed by using statistical methods.

ACTIVITY

When a short distance needs to be measured and a tape measure is not available, some people measure the approximate length by using the length of their own foot as a unit. Measure the distance between two points approximately 5 m to 10 m apart by placing one foot in front of the other and counting the steps. Then, measure the same distance with a tape measure. How close to the standard foot is the length of your own foot? How much error did you generate?

For longer distances, we can measure the approximate length by walking the distance using one stride as approximately 1 yd or 3 ft. Measure the distance between two points approximately 20 m to 30 m apart by pacing off the distance and counting the strides. Then, measure the same distance with a tape measure. Calculate how much error did you generate? What was the uncertainty?

A. Sum or difference: Absolute uncertainties are added. Suppose two physical quantities A and B have measured values $A \pm \Delta A$, $B \pm \Delta B$ respectively where ΔA and ΔB are their absolute uncertainties. The following steps are followed for the result $Z = Z \pm \Delta Z$ in their sum and difference.

Sum: Let $Z = A + B$ and the measured values of A and B are $A \pm \Delta A$ and $B \pm \Delta B$. We have by addition,

$$Z \pm \Delta Z = (A \pm \Delta A) + (B \pm \Delta B).$$

$$Z \pm \Delta Z = (A + B) \pm (\Delta A + \Delta B).$$

The maximum possible uncertainty in

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

Difference: Let $Z = A - B$ and the measured values of A and B are $A \pm \Delta A$ and $B \pm \Delta B$. We have

$$Z \pm \Delta Z = (A \pm \Delta A) - (B \pm \Delta B)$$

$$Z \pm \Delta Z = (A - B) \pm \Delta A + \Delta B$$

The maximum value of the uncertainty ΔZ is again $\Delta A + \Delta B$.

POINT TO PONDER

Error versus uncertainty: It is important not to confuse the terms 'error' and 'uncertainty'. **Error** is the difference between the measured value and the **true value** of the thing being measured. Uncertainty is a quantification of the doubt about the measurement result. Whenever possible we try to correct for any known errors: for example, by applying corrections from calibration certificates. But any error whose value we do not know is a source of uncertainty.

B. Product or quotient: Fractional uncertainties are converted into **percentage uncertainties which are added**. Suppose two physical quantities A and B have measured values $A \pm \Delta A$, $B \pm \Delta B$ respectively where ΔA and ΔB are their absolute uncertainties and $\Delta A\%$ and $\Delta B\%$ are their percentage uncertainties. The following steps are followed for the result $Z = Z \pm \Delta Z$ in their product and quotient.

Product: Suppose $Z = AB$ and the measured values of A and B are $A \pm \Delta A$ and $B \pm \Delta B$. Then

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

Convert fractional uncertainty to percentage uncertainty

$$Z \pm \Delta Z = (A \pm \Delta A\%) (B \pm \Delta B\%)$$

Multiply the product and add percentage uncertainties

$$Z \pm \Delta Z = AB \pm (\Delta A\% + \Delta B\%)$$

$$Z \pm \Delta Z = AB \pm (\Delta A + \Delta B)\%$$

Convert back to fractional uncertainty

$$Z \pm \Delta Z = AB \pm (\Delta Z)$$

Quotient: Suppose $Z = A/B$ and the measured values of A and B are $A \pm \Delta A$ and $B \pm \Delta B$. Then

$$Z \pm \Delta Z = (A \pm \Delta A) / (B \pm \Delta B)$$

Convert fractional uncertainty to percentage uncertainty

$$Z \pm \Delta Z = (A \pm \Delta A\%) / (B \pm \Delta B\%)$$

Divide the ratios and add percentage uncertainties

$$Z \pm \Delta Z = A / B \pm (\Delta A\% + \Delta B\%)$$

$$Z \pm \Delta Z = A / B \pm (\Delta A + \Delta B)\%$$

Convert back to fractional uncertainty

$$Z \pm \Delta Z = A / B \pm (\Delta Z)$$

C. Power: Percent uncertainty is multiplied by power. The result is converted back into fractional uncertainty which will give absolute uncertainty by rounding off.

Suppose $Z = A^n$ and the measured values of A are $A \pm \Delta A$. Then

$$Z \pm \Delta Z = (A \pm \Delta A)^n$$

Convert fractional uncertainty to percentage uncertainty

$$Z \pm \Delta Z = (A \pm \Delta A\%)^n$$

square the term and percentage uncertainty with the power

$$Z \pm \Delta Z = A^n \pm n \times \Delta A\%$$

$$Z \pm \Delta Z = A^n \pm (n\Delta A)\%$$

Convert back to fractional uncertainty

$$Z \pm \Delta Z = A^n \pm (\Delta Z)$$

Example 1.2**THICKNESS OF PIPE**

If $d_1 \pm \Delta d_1 = (101.41 \pm 0.05)$ mm represents the internal diameter of the metal pipe and $d_2 \pm \Delta d_2 = (102.79 \pm 0.05)$ mm represents the external diameter of the metal pipe, then find the thickness of the metal part of the pipe including uncertainty in it.

GIVEN

Internal diameter $d_1 \pm \Delta d_1 = (101.41 \pm 0.05)$ mm

External diameter $d_2 \pm \Delta d_2 = (102.79 \pm 0.05)$ mm

REQUIRED

Thickness of Pipe ' t ' = ?

SOLUTION

To find the thickness of the pipe we would subtract the internal diameter from the external diameter however we will add its fractional uncertainties as

$$d = d_2 - d_1 \pm (\Delta d_1 + \Delta d_2)$$

Putting values

$$d = (102.79 - 101.41) \text{ mm} \pm (0.05 + 0.05) \text{ mm}$$

$$d = (1.38 \pm 0.10) \text{ mm}$$

Be careful not to subtract uncertainties when subtracting measurements uncertainty ALWAYS gets worse as more measurements are combined.

Since the difference in the radius is required for the thickness ' t ' therefore both the diameter and the uncertainty must be divided by 2 (as the percentage uncertainty remains the same), Hence

$$t = \frac{d}{2} = \left(\frac{1.38}{2} \pm \frac{0.10}{2} \right) \text{ mm}$$

$$t = (0.69 \pm 0.05) \text{ mm}$$

Answer

Assignment 1.2**WALL WIDTH**

A physicist calculated the wall width of half brick thickness (the brick is laid in a flat position, lengthwise called stretcher position), as (13.6 ± 0.1) cm. And one brick thickness (the brick is placed in flat position, lengthwise orthogonal to wall, called header position), as (23.6 ± 0.1) cm. Calculate the difference in width of walls with uncertainty in it. (10.0 ± 0.2) cm

Example 1.3**AREA OF ROOM**

The length and width of a rectangular room are measured to be $l = (l \pm \Delta l) = (3.955 \pm 0.005) \text{ m}$ and $w = (w \pm \Delta w) = (3.050 \pm 0.005) \text{ m}$. Calculate the area $A = (A \pm \Delta A)$ of the room and its uncertainty.

GIVEN

length $l = (4.050 \pm 0.005) \text{ m}$

width $w = (2.955 \pm 0.005) \text{ m}$

REQUIRED

Area $A = (A \pm \Delta A) = ?$

SOLUTION

For the product percentage uncertainties are added. The length 'l' and width 'w' in percentage uncertainties are

$$l = 4.050 \text{ m} \pm \frac{0.005 \text{ m}}{4.050 \text{ m}} \times 100\% = 4.050 \text{ m} \pm 0.12\%$$

$$\text{and } w = 2.955 \text{ m} \pm \frac{0.005 \text{ m}}{2.955 \text{ m}} \times 100\% = 2.955 \text{ m} \pm 0.17\%$$

Since the area of a rectangle is the product of length and width

$$A = l \times w \text{ or } A = (4.050 \text{ m} \pm 0.12\%) \times (2.955 \text{ m} \pm 0.17\%)$$

In multiplication the percentage uncertainties are added

$$A = (4.050 \text{ m} \times 2.955 \text{ m}) \pm (0.12\% + 0.17\%) \text{ or } A = 12.20 \text{ m}^2 \pm 0.29\%$$

to convert it back to fractional uncertainty, we have

$$A = (12.20 \pm \frac{0.29}{100} \times 12.20) \text{ m}^2$$

or

$$A = (12.20 \pm 0.035) \text{ m}^2$$

Answer

Assignment 1.3**RESISTANCE**

The voltage ' $V (V \pm \Delta V)$ ' is measured as $7.3 \text{ V} \pm 0.1 \text{ V}$ and current ' $I (I \pm \Delta I)$ ' is measured as $2.73 \text{ A} \pm 0.05 \text{ A}$. Calculate the resistance ' R ' by using Ohm's Law as $R = V/I$.

$$(2.7 \pm 0.08) \Omega$$

Example 1.4

BALL DROP

A ball drops from rest from an unknown height 'h'. The time 't' it takes for the ball to hit the ground is measured to be $(t \pm \Delta t) = (1.3 \pm 0.2) \text{ s}$. The height is related to this time by the equation $h = \frac{1}{2}gt^2$ (where $g = 9.81 \text{ m/s}^2$). Assume that the value for 'g' carries no uncertainty and calculate the height 'h' including its uncertainty.

GIVEN

time t $(t \pm \Delta t) = (1.3 \pm 0.2) \text{ s}$

acceleration due to gravity ' g ' $= 9.81 \text{ m/s}^2$

REQUIRED

height 'h' $= (h \pm \Delta h) = ?$

SOLUTION

For the power percentage uncertainties is multiplied with power. The percentage uncertainty in time 't' is

$$t = 1.3 \text{ s} \pm \frac{0.2 \text{ s}}{1.3 \text{ s}} \times 100\% = 1.3 \text{ s} \pm 15.4\%$$

Since the Height 'h' is given by $h = \frac{1}{2}gt^2$

$$\text{Putting values } h = \frac{1}{2} \times 9.81 \text{ ms}^{-2} \times (1.3 \text{ s} \pm 15.4\%)^2$$

For the power percentage uncertainties is multiplied with power, therefore

$$h = \frac{1}{2} \times 9.81 \text{ ms}^{-2} \times 1.69 \text{ s}^2 \pm 2 \times 15.4\%$$

$$\text{or } h = 8.30 \text{ m} \text{ @ } 30.8\%$$

to convert it back to fractional uncertainty, we have

$$h = (8.30 \pm \frac{30.8}{100} \times 8.30) \text{ m}$$

or

$$h = (8.3 \pm 2.6) \text{ m}$$

Answer

Assignment 1.4

VOLUME OF SPHERE

The radius of sphere 'r' is measured with vernier callipers as $(r \pm \Delta r) = (2.25 \pm 0.01) \text{ cm}$. Calculate the volume of sphere. $(47.7 \pm 0.6) \text{ cm}^3$

1.7 SIGNIFICANT FIGURES

A significant figure is one that is reliably known. In any measurement the accurately known digits and the first doubtful digit are collectively called significant figures.

In many cases the uncertainty of a number is not stated explicitly. Instead, the uncertainty is indicated by the number of meaningful digits, or significant figures, in the measured value. There are some rules that must be followed while dealing with significant figures.

General Rules

1. NON ZERO digits are always significant. That is all the digits from 1 to 9 are significant, e.g the number of significant figures in 47.872 is 5.
2. ZERO in between two significant digits is always significant, e.g the number of significant figures in 301.5006 is 7.
3. ZEROS to the left of significant figures are **not** significant, e.g the number of significant figures in 0.000538 is 3.
4. ZEROS to the right of the significant figure **may or may not** be significant. In decimal fractions zero to the right of a decimal fraction are significant, e.g in 5.200 there are 4 significant figures.

However if the number is an integer, number of significant figures depends upon the least count of the measuring instrument, e.g in number 500,000 we may have 1, 2 or even 6 significant figures.

5. In scientific notation or standard form the figures other than power of ten are significant, e.g in number 2.1000×10^4 , there are 5 significant figures.

Significant Figures in Calculation: When we use a calculator to analyze problems or measurements, we may be able to save time because the calculator can compute faster. However, the calculator does not keep track of significant figures.

(a) Addition and Subtraction: When two or more quantities are added or subtracted, the result is as precise as the least precise of the quantities. After adding or subtracting, round the result by keeping only as many decimal places as are in the figure containing least decimal places of the quantities that were added or subtracted.

For example, $44.56005 + 0.0698 + 1103.2 = 1147.82985$.

We do not want to write all of those digits in the answer.

Rounding to the nearest tenth of the figure, the sum is written = 1147.8 .

(b) Multiplication and Division: When quantities are multiplied or divided, the result has the same number of significant figures as the quantity with the smallest number of significant figures.

For example, a calculator gives $45.26 \times 2.41 = 109.0766$. Since the answer should have only three significant figures, we round the answer to $45.26 \times 2.41 = 109$.

In scientific notation, we write 1.09×10^2 .

TIP

In a series of calculations, rounding to the correct number of significant figures should be done only at the end, not at each step. Rounding at each step would increase the chance that roundoff error could snowball and have an adverse effect on the accuracy of the final answer. It's a good idea to keep at least two extra significant figures in calculations, then round at the end.

Example 1.5

SIGNIFICANT FIGURES CALCULATION

Calculate the answers to the appropriate number of significant figures.

(a) $0.35 - 0.1$

(b) $32.567 + 135.0 + 1.4567$

(c) $420.03 + 299.270 + 99.068$

(d) 14×8

(e) $(2400)(3.45)(16.21)$

(f)
$$\begin{array}{r} 32.09 + 1.2 - 17.035 \\ \hline 19.8 \end{array}$$

SOLUTION

(a) Calculating

$$\begin{array}{r} 0.35 \\ - 0.1 \\ \hline 0.25 \end{array}$$

Not worrying about significant figures, the result of $0.35 - 0.1 = 0.25$.

But, according to the rules of significant figures, the result should have the same number of decimal places as the input with the fewest number of decimal places. The result of our calculation should be rounded to the tenths place—so, $0.35 - 0.1 = 0.2$.

or

$$0.35 - 0.1 = 0.2$$

Answer**(b) Calculating**

$$\begin{array}{r} 32.567 \\ 135.0 \\ + 1.4567 \\ \hline 169.0237 \end{array}$$

But, since according to the rules of significant figures, the result should be rounded to the lowest number of decimal places as in the input given numbers. The result of our calculation should be rounded to one decimal place. So

or

$$32.567 + 135.0 + 1.4567 = 169.0$$

Answer**(c) Calculating**

$$\begin{array}{r} 420.03 \\ 299.270 \\ + 99.068 \\ \hline 818.368 \end{array}$$

But, since according to the rules of significant figures, the result should be rounded to the lowest number of decimal places as in the input given numbers. The result of our calculation should be rounded to two decimal place. Therefore

or

$$420.03 + 299.270 + 99.068 = 818.37$$

Answer**(d) Calculating**

$$\begin{array}{r} 14 \\ \times 8 \\ \hline 112 \end{array}$$

However, according to the rules of significant figures, the result should have the same number of significant figures as the quantity with the smallest number of significant figures. In this case the number 14 has two significant digits and number 8 has one significant digit. Therefore, the result of our calculation should be rounded to only one significant digit. Therefore

or $14 \div 8 = 100 = 1 \times 10^2$ **Answer**

(e) Calculating

$$\begin{array}{r} 2400 \\ 3.45 \\ \times 16.21 \\ \hline 134,218.8 \end{array}$$

However, according to the rules of significant figures for multiplication, the result should have the same number of significant figures as the quantity with the smallest number of significant figures. In this case the number 2400 has two significant digits, number 3.45 has three significant digits and number 16.21 has four significant digits. Therefore, the result of our calculation should be rounded to two significant digits. Hence

or $(2400)(3.45)(16.21) = 130,000$ **Answer**

(f) Calculating

$$\begin{array}{r} 32.09 \\ + 1.2 \\ \hline 33.29 \end{array}$$

Although the answer should have one decimal place, but we will keep both and proceed.

$$\begin{array}{r} 33.29 \\ - 17.035 \\ \hline 16.255 \end{array}$$

Again the answer should have one decimal place, but we will keep all digits.

$$\frac{16.255}{19.8} = 0.820959596$$

However, according to the rules of significant figures for division, the result should have the same number of significant figures as the quantity with the smallest number of significant figures. In this case the number 16.255 has five significant digits and number 19.8 has three significant digits. Therefore, the result of our calculation should be rounded to three significant digits. Hence

or
$$\frac{32.09 + 1.2 - 17.035}{19.8} = 0.821$$
 Answer

Assignment 1.5

SIGNIFICANT FIGURES CALCULATION

Calculate the answers to the appropriate number of significant figures.

(a) $0.31 + 0.1$

(b) $658.0 + 23.5478 + 1345.29$

(c) 8×7

(d) $0.9935 \times 10.48 \times 13.4$

(e) $5.5 / 1.1$

(f) $\frac{73.2 + 18.72 \times 6.1}{3.4}$

(a) 0.4 , (b) 2026.8, (c) 60 (d) 140 or 1.40×10^2 , (e) 5.0 & (f) 55

1.8 PRECISION AND ACCURACY

When a value is measured, two parameters precision and accuracy affect the quality of the measurement. Therefore it is important to clearly distinguish between them.

Precision: In measurements the term precision describes the degree of exactness with which a measurement is made and stated (that is, the position of the last significant digit). So significant figures help keep track of imprecision. For example the precision of the measurement 293,000 km is 1000 km. (The position of the last significant digit is in the thousands place).

Similarly the precision of the measurement 0.0210 s is 0.0001 s. (The position of the last significant digit is in the ten thousandths place).

Precision depends on the instrument and technique used to make the measurement. Generally, the device that has the finest division on its scale produces the most precise measurement. It is important to record the precision of your measurements so that other people can understand and interpret your results. Precision therefore refers to closeness of the set of measurements of the same quantity made in the same way.

Accuracy: In measurement the accuracy describes the closeness of a measured value to the actual value of the measured quantity. The accuracy of a measurement depends upon the number of significant digits. The greater the number of significant digits given in a measurement, the better is the accuracy, and vice versa. For example the accuracy of the measurement 0.025 cm is indicated by two significant digits.

Table 1.4: PRECISION AND ACCURACY

Measurement	Precision	Accuracy (Significant digits)
2642 m	1 m	4
2050 m	10 m	3
34,000 km	1000 km	2
203.05 kg	0.01 kg	5
0.000285 kg	0.000001 kg	3
75 N	1 N	2
4.050 μ s	0.001 μ s	4
100.050 km	0.001 km	6

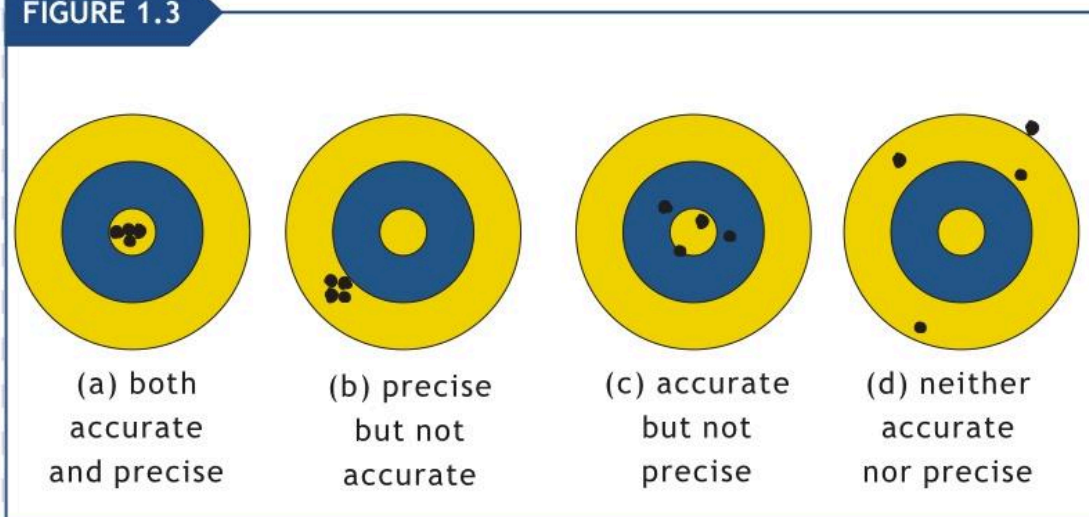
Accuracy shows how well the results of a measured value agree with the actual value (that is the accepted value as measured by competent experimenters). As it is difficult to know the actual (true) value; it is only predicted theoretically, and then is accepted based on the results of repeated experiments.

For example, the accepted value of acceleration due to gravity is 9.80 m/s^2 .

Consider a dart game with bulls-eye at the center as shown in the Figure 1.3.

- If the darts land close to the bulls-eye and close together, there is both accuracy and precision as in Figure 1.3(a).
- If all of the darts land very close together, but far from the bulls-eye, there is precision, but not accuracy as in Figure 1.3 (b).
- If the darts are spread around the bulls-eye there is mathematical accuracy because the average of the darts is in the bulls-eye as in Figure 1.3 (c).
- If the darts are neither close to the bulls-eye, nor close to each other, there is neither accuracy, nor precision as in Figure 1.3 (d).

FIGURE 1.3



1.9 DIMENSIONS OF PHYSICAL QUANTITIES

Dimensions describes the physical nature of quantity. Each basic measurable physical quantity is represented by specific symbol and written within square bracket is called dimension of physical quantity.

By convention physical quantities are organized in a system of dimensions. Each of the seven base quantities used in the SI is regarded as having its own dimension, which is symbolically represented by a single sans serif roman capital letter.

The symbols used for the base quantities, and the symbols used to denote their dimension, are given in table 1.5. All other quantities are derived quantities, which may be written in terms of the base quantities by the equations of physics. The dimensions of the derived quantities are the product of the dimensions of the base quantities of which the quantity is derived. For example area is defined as (length $\times$ length) is dimensionally $[L]^2$

Table 1.5: FUNDAMENTAL DIMENSIONS	
Quantity	Symbol
Length	[L]
Mass	[M]
Time, duration	[T]
Electric current	[I]
Thermodynamic temperature	[Θ]
Amount of substance	[N]
Luminous intensity	[J]

The dimensions of any derived quantity is written as product of powers of the dimensions of the base quantities. In general the dimension of any quantity Q is written in the form of a dimensional product,

$$\dim Q = L^{\alpha} M^{\beta} T^{\gamma} I^{\delta} \Theta^{\epsilon} N^{\zeta} J^{\eta}$$

where the exponents α , β , γ , δ , ϵ , ζ , and η , which are called the **dimensional exponents**.

In this type of representation, the magnitudes are not considered. Thus, a change in velocity, initial velocity, average velocity, final velocity, and speed are all equivalent. Table 1.5 shows some derived dimensions.

Table 1.6: SOME IMPORTANT DERIVED DIMENSIONS			
Quantity	Dimension	Quantity	Dimension
Velocity	$[LT^{-1}]$	Area	$[L^2]$
Acceleration	$[LT^{-2}]$	Volume	$[L^3]$
Force	$[MLT^{-2}]$	Pressure	$[ML^{-1}T^{-2}]$
Work or Energy	$[ML^2T^{-2}]$	Period	[T]
Power	$[ML^2T^{-3}]$	Frequency	$[T^{-1}]$

1.9.1 Some Terms Used With Dimensions: There are few terms that are used in dimensional analysis, which are

A. Dimensional variables: The physical quantities which have the dimensions of variable magnitude are called Dimensional variables. (e. g force, energy, acceleration etc.)

B. Dimensional constants: The physical quantities which have the dimensions but are constant in magnitude are called Dimensional constants. (e. g speed of light, planck's constant, gravitational constant etc.)

C. Dimension-less variables: The physical quantities which have no dimensions but changing magnitude are called dimension-less variables. (e. g plane angle, solid angle, strain etc.)

D. Dimension-less constants: The physical quantities which have no dimensions but having constant magnitude are called dimension-less constants. (e. g pure numbers, the number π etc.)

1.9.2 Dimensional Formula: The expression which shows how and which of the base quantities represent the dimensions of a physical quantity is called the dimensional formula of the given physical quantity. For example, the dimensional formula of the volume is $[M^0 L^3 T^0]$, and that of speed or velocity is $[M^0 L T^{-1}]$. Similarly, $[M^0 L T^{-2}]$ is the dimensional formula of acceleration.

1.9.3 Dimensional Equation: An equation obtained by equating a physical quantity with its dimensional formula is called the dimensional equation of the physical quantity. Thus, the dimensional equations are the equations, which represent the dimensions of a physical quantity in terms of the base quantities. For example, the dimensional equations of volume $[V]$, speed $[v]$, force $[F]$ and mass density $[\rho]$ may be expressed as

$$[V] = [M^0 L^3 T^0], [v] = [M^0 L T^{-1}], [F] = [ML T^{-2}], [\rho] = [ML^{-3} T^0]$$

The dimensional equation can be obtained from the equation representing the relations between the physical quantities.

1.9.4 Advantages of Dimensional Analysis: Using the methods of dimensions called dimensional analysis, we can check the correctness of the equation and also its derivation.

A. Checking the correctness of a physical equation: In order to show the rightness of the physical equation we have to show that the dimensions on both sides of the equation are same, without any regard to the form of the formula.

This is called principle of the dimensional homogeneity of a physical equation. (see example 1.6)

Limitation: Even if a physical relation is dimensionally correct, it doesn't prove that the relation is physically correct. Thus, a dimensionally correct equation need not be actually an exact (correct) equation, but a dimensionally wrong (incorrect) or inconsistent equation must be wrong.

B. Deriving a possible formula: Dimensional analysis can be used to derive a possible formula, but the success of this method depends upon the correct guessing of various factors on which the physical quantity depends. (see example 1.7)

Limitation: 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.

Example 1.6

DIMENSIONAL FORMULA FOR DRAG FORCE

Using the dimension analysis to find the correct relation

$$(a) \quad F = \frac{mv^2}{r^2} \quad \text{or} \quad (b) \quad F = \frac{mv^2}{r}$$

GIVEN

Dimensions of force ' F ' = $[M^1L^1T^{-2}]$, Dimensions of mass ' m ' = $[M^1]$
 Dimensions of velocity ' v ' = $[L^1T^{-1}]$ & Dimensions of radius ' r ' = $[L^1]$

REQUIRED

Correct relation for force ' F ' = ?

SOLUTION

For the equation to be correct the principle of dimensional homogeneity of physical equation suggest that the dimensions on the left hand side of the equation must be equal to the dimensions on the right hand side.

(a) Dimensions on the right hand side (R.H.S) of the equation

$$\text{R.H.S} = [M^1L^1T^{-2}] \quad \text{--- ①}$$

Whereas the dimensions on the left hand side (L.H.S) of the equation

$$\text{L.H.S} = \frac{[M^1][L^1T^{-1}]^2}{[L^1]^2} \quad \text{or} \quad \text{L.H.S} = \frac{[M^1][L^2][T^{-2}]}{[L^2]}$$

$$\text{L.H.S} = [M^1][L^{2-2}][T^{-2}]$$

$$\text{L.H.S} = [M^1L^0T^{-2}] \text{ — (2)}$$

from Equation 1 and 2 it is clear that

$$\dim [] \text{ R.H.S} \neq \dim [] \text{ L.H.S}$$

$$F = \frac{mv^2}{r^2} \text{ is not a dimensionally correct relation}$$

Answer

(b) Dimensions on the right hand side (R.H.S) of the equation

$$\text{R.H.S} = [M^1L^1T^{-2}] \text{ — (3)}$$

Whereas the dimensions on the left hand side (L.H.S) of the equation

$$\text{L.H.S} = \frac{[M^1][L^1T^{-1}]^2}{[L^1]} \quad \text{or} \quad \text{L.H.S} = \frac{[M^1][L^2][T^{-2}]}{[L^1]}$$

$$\text{L.H.S} = [M^1][L^{2-1}][T^{-2}]$$

$$\text{L.H.S} = [M^1L^1T^{-2}] \text{ — (4)}$$

from Equation 3 and 4 it is clear that

$$\dim [] \text{ R.H.S} = \dim [] \text{ L.H.S}$$

hence $F = \frac{mv^2}{r}$ is a dimensionally correct relation

Answer

Assignment 1.6

FORMULA FOR TIME PERIOD

Show that the equations (a) $v_f = v_i + at$ (b) $S = v_it + \frac{1}{2}at^2$ are dimensionally correct.

Example 1.7

DIMENSIONAL FORMULA FOR DRAG FORCE

When a solid sphere moves through a liquid, the liquid opposes the motion with a force F . The magnitude of F depends on the coefficient of viscosity η (having dimensions $\eta = [M^1 L^{-1} T^{-1}]$) of the liquid, the radius r of the sphere and the speed v of the sphere. Assuming that F is proportional to different powers of these quantities, guess a formula for F using the method of dimensions.

GIVEN

Dimensions of coefficient of viscosity ' η ' = $[M^1 L^{-1} T^{-1}]$

Dimensions of radius ' r ' = $[L^1]$

Dimensions of velocity ' v ' = $[L^1 T^{-1}]$

Dimensions of force ' F ' = $[M^1 L^1 T^{-2}]$

REQUIRED

Possible formula for drag force ' F ' = ?

SOLUTION

Let the drag force depends upon coefficient of viscosity ' η ', radius ' r ' and velocity ' v ' by the following equation

$$F_D \propto \eta^a r^b v^c \quad \text{or} \quad F_D = k \eta^a r^b v^c \quad \text{--- (1)}$$

Where k is constant of proportionality, now putting appropriate dimensions

$$[M^1 L^1 T^{-2}] = [M^1 L^{-1} T^{-1}]^a [L^1]^b [L^1 T^{-1}]^c$$

$$[M]^1 [L]^1 [T]^{-2} = [M]^a [L]^{-a+b+c} [T]^{-a-c}$$

Comparing the powers of similar physical quantities

For M	For T	For L
$[M]^1 = [M]^a$	$[T]^{-2} = [T]^{-a-c}$	$[L]^1 = [L]^{-a+b+c}$
$a = 1$	$-a - c = -2$	$-a + b + c = 1$
	as $a = 1$	as $a = 1$ and $c = 1$
	$-1 - c = -2$	$-1 + b + 1 = 1$
	$-c = -2 + 1$	$b = 1$
	$-c = -1$	
	$c = 1$	

putting values of a, b and c in equation 1 we get

$$F_D = kh^1 r^1 v^1$$

$$F_D = khrv$$

Dimension analysis does not give information about the value of constant, however from experiment we know that this constant is 6π .

or

$$F_D = 6\pi hrv$$

Answer

Assignment 1.7

FORMULA FOR TIME PERIOD

Find an expression for the time period ' T ' of a simple pendulum. The time period ' T ' may depend upon (i) mass ' m ' of the bob of the pendulum, (ii) length ' l ' of pendulum, (iii) acceleration due to gravity ' g ' at the place where the pendulum is suspended.

$$T = 2\pi \sqrt{\frac{l}{g}}$$

KEY POINTS

Physics: The study of the physical world in specific and physical universe in general.

System International (SI): System of units is adopted specifically by the science community for measurement of physical quantities. The SI units consists of seven fundamental units from which all the units for other physical quantities developed called derived units.

Least count or resolution: The smallest increment measurable by measuring instrument.

Error: The doubt that exists about the result of any measurement.

Uncertainty: The quantification or magnitude of error or doubt in measurement.

Precision: The degree of exactness with which a measurement is made and stated.

Accuracy: The closeness of a measured value to the actual value of the measured quantity.

Significant figures: In any measurement the number of accurately known digits and first doubtful digit.

Dimension: Expressing a physical quantity in terms of base physical quantities (by using special symbols). Dimensions of a physical quantity help to understand its relation with base physical quantities.

EXERCISE

MULTIPLE CHOICE QUESTIONS

Choose the best possible answer

- 1 What is the radian measure between the arms of watch at 5:00 pm?
A. 1 radian B. 2 radian C. 3 radian D. 4 radian
- 2 $1^\circ =$ _____
A. 0.01745 radian B. 1 radian C. 3.14 radian D. 2π radian
- 3 The metric prefix for 0.000001 is
A. hecto B. micro C. deca D. nano
- 4 Which of the following is the CORRECT way of writing units?
A. 71 Newton B. 12 $\mu\text{p s}$ C. 8 Kg D. 43 kg m^{-3}
- 5 A student measures a distance several times. The readings lie between 49.8 cm and 50.2 cm. This measurement is best recorded as
A. $(49.8 \pm 0.2) \text{ cm}$. B. $(49.8 \pm 0.4) \text{ cm}$.
C. $(50.0 \pm 0.2) \text{ cm}$. D. $(50.0 \pm 0.4) \text{ cm}$.
- 6 The percent uncertainty in the measurement of $(3.76 \pm 0.25) \text{ m}$ is
A. 4% B. 6.6% C. 25% D. 376%
- 7 The temperatures of two bodies measured by a thermometer are $t_1 = (20 \pm 0.5)^\circ\text{C}$ and $t_2 = (50 \pm 0.5)^\circ\text{C}$. The temperature difference and the error therein is
A. $(30 \pm 0.0)^\circ\text{C}$ B. $(30 \pm 0.5)^\circ\text{C}$
C. $(30 \pm 1)^\circ\text{C}$ D. $(30 \pm 1.5)^\circ\text{C}$
- 8 $(5.0 \text{ m} \pm 4.0\%) \times (3.0 \text{ s} \pm 3.3\%) =$
A. $15.0 \text{ ms} \pm 13.2\%$ B. $15.0 \text{ ms} \pm 7.3\%$
C. $15.0 \text{ ms} \pm 0.7\%$ D. $15.0 \text{ ms} \pm 15.3\%$
- 9 $(2.0 \text{ m} \pm 2.0\%)^3 =$
A. $8.0 \text{ m}^3 \pm 1.0\%$ B. $8.0 \text{ m}^3 \pm 2.0\%$
C. $8.0 \text{ m}^3 \pm 5.0\%$ D. $8.0 \text{ m}^3 \pm 6.0\%$

- 10 The number of significant figures in measurement of 0.00708600 cm are
A. 3 B. 4 C. 6 D. 9
- 11 How many significant figures does $1.362 + 25.2$ have?
A. 2 B. 3 C. 5 D. 8
- 12 Compute the result to correct number of significant digits
 $1.513 \text{ m} + 27.3 \text{ m} =$
A. 29 m B. 28.8 m C. 28.81 m D. 28.813 m
- 13 If 7.635 and 4.81 are two significant numbers. Their multiplication in significant digits is:
A. 36.72435 B. 36.724 C. 36.72 D. 36.7
- 14 The precision of the measurement 385,000 km is
A. 10 km B. 100 km C. 1000 km D. 1000000 km
- 15 $[M^0 L^0 T^0]$ are dimension of
A. strain B. refractive index C. magnification D. All of these
- 16 The dimensions of torque are
A. $[MLT]$ B. $[M^2 L^2 T]$ C. $[ML^2 T^{-2}]$ D. $[ML^2 T^2]$

CONCEPTUAL QUESTIONS

Give a short response to the following questions

- 1 For an answer to be complete, the units need to be specified. Why?
- 2 What are the advantages of using International System of Units (SI)?
- 3 How many radians account for circumference of a circle? How many steradians account for circumference of a sphere?
- 4 What is least count error? How can least count error be reduced?
- 5 Why including more digits in answers, does not make it more accurate?
- 6 What determines the precision of a measurement?
- 7 If two quantities have different dimensions, is it possible to multiply and/or divide. Can we add and/or subtract them?

- 8 The human pulse and the swing of a pendulum are possible time units. Why are they not often used?
- 9 If an equation is dimensionally correct, is that equation a right equation?

COMPREHENSIVE QUESTIONS

Give extended response to the following questions

- 1 Define Physics? Explain the scope and importance of physics in science, technology and society?
- 2 What is system of units? In SI what is meant by base, derived and supplementary units?
- 3 What conventions are used in SI to indicate units?
- 4 What are errors? Differentiate between systematic and random errors?
- 5 What is uncertainty in measurement? explain the propagation of uncertainty in addition, subtraction, multiplication and division?
- 6 What are significant figures? What are the rules for determining significant figures in the final result after addition, subtraction, multiplication and division?
- 7 Differentiate between precision and accuracy in the measurement.
- 8 What is meant by dimensions of physical quantities? What are limitations and applications of dimensional analysis?

NUMERICAL QUESTIONS

- 1 A circular pizza into 3 equal parts, one piece of pizza is taken out. Estimate the degree measure of the single piece of pizza and convert the measure into radians. What is the radian measure of the angle of the remaining part of pizza?
 $(4\frac{\pi}{3}\text{rad}=4.19\text{rad} \ \& \ 2\frac{\pi}{3}\text{rad}=2.09\text{rad})$
- 2 The length of a pendulum is (1.5 ± 0.01) m and the acceleration due to gravity is taken into account as $(9.8 \pm 0.1) \text{ m s}^{-2}$. Calculate the time period of the pendulum with uncertainty in it.
 $(2.5 \pm 0.8 \%)$
- 3 Determine the area of a rectangular sheet with length $(l \pm \Delta l) = (1.50 \pm 0.02)$ m and width $(w \pm \Delta w) = (0.20 \pm 0.01)$ m. Calculate the area $(A \pm \Delta A)$.
 $(0.30 \text{ m}^2, \pm 0.02 \text{ m}^2)$

- 4 Calculate the answer up to appropriate numbers of significant digits

(a) $246.24 + 238.278 + 98.3$

(b) $1.4 \times 2.639 + 117.25$

(c) $(2.66 \times 10^4) - (1.03 \times 10^3)$

(d) $(112 \times 0.456) / (3.2 \times 120)$

(e) 168.99×9

(f) $1023 + 8.5489$

(a) 582.8 , (b) 120.9, (c) 2.56×10^4

, (d) 0.13 , (e) 2000 & (f) 1032

- 5 Calculate the answer up to appropriate numbers of significant digits

(a) The ratio of mass of proton ' m_p ' to the mass of electron ' m_e '

$$\frac{m_p}{m_e} = \frac{1.67 \times 10^{-27} \text{ kg}}{9.1096 \times 10^{-31} \text{ kg}}$$

(b) The ratio of charge on electron ' q_e ' to mass of electron ' m_e '

$$\frac{q_e}{m_e} = \frac{1.6 \times 10^{-19} \text{ C}}{9.1096 \times 10^{-31} \text{ kg}}$$

(a) 1.83×10^3 & (b) $1.8 \times 10^{11} \text{ C/kg}$

- 6 Find the dimensions of

(a) planck's constant ' h ' from formula $E = hf$

Where E is the energy and f is frequency.

(b) gravitational constant ' G ' from the formula $F = G \frac{m_1 m_2}{r^2}$

Where ' F ' is force, ' m_1 ' and ' m_2 ' are masses of objects and ' r ' is the distance between centers of objects.

(a) $[M^1 L^2 T^{-1}]$ & (b) $[M^{-1} L^3 T^{-2}]$

- 7 Show that

(a) $KE = \frac{1}{2} mv^2$ and (b) $PE_g = mgh$

are dimensionally correct.