Chapter No: 1

PHYSICAL QUANTITIES AND MEASUREMENT

Q#1: Define Physics. What are Physical quantities? Explain how physics is based on physical quantities. What are the components of physical quantities?

Ans: Physics, derived from the Greek words "phusikos" (meaning natural) and "physis" (meaning nature), is fundamentally the study of nature. In current form of physics we study physical properties of non-living things present in nature.

Definition:

The branch of science that studies matter, energy, space, and time, along with how they interact and connect with each other.

Physical Quantities are **defined** as those quantities that we can measure, and laws of physics can be expressed in terms of the relationship among these quantities. Some examples of physical quantities are mass, length, time, force, speed, velocity etc.

For us to reach at moon and other planets, we need the measurement of distances, speeds and time etc. Similarly, to build a house we need measurements of area of place and amounts of required materials. This essence of measurement is the cornerstone of physics, which shows that physics is based on physical quantities. They help us to understand and describe the world around us.

Components of physical quantities:

There are two essential components of a physical quantity, numerical magnitude and unit. **Numerical magnitude** refers to a numerical value or a number which represents the size of quantity, while **unit** is standard of measurement for quantity. For example, if the height of a person is 1.4 meters then 1.4 is numerical magnitude and meter is the unit.

Q#2: Differentiate between Physical and Non-Physical quantities.

Ans:

Physical Quantities	**Non-Physical quantities**
The quantities which can be measured are called physical quantities.	Non measureable quantities are called non-physical quantities.
They have a numerical magnitude and a unit.	They can have a numerical magnitude but not a unit, because there is no standard for them.
Examples: Length, mass, time, speed and force etc. are examples of physical quantities	**Examples:** Mathematical numbers, hate, smell, feelings and emotions etc. are non-physical quantities

Q#3: What is SI? Name SI base quantities and their units?

Ans: International System of Units:

Scientist adopted an international system of units (SI) at General Conference on Weights and Measures held near Paris, France in 1960. In this system seven quantities were chosen as basic quantities. The units of these quantities are defined and they are known as Base units, from which all other

Base Quantity	**SI Base Unit**	**Symbol of SI Unit**
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

units are derived from these base units.

The seven basic physical quantities, their SI base units and symbols are given in table.

Q#4: Distinguish between base and derived physical quantities.

Ans:

Base Quantities	Derived Quantities
Limited number of physical quantities that are used to express other quantities are called base quantities.	The physical quantities that are formed by the combination i.e. multiplication and division of base quantities are called derived quantities
These are seven in number.	These are multiple.
Examples: Length, mass, time, electric current, temperature, amount of substance and intensity of light.	**Examples:** Speed, area, volume , force, density, work and momentum etc.

Q#5: Differentiate between base and derived units.

Ans:

Base Units	Derived Units
Units of base quantities are called base units.	The units of derived quantities are called derived units.
As base quantities are seven so base units are also seven.	These are formed by combination of base units and are multiple.
Examples: Base units of Length, mass and time are meter, kilogram and second respectively.	**Examples:** Derived units of speed, area, volume, force are m/s, m^2, m^3 and newton respectively.

Note: The examples of units given above are SI units, there can be other units of physical quantities in other system of units obtained by multiplying them with multiples and submultiples of 10.

Q#6: How would you represent unit of force and pressure in terms of base units?

Ans: Derived units in terms of base units are obtained by solving formulas of derived quantities using base units.

Force is given as,

$$F = ma$$

$$F = kg \times ms^{-2} = kgms^{-2}$$

Above equation gives SI unit of force in terms of base units. As N (newton) is also SI unit of force, so it also proves that N = $kgms^{-2}$.

Similarly, pressure is given as

$$P = \frac{F}{A} = \frac{kgms^{-2}}{m^2} = kgm^{-1}s^{-2}$$

Which is also equal to Pa (pascal's) or N/m^2.

Derived quantity		S.I Unit	
Name	**Formula**	**Fundamental units**	**Special name**
Area	l x w	m x m= m^2	-
Volume	l x w x h	m x m x m= m^3	-
Velocity	d/t	m/s = ms^{-1}	-
Acceleration	$\frac{v_f - v_i}{t}$	$m/s^2 = ms^{-2}$	-
Density	m/V	$kg/m^3 = kgm^{-3}$	-
Momentum	mv	kg x ms^{-1}=$kgms^{-1}$	-
Electric charge	I × t	A × s = As	coulomb, C
Force	ma	kg × ms^{-2} = $kgms^{-2}$	newton, N
Work	Fd	$kgms^{-2} \times m = kgm^2s^{-2}$ or N×m = Nm	joule, J
Power	$\frac{W}{t}$	J/s = Js^{-1} = kgm^2s^{-3} =Nms^{-1}	watt, W
Frequency	$\frac{1}{T}$	$\frac{1}{s} = s^{-1}$ = Hz	hertz, Hz
Pressure	$\frac{F}{A}$	kg $ms^{-2}/m^2 = kgm^{-1}s^{-2}$ or $N/m^2 = Nm^{-2}$	pascal, Pa

Q#7: Differentiate between vector quantities and scalar quantities.
Ans:

Scalar Quantities	Vector Quantities
Those physical quantities which are completely described by their magnitude only are called scalar quantities or scalars.	Those physical quantities which are completely described by their magnitude as well as direction are called vector quantities or vectors.
The scalars can be added, subtracted, multiplied and divided by ordinary mathematical methods.	The vectors can be added, subtracted, divided and multiplied by graphical or geometrical method.
Examples: Speed, distance, temperature, energy, volume, power, electric current etc.	**Examples:** Force, velocity, acceleration, displacement etc. are the examples of vector quantities.

Q#7.1 Justify that displacement is a vector quantity while energy is a scalar quantity

Ans: **Displacement** is a vector quantity because it requires both **magnitude** (how far something has moved) and **direction** (in which direction it has moved) to be fully described. E.g. Imagine walking 5 meters north. Just saying 5 meters isn't enough information - you need to know you went north as well.

Energy is a scalar quantity because it only has a **magnitude** (how much energy there is). It doesn't have a direction. E.g., you can say an object has 10 Joules of thermal energy, but it doesn't make sense to specify a direction for thermal energy.

Q#8: How can we represent vectors symbolically?

Ans: Symbolically a vector can be represented by a bold letter (e.g. **F, P, S and a** etc.) or a letter with an arrow over it (e.g. $\vec{F}, \vec{P}, \vec{S}$ and $\vec{a}$ etc). Letters can be either small or capital.

Q#9: Explain graphical representation of vectors?

Ans: **Graphical Representation of Vector Quantities:**

Graph is a pictorial way to present physical quantities or relationship of physical quantities with each other.

Graphically, a vector is represented by an arrow where the length of arrow shows the magnitude (under certain scale) and the arrow head shows the direction of the vector.

The direction of the vector can either be represented by **"Geographical" Coordinate System (NEWS)"** or **"Cartesian Coordinate System**".

Q#9.1 Define coordinate system and Cartesian coordinate system. What is reference point?

Ans: A **coordinate system** is a structured way to represent the position of points using ordered pairs of reference coordinates called axis.

Cartesian coordinates system or rectangular coordinate system consists of perpendicular reference coordinates called x axis (horizontal coordinate) and y axis (vertical coordinate) in two dimensions. The point where these coordinates intersect each other is called **reference point** or **origin.** The coordinate system from which points are located is called **reference frame**.

Steps to represent a vector:

The following method is used to represent a vector.

1. Draw a coordinate system.
2. Select a suitable scale.
3. Draw a line in the specified direction. Cut the line equal to the magnitude of the vector according to the selected scale.

4. Put an arrow in the direction of the vector.

Example:

We can explain the graphical representation of a vector with the help of an example.

Suppose a bus has moved 25.5 km towards south of east (direction).

1. First of all, draw the Cartesian coordinate system and label east on x-axis, west on negative x-axis, north on y-axis and south on negative y-axis.
2. Now, we select a **suitable scale** i.e.,
   Let,
   5km= 1cm
   Then
   25.5km = 5.1 cm
3. Specify the **direction** by placing protractor on the origin with the 90˚ mark on the south axis and 0˚ mark on the east axis. Measure 35˚ angle (direction) from the east axis toward the south axis.
4. Draw the line at measured angle of 35˚(direction) and cut the line at 5.1 cm (magnitude).

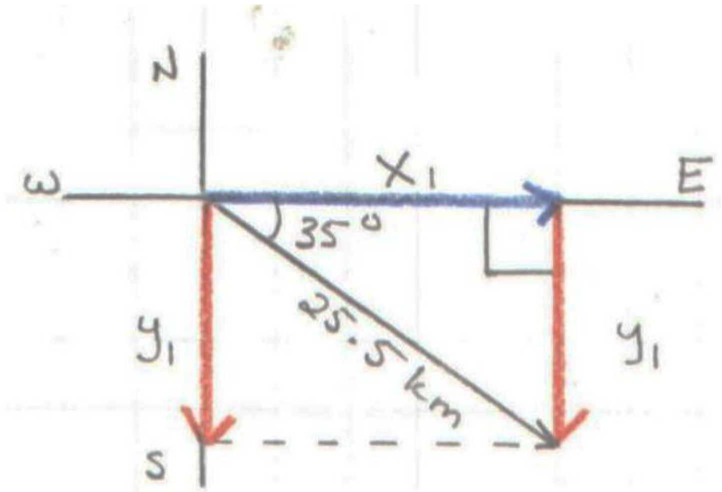


Figure 1

Q#10 Define resultant vector. How can we obtain resultant vector by addition of Parallel and Nom-Parallel vectors?

Resultant Vector:

A resultant vector is the vector sum of two or more vectors and it represents the combined effect of added vectors. Resultant vector can obtained by addition of vectors.

Addition of Parallel Vectors

The addition of vectors is simple for parallel vectors. In case of like parallel vectors, add the magnitude of vectors and in case of unlike parallel vectors, subtract the magnitude of vectors.

Addition of Non – Parallel Vectors:

When the vectors are non-parallel that the angle between them is between 0^{O} and 180˚, then for addition of such vectors, we apply a special method called Head to tail rule in order to find their resultant vector.

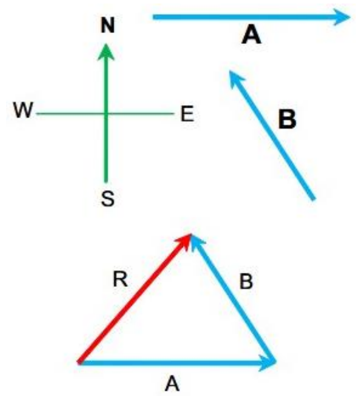


Figure 2

Head to tail rule:

According to head to tail rule, we will get a resultant vector by drawing the representative lines of the given vectors in such a way that the tail of first vector **A** joins with the head of last vector **B**, then **resultant vector R** is obtained by joining the tail of first force vector to the head of last one. This method of adding forces is known as "head to tail rule" of addition of forces.

Note: Order of vectors does not affect the resultant vector. The resultant vector will have same magnitude and direction as before. Vector addition obeys commutation property.

Q#11 Explain addition of perpendicular vectors.

Ans: Consider vector **A** along x axis and **B** along y axis, which are perpendicular to each other. They are added by placing vector **B** over head of vector **A** keeping same scale. The resultant vector **R** is obtained by joining tail of vector **A** with head of vector **B.** The **magnitude of resultant vector R** in this case can be obtained using Pythagoras theorem as vectors are forming a right angle triangle. According to Pythagoras theorem,

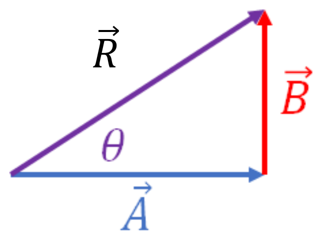


Figure 3

$$(Hyp)^2 = (Perp)^2 + (Base)^2$$
$$R^2 = B^2 + A^2$$
$$R = \sqrt{B^2 + A^2} \ldots\ldots\ldots\ldots(1)$$

The direction of the resultant vector can be obtained as follow,

$$\tan\theta = \frac{Perp}{Base}$$
$$\theta = \tan^{-1}\left(\frac{Perp}{Base}\right)$$
$$\theta = \tan^{-1}\left(\frac{B}{A}\right)\ldots\ldots\ldots\ldots(2)$$

θ is angle of resultant vector **R** with x axis or vector **A.**

Q#12: What is standard form or scientific notation?

Ans: **<u>Scientific Notation:</u>**

Scientific notation is a concise way of writing numbers that are too big or too small to be easily written using power of 10 with some rules. A number is written in standard form if a number greater than or equal to 1 and less than 10 is multiplied with some integral power of 10.

<u>Explanation:</u>

To be more specific, if a number is written in form $\mathbf{A \times 10^n}$ and A is greater than or equal to 1 and less than 10, and n is an positive integer (when **A** is smaller than given number) or negative integer (when **A** is larger than given number) then it will be in standard form.

<u>Example:</u>

The mass of moon is approximately 70,000,000,000,000,000,000,000kg, which in standard form or scientific notation is 7×10^{22} kg.

Similarly, the diameter of atomic nucleus is about 0.000000000000001m, which in standard form or scientific notation is 1×10^{-14} m.

Note: See pg 28 and 29 on book, how to convert a large or a small number to standard form and rules to perform addition, subtraction, multiplication and divisions of numbers in standard form.

Q#13: What are prefixes? What is the use of prefixes in measurements? Explain with examples.

Ans: **<u>Prefixes:</u>**

Pre means before and fixes means fixed values. So "**prefixes** are fixed values in power of 10 named with specific words, and are used before units of physical quantities".

Prefixes with positive power of 10 are called **multiples** while with negative power of 10 are called **submultiples.**

Prefixes are used before a standard unit to show how much larger

Multiples	Prefix	Symbol	Sub-multiples	Prefix	Symbol
10^{18}	Exa	E	10^{-1}	deci	d
10^{15}	Peta	P	10^{-2}	centi	c
10^{12}	Tera	T	10^{-3}	milli	m
10^{9}	Giga	G	10^{-6}	micro	μ
10^{6}	Mega	M	10^{-9}	nano	n
10^{3}	Kilo	k	10^{-12}	pico	p
10^{2}	Hecto	h	10^{-15}	femto	f
10^{1}	Deca	da	10^{-18}	atto	a

or smaller the given physical quantity is as compared to the standard unit of that quantity.

Prefixes make standard form to be written even more easily. Large numbers are simply written in more convenient prefix with units.

Examples:

200 m/s in standard form is 2×10^2 m/s, in prefix form it can be written as 2 hm/s, where h represents hecto.

Similarly, if 5,000,000 m is to be written with suitable prefix then it will be 5 Mm, where M represent Mega, but it can also be written with any other prefix to have a specific order of magnitude. For example, in kilometres it will be 5,000 km.

Express the following measurement

(i) 300 milligrams in grams.
(ii) 0.0045 kilometers to meters.
(iii) 1500 microseconds in milliseconds

Q#13.1 Show that prefix micro is thousand times smaller than prefix milli by making a relationship between them using concept or ratio

Ans: As we know that

$m = 10^{-3}$ and $\mu = 10^{-6}$

ratio between milli and micro will be given as

$$\frac{m}{\mu} = \frac{10^{-3}}{10^{-6}}$$

$$\frac{m}{\mu} = 10^{-3+6}$$

$$\frac{m}{\mu} = 10^{+3}$$

$$m = 10^{+3} \times \mu$$

$$\mu = \frac{m}{10^{+3}} = \frac{m}{1000}$$

Above equation shows that micro is thousand times smaller than prefix milli.

Q#14: Define error. Differentiate between systematic errors and random errors. How can we reduce them?

Error:

The difference in actual value and measured value is called error in measurement.

Systematic Errors	**Random Errors**
Errors caused by faulty equipment or mistakes made by individuals during the measurement process are systematic errors	Unpredictable and uncontrollable error in a measurements whose value change on every repetition is called random error.
They are predictable and occur in one direction, either positive or negative.	Can be positive one time and negative next time.
Examples: Zero error, unsymmetrical divisions on a bent meter rule and errors due to carelessness are examples of systematic errors.	**Examples:** Limitations of techniques and tools, random change in environmental conditions like wind speed and air pressure are examples of random errors.
They can be reduced by elimination of zero error and taking reading correctly.	They can be reduced by repeating measurement multiple times and taking average, using more precise instrument and maintaining consistent lab conditions.

Q#14.1 How can making multiple readings help in reducing the impact of random error?

Ans: When we take lots of measurements, these random errors start to balance each other out. The positive ones cancel out the negative ones, and the result becomes more accurate. So, averaging our measurements helps make our data more precise and reliable.

Q#15 Define least count of an instrument. Explain its importance.

Ans: Least count of an instrument is defined as the smallest difference in a reading that an instrument can measure or smallest measurement that can be taken accurately with instrument.

For example, in a meter rule there are 10 small divisions within a centimetre, its least count will be given as

$$\mathrm{L.C} = \frac{1\ \mathrm{cm}}{10} = 0.1\ \mathrm{cm} = 0.1 \times 10\ \mathrm{mm} = 1\mathrm{mm}$$

The least count of a measuring instrument is crucial for understanding its precision and accuracy. As it determines the smallest measurement that can be taken accurately with the instrument, it helps the user to know when it is useable and when it is not useable. A smaller least count indicates higher precision and the ability to measure finer differences, contributing to more accurate scientific experiments and observations e.g. while measuring sizes of mechanical parts of machines, it requires very precise and accurate measurements.

Q#16 Differentiate between precision and accuracy.

Ans:

Precision	**Accuracy**
Precision in an instrument is its ability to provide similar values which are close to each other when measurements are repeated.	Accuracy of an instrument or experiments refers to its ability to provide measured values close to true or accepted values.
It depends on the least count of an instrument and random errors. Smaller the least count, more precise are the measurements.	It depends on both systematic and random errors present. Smaller the errors, greater is the accuracy. Least count has little effect on accuracy.
Example: A screw gauge with smaller least count (0.01mm) is more precise than vernier caliper having larger least count (0.1mm).	**Example:** A screw gauge having greater zero error than vernier caliper will be less accurate than vernier caliper.
An instrument with greater precision is reliable and measurement will be reproducible.	An accurate experiment shows absence of errors.

Q#17 What is meter rule? What is the least count and maximum length of meter rule?

Ans: A meter rule is a tool commonly used for measuring lengths of objects or distances between points from 1mm upto few meters.

- The least count of a typical meter rule is 1 mm.
- Smallest division on meter rule is 1 mm.
- Maximum length of metre rule is 1 m, which is equal to 100 cm or 1000 mm.
- There are 10 small divisions in 1 cm called millimetres.

Q#18 How to take measurement using meter rule? What sort of errors are possible while taking measurement with metre rule and how can we avoid them?

Ans: To accurately measure the length of an object, align it along a ruler, start from zero mark, keep your eye directly perpendicular at ending point then ending mark will give the length of object.

Possible errors:

i) Systematic errors

a) Zero error: In a broken ruler or a ruler where 0 mark is not correctly visible, to avoid zero error, object is not started from 0 mark but from a mark which is correctly visible and this mark is subtracted from ending mark to obtain correct length of object).

b) Parallax error: It appears when reading is observed from an angle other than 90 degrees, it can make readings seem misaligned. To avoid this error, eye is kept directly at 90 degrees of angle.

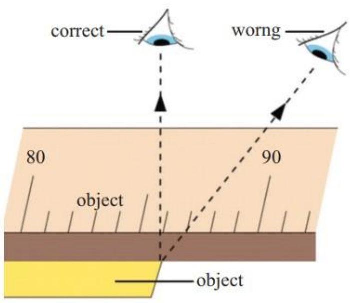


Figure 4

ii) Random error

It can arise due to measuring limitation of meter rule such as least count. Reading can lie between two digits leading to doubtful measurement. To avoid this error, we use more precise instruments, such as vernier caliper or screw gauge.

Q#19 What is measuring tape? What are its advantages over metre rule?

Ans: Measuring tape is a flexible ruler used to measure larger distance such as few feets to several meters. The least count is same a meter rod i.e. 1 mm. It is commonly used in sewing by tailors, measurements of lands, carpentry and construction works.

Following are some reason that we prefer measuring tape over meter rod.

i. Measuring tapes are mostly made of flexible materials like, metal, fiberglass or cloth which allows them to bend around objects or curves.
ii. They are compact and easy to carry around.
iii. They are available in different lengths, ranging from few feet to over hundred feet, due to which they have greater measuring range.
iv. They are often more affordable considering the range of features and lengths available.

But in some special cases meter rod is preferred e.g. in labs where we need hard and straight measuring tools, when we need more durability and consistency etc.

Note: While measuring with Measuring tape, we can have same sort of errors that can occur in meter rod.

Q#20 What is Vernier calliper. Describe its construction, use and least count.

<u>Vernier Calliper:</u>

A device used to measure a fraction of smallest main scale division by sliding another scale i.e. vernier scale over it is called vernier calliper.

It is used when we need accuracy upto 0.1 mm or even 0.05 mm. It is used to measure thickness, diameters (inner and outer diameter of cylinders), width, depths of beakers and test tubes directly while radius and volumes indirectly using mathematical equations.

<u>Construction:</u>

There are following parts of vernier calliper

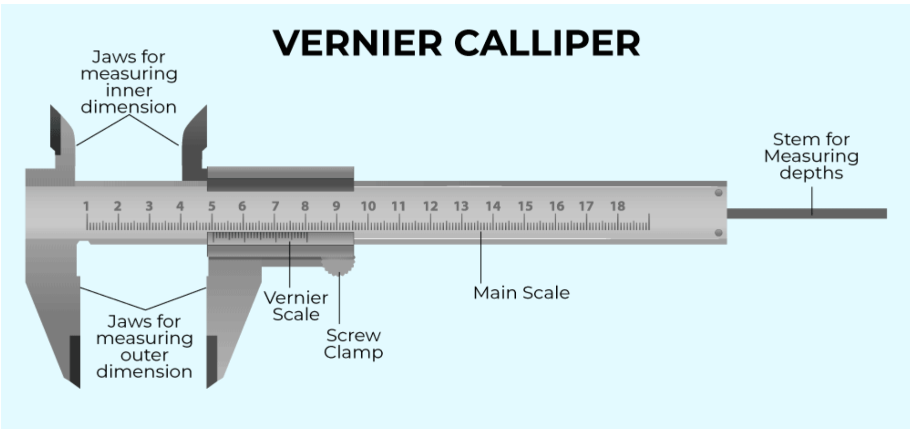


Figure 5

1. <u>Main Scale:</u>

A main scale which has markings of usually of 1mm each and it contains jaw on its left end called fixed jaw.

2. <u>Vernier Scale:</u>

A vernier (Sliding) scale which usually has 10 or 20 divisions. The vernier scale usually has length of 9 mm and is divided equally into 10 or 20 divisions. The separation between two lines on vernier scale is $\frac{9}{10}$ mm = 0.9 mm or $\frac{9}{20}$ mm = 0.45 mm. Vernier scale also contains a jaw on its left end called moveable jaw.

3. <u>Inside jaws</u>

Inside jaws lie on lower side of vernier calliper. They are used to calculate outer diameter/thickness of a cylinder or any object by placing it inside these jaws.

4. Outside Jaws

Outside jaws lie on upper side of vernier calliper. They are used to calculate inner diameter of a cylinder or inner length of a hollow cube by fixing them outside of these jaws.

5. Stem or Depth probe

Depth probe is fixed behind main scale and it is moveable. Depth of a beaker or a test tube can be calculated by inserted the probe inside the beaker or tube keeping it in exact vertical position.

Vernier Constant or Least Count:

Minimum length which can be measured accurately with the help of a vernier callipers is called vernier constant or least count of vernier callipers. The least count of vernier callipers is calculated by:

$$\text{Least count} = \frac{\text{Smallest division on main scale}}{\text{Total no. of divisions on vernier scale}}.$$

If the smallest main scale division is 1mm and vernier scale division has 10 divisions on it then the least count is:

$$\text{Least count} = \frac{1\text{mm}}{10}$$
$$= 0.1\text{mm} = 0.01\text{ cm}$$

Q#21 What is zero error in vernier calliper. How can we calculate and make zero error correction?

Ans: If zero mark of vernier scale does not coincide with zero mark of main scale upon closing the jaws without inserting any object then there is zero error in vernier calliper. It is a systematic error.

Types of Zero error

There are two types of zero errors.

a) Positive zero error and its calculation

If zero mark of vernier scale is on right side of zero mark of main scale then zero error is positive.

Figure below shows reading when jaws are closed and zero mark of vernier scale is on right side of main scale, which indicates positive zero error. The division which is exactly coinciding with any division of main scale will be noted and multiplied with least count to get value of zero error.

In this case,

Coinciding division of vernier scale = 9

Positive Zero error = 9 × 0.01 cm = +0.09 cm

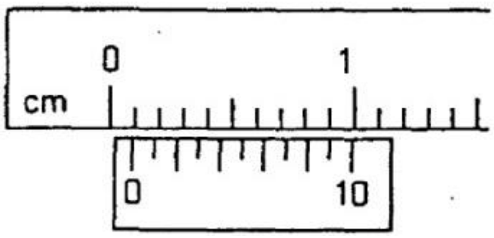


Figure 6

b) Negative zero error and its calculation

If zero mark of vernier scale is on left side of zero mark of main scale then zero error is negative.

Figure below shows reading when jaws are closed and zero mark of vernier scale is on left side of main scale, which indicates negative zero error. The division which is exactly coinciding with any division of main scale will be subtracted from 10 and multiplied with least count to get value of zero error.

In this case,

Coinciding division = 7

Zero error = - (10 – 7) × 0.01 cm = - 0.03 cm

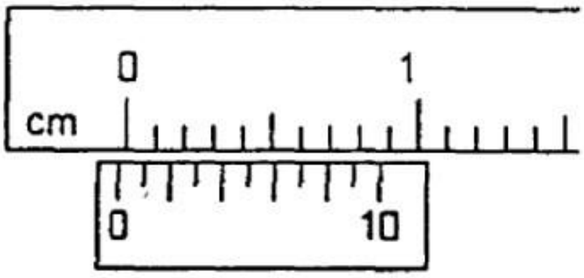


Figure 7

Zero error correction

Zero error correction is done mathematically by following formula.

Actual Reading = Reading on vernier calliper – (Zero error)

Q#22 Write down the working of vernier calliper in steps to calculate the inner diameter of a beaker.

1. Calculate and note the least count. Calculate zero error if any.
2. Fix the beaker on inside jaws and note the **Main scale reading** in cm which is behind zero of vernier scale. In above diagram 3.2 cm is main scale reading.
3. Note the vernier scale division which is coinciding with any division of main scale, multiplying it with least count in cm will give **vernier scale reading**. In this case, coinciding division is 4 and vernier scale reading is 4 × 0.01 cm = 0.04 cm.
4. Add main scale reading and vernier scale reading to get **vernier calliper reading**.

   vernier calliper reading = 3.2 cm + 0.04 cm = 3.24 cm
5. Perform zero error correction if any to get **actual reading**.

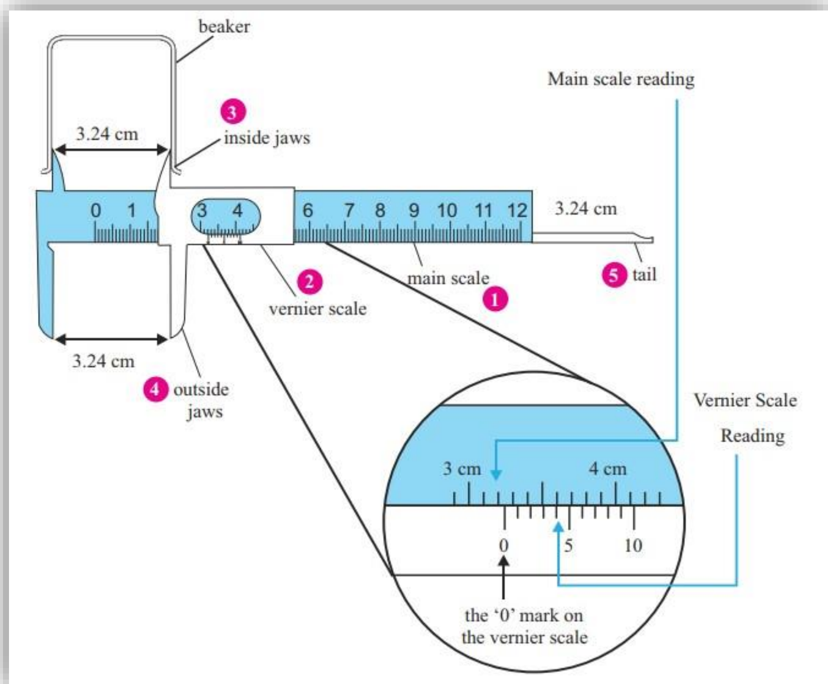


Figure 8

Q#23 What is screw gauge? Describe the use, construction and least count of Screw gauge.

Screw Gauge:

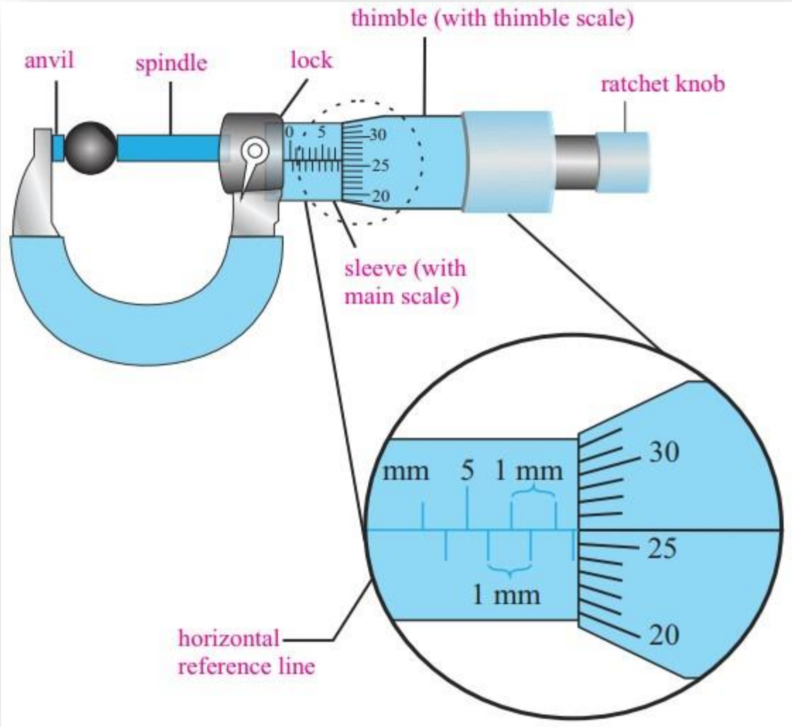
A device used to measure a fraction of smallest main scale division by rotatory motion of circular scale over it is known as screw gauge.

It is used when we need more precise and accurate measurements than vernier calliper. It can measure upto 0.01 mm. It is used to measure thickness of thin sheets, diameters, and width directly while radius and volumes indirectly using mathematical equations.

Construction:

It typically consists of

- A U-shaped metal frame with a solid metal stud on one end.
- Hollow cylinder (or sleeve) marked with a millimeter scale **(Main scale)** along an index line parallel to its axis. This cylinder is fixed and acts as a nut.
- A rotating thimble attached with circular scale, inside which there's a threaded spindle. Each complete rotation of the thimble moves the spindle 0.5 mm or 1mm along the index line. This movement is called **pitch** of the screw on the spindle, which is the distance between consecutive threads.
- A ratchet, used to close the gap between anvil and spindle



Least Count of Screw Gauge:

The minimum length which can be measured accurately by a screw gauge is called least count of screw gauge. The least count of screw gauge is found by dividing its **pitch** (pitch is the distance travelled by the circular scale on linear scale in one rotation) by the total number of circular scale division.

$$\text{Least count} = \frac{\text{Pitch of Screw Gauge}}{\text{no.of division on circular scale}}$$

If the pitch of the screw gauge is 0.5mm and the number of divisions on circular scale is 50 then

$$\text{Least Count} = \frac{0.5\text{ mm}}{50}$$

$= 0.01$ mm or

$= 0.001$ cm

Q#24 What is zero error in Screw gauge? How can we calculate and make zero error correction?

Ans: Zero Error:

If the zero mark on circular scale does not coincide with index line upon closing spindle and anvil without inserting object, then there is zero error in screw gauge.

Positive Zero Error:

If the zero of the circular scale remains below the index line then such zero error is called positive zero error.

In order to calculate positive zero error, multiply the division (which is coinciding with index line) with least count. In the given diagram

Coinciding division = 3

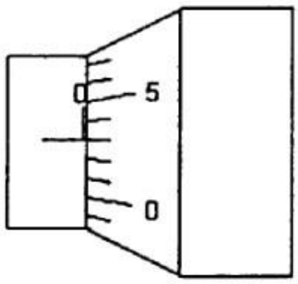


Figure 10 Positive Zero error

Zero Error = coinciding division × L.C = 3 × 0.01 mm = 0.03 mm

Negative Zero Error:

If the zero of the circular scale remains above the horizontal line of the linear scale then such zero error is called negative zero error.

In order to calculate negative zero error, subtract the coinciding division from total number of divisions on circular scale and multiply (which is coinciding with index line) with least count. In the given diagram,

Coinciding division = 48

Total divisions on circular scale = 50

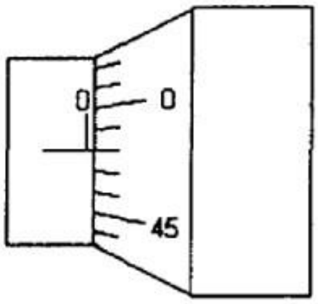


Figure 11 Negative Zero error

Negative Zero Error = - (Total divisions on circular scale – coinciding division) × L.C

= - (50 - 48) × 0.01 mm = - (2) × 0.01 mm = - 0.02 mm

Zero Error Correction:

If there is zero error, then for correct measurement, value of negative zero error is added and positive zero error is subtracted from the screw gauge reading. The general formula for zero error correction is given as

Actual Reading = Reading on screw gauge – (Zero error)

Q#25 Write down the working of vernier calliper in steps to calculate the diameter of a hard ball

Measurement with Screw Gauge:

Suppose we want to measure the diameter of a small sphere by using screw gauge we will use the following method;

i. Note the least count and zero error if any.
ii. Place the object between anvil and spindle and tight the sphere by rotating the ratchet clockwise until it starts clicking.
iii. Note the last visible reading in mm on linear scale, it will be **main scale** reading. In fig. 6 the main scale reading is 7.5 mm.
iv. Now note a division on circular scale which coincides with the index line of the main scale. Now multiply this division with the least count. It will be **circular scale reading.** In fig. 6,
    Coinciding circular scale division = 26
    Circular scale reading = 26 × L.C = 26 × 0.01 mm = 0.26 mm
v. Adding main scale reading and circular scale reading gives **screw gauge reading.**
    Screw gauge measurement = Main scale reading + Circular scale reading
    = 7.5 mm + 0.26 mm = 7.76 mm
vi. Perform zero error correction if any to get actual final reading, otherwise screw gauge reading will be actual final reading of diameter.

Q#26 What is a beam balance. Explain its working.

Ans: Beam balance is a mass measuring instrument being in use since the times of Romans and Greeks. It has a least count upto 0.1 g or 100 mg.

In a beam balance, the unknown mass is placed in one pan. It is balanced by putting known masses in the other pan.

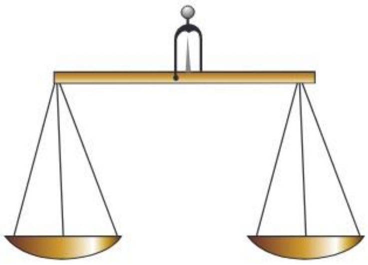


Figure 12 Beam Balance

Q#27 What is a physical balance. Explain its construction and working.

Ans: A physical balance is used in the laboratory to measure the mass of various objects by comparison. Least count of the physical balance may be as small as

0.01 g or 10 mg

<u>Construction and Working</u>:

It consists of a **beam** resting at the centre on a **knife edge**. The beam carries **scale pans** over the **hooks** on either side. **Levelling screws** at bottom are used to level plateform of physical balance and plumbline confirms if instrument is levelled or not. **Arrestment knob** is used to raise the beam (by rotating clockwise) or lower the beam (by rotating anticlockwise) on the knife edge. **Balancing screws** at beam sides are used to remove any zero error by setting the pointer at zero when beam is raised. **Unknown mass** is placed on the **left pan** when beam is at lowered position. Suitable **standard masses** are placed on **right pan** and beam is raised used knob. If not balanced on raising the beam then repeat process with different known masses.

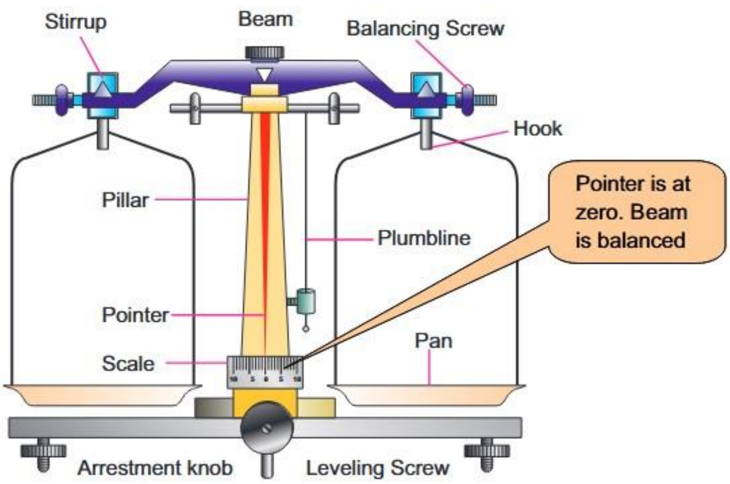


Figure 13 Physical Balance

Q#28 What electronic balance? Explain its construction and working.

Ans: Electronic balance is a digital mass measuring instrument with higher accuracy than beam balance and physical balance. It can measure upto 1mg or 0.001 g.

<u>Construction and Working:</u>

It has **levelling screws** used to level the instrument on surface, a digital meter which can show atleast 3 digits after decimal point, a pan where object with unknown mass is placed and a glass cover to avoid interference of air and dust.

Before measuring the mass of a body, it is switched ON and its reading is set to zero. Next place the object to be weighed. The reading on the balance gives you the mass of the body placed over it.

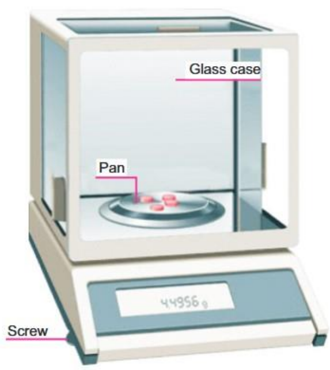


Figure 14 Electronic Balance

Q#21 Define volume? What are some common units to measure volume?

Ans: Volume is the quantity of space occupied by an object, and it is typically measured in cubic units.

The SI unit of volume is the cubicmeter (m^3), but this unit is often too large for everyday use. As a result, smaller units of cubic centimeters (cm^3) or milli litre and cubic decimetres (dm^3) or litre are commonly used for convenience.

Unit conversions:

<u>Cubic meter to Litre</u>

$1\ m^3 = 1000\ L$

<u>Cubic decimetre to Litre</u>

$1\ (dm)^3 = 1000 \times (10^{-1})^3\ L$

$1\ (dm)^3 = 1\ L$

<u>Cubic centimetre to Litre and millilitre</u>

$1\ (cm)^3 = 1000 \times (10^{-2})^3\ L$

$= 10^{-3}\ L$

$1\ (cm)^3 = 1\ mL$

Q#22 What is measuring cylinder or graduated cylinder? Write down the steps to find volume of an irregular shaped substance using measuring cylinder. What are precautions?

Ans:

- Measuring cylinder is a common lab instrument made of transparent glass or plastics used to measure volume of liquids, powdered substance and irregular shaped objects denser than water.
- It has a vertical scale in centimetres cube or millilitres.
- Least count is 1 cm^3 or 1 mL.
- Height of liquid inside cylinder represents volume.

Steps to measure volume of irregular shaped denser substance

- Insert some water in measuring cylinder and measure its volume, name it V_1.
- Insert the object inside water and measure volume again when it is completely immersed and name it V_2.
- Volume of object V will be obtained by subtracting V_1 from V_2.

$$V = V_2 - V_1$$

Precautions:

1. Position your eye at the same level as the liquid surface (meniscus) to avoid parallax errors.

2. Make sure object is completely immersed when you measure volume V_2.

3. Avoid formation of bubbles inside water.

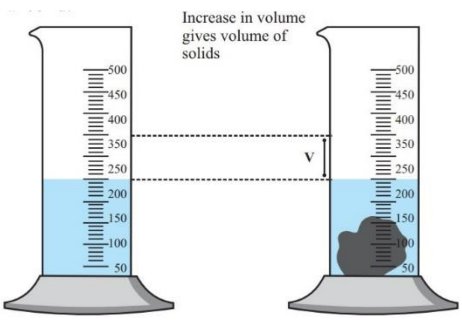


Figure 15 Measuring cylinder

Q#23: Discuss construction and use of devices used to measure time interval.

Ans:

Stopwatch:

Stopwatches are the devices used to measure time interval of any event. There are two types of stopwatches.

a) Mechanical/Analog Stopwatch:

- Mechanical watch has two circular dials. A large circular dial has a rotating hand which is used to measure seconds and a small circular dial which has a rotating hand which is used to measure minutes.
- It has a mechanical knob, by pressing it once watch starts and when pressed twice, watch stops. Hands are reset to zero if knob is pressed for some time.

Note: Least count of commonly used mechanical stopwatch is one-fifth of a second.

(b) Digital Stopwatch:

A digital clock is a type of clock with a digital display.

OR

Digital Stopwatch shows the time in the form of digits.

WORKING:

- There are two button. Pressing the left button starts the timer running, and pressing the button a second time stops it, leaving the elapsed time displayed.
- A press of the right button then resets the stopwatch to zero.
- The right button is also used to record split times or lap times. When the split time button is pressed while the watch is running, the display freezes, allowing the elapsed time to that point to be read, but the watch mechanism continues running to record total elapsed time.

Note: Least count of common digital stopwatch is $1/100^{th}$ of a second or 0.01 s.

Q#23.1: Differentiate between mechanical and digital stopwatch.

Mechanical Stopwatch	Digital Stopwatch
It is built up with a spring which stores energy when knob is pressed. This energy is used to run small gears	It Uses an electronic circuit with an **oscillator** that produces a very precise and stable time counting, and the elapsed time is displayed on a screen.
It does not require a battery and cannot have a memory.	It requires a battery to operate and have a memory of readings.
There are more chances of errors due to change in tension in string and friction in mechanical gears. Least count is usually 0.2s or 0.1s	it's very precise. It can show time in milliseconds (0.001 seconds) and there are less chances of errors.

Q#24: What is meant by the significant figures of measurement? What are the general rules to determine the significant figures in measurements?

Ans: Significant Figures:

The number of accurately known figures and the first doubtful figure in a measurement are known as significant figures.

Explanation:

There are two types of values, exact and measured. Exact values are those that are counted clearly. For example, while reporting 3 pencils or 2 books, we can indicate the exact number of these items.

On the other hand, values associated with measurements of any kind are uncertain to some extent. For example, if we want to measure the length of a pencil with an ordinary meter ruler having least count of 1mm and we note that the length of the pencil is greater than 67 mm and less than 68 mm. We can estimate that the length of the pencil is 67.5 mm. This length is accurate in mm upto 67, but the last fraction of mm has been guessed. There is a chance of error in the last figure. It is known as the doubtful figure.

General Rules For Significant Figures:

1. Non-zero digits are always significant. That is all the digits from 1 to 9 are significant. For example, the number of significant figures in 47.73 m is four.
2. Zero in between two significant digits is always significant. For example, the number of significant figures in 32.50063m is seven.
3. Zeros to the left of significant figures are not significant. For example, the number of significant figures in 0.00467m is three.
4. In scientific notation or standard form, the figures other than power of ten are all significant, for example mass of electrons is 9.11×10^{-31}kg. There are three significant figure in it
5. Zeros to the right of the significant figures in a decimal fraction are significant. For example, in 7.400 m there are four significant figures.
6. In non decimal or whole numbers, zeros on right are may be or may be not significant. It depends on least count of instrument.

   For example, in 800 kg we may have 1, 2 or even 3 significant figures. If least count is 100 kg then zeros on right will be non-significant and there will be 1 significant digit.

   If least count is 10 kg, then we write the number in standard form upto 2 significant figure i.e. 800 kg will be written as 8.0×10^2 kg. Similarly if least count is 1kg then 8.00×10^2 kg.

Q#24 What is rounding numbers? What are the rules and steps for rounding off whole numbers and decimal numners

Ans: The word rounding off means to finish something in a good or suitable way.
In physics and math, rounding off is act of approximating a number to a simpler form without loosing the accuracy

<u>Steps and rules for Rounding Off Whole numbers:</u>

1. **Identify the digit to be rounded**: Determine the digit in the place value you are rounding to. For example, if rounding to the nearest ten, you look at the ones e.g. in 78, 8 is in place of ones and 7 is in place of tens. If rounding to the nearest hundred, you look at the tens digit, and so on.
2. **Look at the next digit**: Examine the digit to the right of the one you're rounding to.
3. **Round up or down**: If the digit to the right is 5 or greater, increase the rounding digit by one e.g. in 79, we replace 7 by 8. If it's less than 5, leave the rounding digit unchanged e.g. in 74, 7 remains unchanged.
4. **Change all digits to the right to zero**: After rounding, change all the digits to the right of the rounded digit to zero e.g. 79 is written as 80 and 74 is written as 70.

<u>Steps and rules for Rounding Off Decimal numbers:</u>

1. **Identify the digit to be rounded**: Determine the digit in the place value you are rounding to. For example, if rounding to two decimal places, you look at the digit in the third decimal place e.g. in 3.876, 7 is at 2nd decimal place and 6 is at 3rd decimal place.
2. **Look at the next digit**: Examine the digit to the right of the one you're rounding to.
3. **Round up or down**: If the digit to the right is 5 or greater, increase the digit to be rounded to by one. If it's less than 5, leave the digit unchanged e.g. 3.876 is rounded as 3.88 to two decimal places and 3.874 is rounded as 3.87.
4. **Consider ties**: If the digit to the right is exactly 5, you round up digit to be rounded is odd e.g. 1.235 is rounded as 1.24, and remains unchanged if it's even e.g. 1.245 is rounded as 1.24.
5. **Removing digits:** After rounding, the digit we were looking at is removed.

Q#25: What are the rules for addition and multiplication of measured values?

In **addition or subtraction**, the result should have no more decimal places than the measurement having least decimal places. For example, when adding 203.4 m and 105.214 m, the result would be 308.6 m because the measurement 203.4 m has least decimal places and has only one decimal place, so result would be rounded off to one decimal place.

When measurements are multiplied or divided, the result can contain no more significant figures than the least precise measurement. For example, when multiplying 6.7 cm and 3.42 cm, the result is rounded off to two significant figures, resulting in 23 cm^2.

Conceptual Questions:

Q#1: Why are measurements important?

Ans: Measurement is one of the most basic concepts in science. Physics deals with physical quantities which can be measured. So, measurement provides a standard for everyday things and processes.

Examples:

Some examples from daily life have shown the importance of measurement.

1. Without the ability to measure, it would be difficult for scientists to conduct experiments.
2. Without measurements, there would be no concept of freezing point, boiling point and density etc.
3. Without measurements, patients are unable to take correct dose of medicines.
4. Without measurements, buying and selling of things becomes difficult.
5. It is also essential in farming, engineering, construction, and manufacturing etc.
6. From weight, temperature, length, even time is a measurement and it does play a very important role in our lives.

Q#2: Estimate your age in minutes, seconds and milliseconds.

Ans: Let present age is = 15 years

= 15 × 365 days = 5475 days

= 5475 × 24 hours = 131400 hours

= 131400 × 60 minutes = 7884000 minutes

= 7884000 × 60 seconds = 473040000 seconds

= 473040000 × 10^3 × 10^{-3} seconds = 473040000000 milliseconds

Q#3: What role has SI units played in the development of science?

Ans: With the development in the field of science and technology, the need for commonly acceptable system of units was seriously felt all over the world particularly to exchange scientific and technical information To fulfil this need a world-wide system of measurements called international system of units was adopted

Q#4: What do you understand by zero error of an instrument?

Ans: The error in a measuring instrument due to non-uniform or wrongly marked graduation due to which a measurement may be less or greater than actual measurement is called zero error.

Q#5: How is precision related to the significant figures in a measured quantity?

Ans: An improvement in the quality of measurememt by using better instrument having less least count increases significant figures in a measured result. More significant figure means greater precision E.g. measurement of screw gauge would be more precise than a vernier calliper and vernier calliper would be more precise than metre rule, therefore measurement taken by screw gauge have more significant figures than vernier calliper and metre rule.

Q#6: Why do we need to consider significant figures in measurements?

Ans: Significant figures are a universal way to communicate the precision of measurements in science. By reporting them correctly, scientists ensure everyone understands the level of precision associated with the data because they tell us about limitation of instrument. That is the reason that significant figures must be considered when reporting a measurement.

Q#7: Why area is a derived quantity?

Ans: A derived quantity is the combination of various base quantities. Thus, area is a derived quantity because in area the same base quantity "length" occurs twice (in the form of length and breadth).

As we know that

Area = Length x breadth

Area = $l \times l$

= l^2

As unit of length is "m". So, unit of area is 'm^2'.

Unit 1: Physical Quantities and Measurement

Problems

1.1: Express the following quantities using prefixes.

(a) 5000 g
(b) 2000 000 W
(c) 52 x 10^{-10} kg
(d) 225 x 10^{-8} s

Ans:

(a) 5000 g = 5 x 10^3 g = 5kg
(b) 2000 000 W = 2 x 10^6 W = 2 MW
(c) 52 x 10^{-10} kg = 5.2 x 10^1 x 10^{-10} x 10^3 g = 5.2 x 10^{-6} g = 5.2 μ g
(d) 225 x 10^{-8} s = 2.25 x 10^2 x 10^{-8} s = 2.25 x 10^{-6} s = 2.25 μ s

1.2: How do the prefixes micro, nano and pico relate to each other?

Ans: **Relation between micro and nano:**

$$1 \text{ nano} = 10^{-9}$$
$$= 10^{-3} \times 10^{-6}$$
$$\boxed{1 \text{nano} = 10^{-3} \text{ micro}}$$

Relation between micro and pico

$$1 \text{ pico} = 10^{-12}$$
$$= 10^{-6} \times 10^{-6}$$
$$\boxed{1 \text{pico} = 10^{-6} \text{ micro}}$$

Relation between nano and pico

$$1 \text{ pico} = 10^{-12}$$
$$= 10^{-3} \times 10^{-9}$$
$$\boxed{1 \text{pico} = 10^{-3} \text{ nano}}$$

1.3: Your hairs grow at the rate of 1mm per day. Find their growth rate in ms^{-1}.
(LHR 2013, GUJ 2015)

Ans: Growth rate = 1 mm per day

$$= \frac{1 \text{mm}}{1 \text{day}}$$

$$= \frac{1 \times 10^{-3} \text{m}}{8.64 \times 10^4 \text{s}}$$

$$= \frac{1}{8.64} \times 10^{-3} \times 10^{-4}\ ms^{-1}$$
$$= 0.1157 \times 10^{-7}\ ms^{-1}$$
$$= 11.57 \times 10^{-2} \times 10^{-7}\ ms^{-1}$$
$$= 11.57 \times 10^{-9}\ ms^{-1} = 11.57\ nms^{-1}$$

1.4: Rewrite the following in standard form.

(a) 1168×10^{-27}
(b) 32×10^{5}
(c) 725×10^{-5} kg
(d) 0.02×10^{-8}

Ans:

(a) $1168 \times 10^{-27} = 1.168 \times 10^{3} \times 10^{-27} = 1.168 \times 10^{-24}$
(b) $32 \times 10^{5} = 3.2 \times 10^{1} \times 10^{5} = 3.2 \times 10^{6}$
(c) $725 \times 10^{-5}\ kg = 7.25 \times 10^{2} \times 10^{-5} \times 10^{3}\ g = 7.25\ g$
(d) $0.02 \times 10^{-8} = 2.0 \times 10^{-2} \times 10^{-8} = 2.0 \times 10^{-10}$

1.5: Write the following quantities in standard form.

(a) 6400 km
(b) 380 000 km
(c) 300 000 000 ms^{-1}
(d) seconds in a day

Ans:

(a) 6400 km = 6.4×10^{3} km
(b) 38000 km = 3.8×10^{5} km
(c) 300 000 000 ms^{-1} = $3.0 \times 10^{8}\ ms^{-1}$
(d) 1 day = 24 hours = 24 x 3600 s = 86400 s = 8.64×10^{4} s

1.6: On closing the jaws of a vernier callipers, zero of the Vernier scale is on the right of it main scale such that 4th division of its vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

Ans: Number of division of Vernier scale = 4
Least count of Vernier calipers = 0.01 cm
Zero error = 4 x 0.01 cm = 0.04 cm
As zero of the Vernier scale is at the right side of the zero of the main scale so zero error will be positive.
So Zero correction = - 0.04 cm

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1.7: A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5 mm. What is its least count? (LHR 2013)

Ans: No. of divisions on circular scale = 50

Pitch = 0.5 mm

$$\text{As least count} = \frac{\text{pitch of screwguage}}{\text{Number of circular scale divisions}}$$

$$\text{Least Count} = \frac{0.5\text{mm}}{50} = 0.01 \text{ mm} = 0.001 \text{ cm}$$

1.8: Which of the following quantities have three significant figures? (LHR 2015, GRW 2015)

(a) 3.0066 m
(b) 0.00309 kg
(c) 5.05 x 10^{-27} kg
(d) 2001 s

Ans: b and c

1.9: What are the significant figures in the following measurements? (LHR 2015, GRW 2015)

	(a) 1.009 m	(b) 0.00450 kg	(c) 1.66 x 10^{-27} kg	(d) 2001 s
Ans:	(a) 4	(b) 3	(c) 3	(d) 4

1.10: A chocolate wrapper is 6.7 cm long and 5.4 cm wide. Calculate its area up to reasonable number of significant figures. (GRW 2013, LHR 2014)

Ans: Given data:

Length of chocolate wrapper = l = 6.7 cm

Width of chocolate wrapper = w = 5.4 cm

Required:

Area of chocolate wrapper = A =?

Solution:

As we know that

Area =length x width

By putting the values we have

Area = 6.7 cm x 5.4 cm

= 36.18 cm^2

Result:

As the least number of significant figures in observed measurements are 2

So Area = 36 cm^2

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ASSIGNMENT QUESTIONS

1. The mass of earth is 5,980,000,000,000,000,000,000,000 kg. Write this number in standard form/ scientific notation.
2. Calculate the number of seconds in a week. Express the number in power of 10 notation.
3. Adult housefly (Musca domestica) is having a mass of only about 0.0000214kg. Express this number in standard form/ scientific notation.
4. The smallest bird is the bee hummingbird. Males measure only 0.057m, convert this number to standard form and write this number in millimeters.
5. Calculate the distance from Peshawar to Lahore in millimeters.
6. Which of the following is the accurate device for measuring length;
   - **a.** A vernier calipers with main scale of 1mm marking and 50 divisions on sliding scale.
   - **b.** A screw gauge of pitch 1mm and 25 divisions on the circular scale.
7. A breaker contains 200ml of water, what is the volume of water in cm^3 and m^3.
8. Write the number in prefix to power of ten,
   - **a.** Mechanical nano-oscillators can detect a mass change as small as 10^{-21}kg.
   - **b.** The nearest neutron star (a collapsed star made primarily of neutrons) is about $3.00x10^{18}$m away from Earth.
   - **c.** Earth to sun distance is 149.6 million km.
9. An angstrom (symbol A*) is a unit of length (commonly used in atomic physics), defined as 10^{-10}m which is of the order of the diameter of an atom.
   - **a.** How many nanometers are in 1.0 angstrom?
   - **b.** How many femtometers or fermis (the common unit of length in nuclear physics) are in 1.0 angstrom?
   - **c.** How many angstroms are in 1.0m?

10. The speed of light is c= 299,792,458m/s.
    - **a.** Write this value in scientific notation.
    - **b.** Express the speed of light to
    - **c.** Five significant figures
    - **d.** Three significant figures
11. Express the following in terms of power of 10
    - **a.** 7 nanometer
    - **b.** 96 megawatt
    - **c.** 2 gigabite
    - **d.** 43 picofarad
    - **e.** 2 millimeter

12. Write the following numbers in standard form;
    - **a.** Mass of Bacterial cell;0.000,000,000,005kg
    - **b.** Diameter of sun; 1,390,000,000 m