A Textbook of

PHYSICS

Grade

IX

FREE FROM GOVERNMENT
NOT FOR SALE

Khyber Pakhtunkhwa Textbook Board,
Peshawar

CONTENTS

Unit

1

PHYSICAL QUANTITIES AND MEASUREMENT

CHECK LIST

After studying this unit you should be able to:

- ✓ Describe the crucial role of Physics in Science, Technology and Society.
- ✓ Explain with examples that Science is based on physical quantities which consist of numerical magnitude and a unit.
- ✓ Differentiate between base and derived physical quantities.
- ✓ List the seven units of System International (SI) along with their symbols and physical quantities
- ✓ Interconvert the prefixes and their symbols to indicate multiples and sub-multiples for both base and derived units.
- ✓ Write the answer in scientific notation in measurements and calculations.
- ✓ Describe the working of vernier callipers and screw gauge for measuring length.
- ✓ Identify and explain the limitation of measuring instruments such as metre rule, vernier callipers and screw gauge.
- ✓ Describe the need for using significant figures for recording and stating results in the laboratory.

All the quantities we deal in physics require measurements. This chapter is built on Unit 8: Measurement of physical quantities of general science for grade 8.

Measurement is not only a key concern in physics; in our daily life we are always making measurements. For example when we go to a tailor shop before sewing our cloths he takes the required measurements.

TELESCOPE

The telescope in the foreground is Gemini North, one of a pair of twin 8.1-m telescopes located on Mauna Kea in Hawaii. Together, these two telescopes are used to see the visible universe.

1.1 INTRODUCTION TO PHYSICS

Man has always been curious to know the 'how' and 'why' behind the working and function of things. He asks the fundamental questions like how did the universe begin? How does it change? What rules govern its behaviour? Why do things fall to the ground? Why does the moon seem to change shape during the month? What goes inside the sun to make it hot? Physics is all about trying to answer questions like these. All of these phenomena in the universe involve the study of matter and energy.

'Physics is the branch of science that involves the study of physical universe: energy, matter, and how they are related'.

The study of physics is to understand the world around us, the world inside us and the world beyond us. Physics covers a wide range of phenomena, from the smallest sub-atomic particles to the largest galaxies and universe.

Physicists investigate the motions of electrons and rockets, the energy in sound waves and electric circuits, the structure of the proton and of the universe.

MILKY WAY GALAXY

Our solar system is located in a large spiral-shaped galaxy called the Milky Way and the Sun is just one of at least 100 billion stars in this galaxy.

Mathematics-The Language of Physics: Physics and human conditions improved when mathematics was incorporated in physics some 400 years ago. When the ideas of physics are expressed in mathematical terms, they are clearer. They don't have multiple meanings that so often confuse the discussion of ideas expressed in common language.

The equations of physics provide compact expressions of relationships between concepts. Also when findings in nature are expressed mathematically, they are easier to verify or to disprove by experiment.

Physics and Science:

Physics is at the root of every field of science. Most of the major developments in Chemistry, Biology, Geology, Agricultural, Environmental science, Astronomy, Engineering and even in medicine have been made by physicists.

Recall GENERAL SCIENCE for GRADE 7, CHAPTER 11, CIRCUITS AND ELECTRIC CURRENT:

You have already used mathematics in physics when you defined electric current '*I*', as time rate of flow of electric charge '*Q*' through a given cross-section of a conductor as

$I = \frac{Q}{t}$ where I = current, Q = charge, t = time

Physics, Technology and its Impact on our Society:

Physics and technology are closely related however they are also different from each other. Physics is concerned with gathering knowledge and organizing it. Technology lets humans use that knowledge for practical purposes. Physical phenomenon is there behind every technology and therefore physics has a key role in the progress of humankind and in the improvement of quality of living.

Physics provide basic understanding for developing new instrumentation for medical applications such as Computed Tomography (CT Scan), Magnetic Resonance Imaging (MRI), and laser surgeries. The image shown an advance medical imaging device called Positron Emission Tomography (PET).

PET

The use of physics in information technology has improved the standard of communication. Mobile cell phones are commonly used even by illiterates. Hologram technology is a three-dimensional image, created with photographic projection. The hologram technology is also incorporated in cell phones.

HOLOGRAM

QURAAN AND PHYSICS

It is generally accepted that there are more than 700 A'yahat in the Quraan dealing with the natural phenomena. Many A'yahat of Quraan ask mankind to study nature, few are described

لَا الشَّمْسُ يَنْبَغِي لَهَا أَنْ تُدْرِكَ الْقَمَرَ وَلَا الَّيْلُ سَابِقُ النَّهَارِ ۚ وَكُلٌّ فِي فَلَكٍ يَسْبَحُونَ ﴿40﴾ (سورہ یٰسٓ - 40)

نہ تو سورج ہی سے ہو سکتا ہے کہ چاند کو جا پکڑے اور نہ رات ہی دن سے پہلے آسکتی ہے اور سب اپنے اپنے دائرے میں تیر رہے ہیں۔

The sun is not to overtake the moon, nor is the night to outpace the day. Each floats in an orbit.

يَا مَعْشَرَ الْجِنِّ وَالْإِنْسِ إِنِ اسْتَطَعْتُمْ أَنْ تَنْفُذُوا مِنْ أَقْطَارِ السَّمٰوٰتِ وَالْأَرْضِ فَانْفُذُوا ۚ لَا تَنْفُذُونَ إِلَّا بِسُلْطٰنٍ ﴿33﴾ (سورہ رحمٰن - 33)

اے گروہ جن وانس اگر تمہیں قدرت ہو کہ آسمان اور زمین کے کناروں سے نکل جاؤ تو نکل جاؤ اور زور کے سوا تو تم نکل سکتے ہی نہیں۔

O company of Jinn and men, if you can (and want) to cross the limits sky and earth, then cross, you will not cross except by the authority (from Allah).

الَّذِي خَلَقَ سَبْعَ سَمٰوٰتٍ طِبَاقًا ۖ مَا تَرٰى فِي خَلْقِ الرَّحْمٰنِ مِنْ تَفٰوُتٍ ۖ فَارْجِعِ الْبَصَرَ ۙ هَلْ تَرٰى مِنْ فُطُورٍ ﴿3﴾ (سورہ ملک - 3)

اس نے سات آسمان اوپر تلے بنائے (اے دیکھنے والے) کیا تو (اللہ) رحمٰن کی آفرینش میں کوئی نقص دیکھتا ہے؟ ذرا آنکھ اٹھا کر دیکھ تجھ کو (آسمان میں) کوئی شگاف نظر آتا ہے۔

He who created seven heavens in layers. You see no discrepancy in the creation of the compassionate. Look again can you see any fault?

أَفَلَا يَنْظُرُونَ	أَفَلَا يَتَدَبَّرُونَ	أَفَلَا يَتَفَكَّرُونَ
آیا یہ لوگ نہیں دیکھتے۔	بھلا یہ لوگ غور نہیں کرتے۔	بھلا یہ لوگ غور و فکر نہیں۔
Do they (people) not look?	*Do they not contemplate?*	*Do they not think?*

CONTRIBUTION TO PHYSICAL SCIENCE BY ISLAMIC WORLD

Scientists of the Islamic world contributed in the development of physics. Few of the notable scientists are:


YAQUB KINDI

Yaqub Kindi (800 - 873):

He was born in Busra, Iraq. He produced extensive research monographs on metrology, specific gravity and tides. His most important work was done in the field of optics, especially on reflection of light.

Ibnal Haitham (965 - 1039):

He was born in Busra, Iraq. He was great scholar of his time. His greatest work is the book on optics named KITAB UL MANAZIR. He is also considered as the inventor of the pin-hole camera.


IBNAL HAITHAM

Al Beruni (973-1048):

He is afghan scholar and wrote about 150 books on physics, cosmology, geography, culture, archeology and medicine. Al Beruni discussed the shape of earth the movement of sun, moon and phases of moon.


AL BERUNI

FAMOUS PAKISTANI PHYSICISTS

Mohammad Abdus Salam:

(29 January 1926 - 21 November 1996), was a Pakistani theoretical physicist. A major figure in 20th century theoretical physics, he shared the 1979 Nobel Prize in Physics with Sheldon Glashow and Steven Weinberg for his contribution to the electroweak unification theory. He was the first Pakistani to receive a Nobel Prize in science.

Abdul Qadeer Khan:

Abdul Qadeer Khan known as A. Q. Khan (born in 27 April 1936) is a Pakistani nuclear physicist and a metallurgical engineer, who founded the uranium enrichment program for Pakistan's atomic bomb project. He founded and established Kahuta Research Laboratories (KRL) in 1976, and served as both its Senior Scientist and Director-General until he retired in 2001.

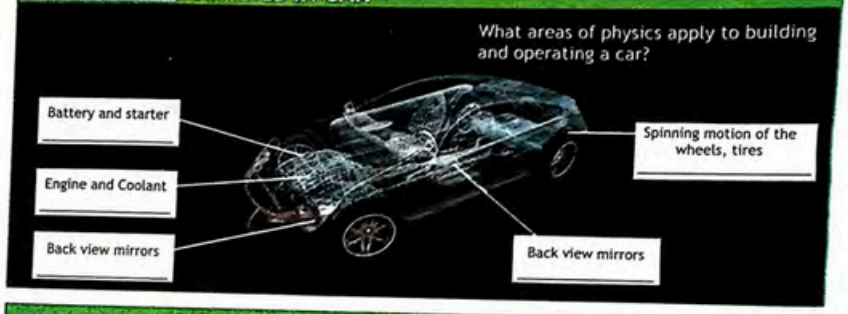
BRANCHES OF PHYSICS

Due to vast scope and research in physics it is usually divided into a number of branches some of them given below.

TABLE 1.1 BRANCHES OF PHYSICS

Area within physics	Description	Examples
Mechanics	Motion of objects and how it relates to forces	falling objects, friction, weight, spinning objects
Heat and Therodynamics	Heat and temperature and their relation to energy.	melting and freezing processes, engines, refrigerators
Oscillations and Waves	to and fro motion	Springs, Water waves, Sound
Optics	Light and the instrument created to use or detect it	Mirrors, Lenses, telescopes, Eye
Electricity and Magnetism	Static as well as moving charges and associated physical phenomena	electrical charge, circuitry, magnets, electromagnets
Atomic and Nuclear Physics	Structure and properties of individual atoms and nuclei of an atom.	X-rays, LASERS, Nuclear Reactor, MRI, CT Scan, PET Scan
Relativity	Moving Object (including very high speed) and gravitation	Particle accelerators, Nuclear Energy
Quantum Physics	Discrete, indivisible units of energy called quanta	the atom and its parts
Particle Physics	nature of the particles that constitute matter and radiation	Quarks, Leptons, Photons, Bosons
Cosmology and astrophysics	the origin, evolution, and eventual fate of the universe	Stars, galaxies and black holes
Biophysics and Medical Physics	physical interactions of biological processes and Application of physics health processes such as prevention, diagnosis, and treatment.	MRI, CT Scan, Radiotracers and conduction in living cells.

ACTIVITY 1.1 PHYSICS IN CAR



Measurement: Recall

Measurement is a comparison between an unknown quantity (measurable quantities like mass, length etc) and standard to see how many times as big it is.

Unit is standard with which things are compared. Before a measurement can be made, a standard or unit must be chosen. The size of the quantity to be measured is then found with an instrument having a scale marked in the unit.

1.2 PHYSICAL QUANTITIES

'All the quantities that can be measured are called physical quantities'.

In physics we study only those quantities which can be defined and measured. Quantities like length, mass, time, density, temperature can be measured therefore they are called physical quantities.

For example the length of the book can be measured, the duration of our stay at school is measurable, hence these are physical quantities. Physical quantities are classified into two categories:

? CAN YOU TELL?

Are there quantities which we can not measure?

A. **Base quantities:**

Minimum Number of physical quantities selected and their units are defined and standardized such that in terms of these all other physical quantities can be expressed are called base quantities. The corresponding units for these quantities are called base units.

B. **Derived quantities:**

The physical quantities defined in terms of base quantities are called derived quantities. The corresponding units for these quantities are called derived units.

1.3 INTERNATIONAL SYSTEM OF UNITS

'A complete set of units for all physical quantities is called system of units'. The international system of unite's is abbreviated as SI units. Actually, SI units is a short form of the French name 'System International (d' Units') which means 'International System of Units'. The international system of units is based on seven base units (or seven basic units) from which all other units are derived. The seven basic physical quantities, their SI base units and symbols are given in the table 1.2.

INFORMATION

Aeroplane pilot require large number of measuring and information instruments for safe flight.

TABLE 1.2 BASE UNITS FOR INTERNATIONAL SYSTEM OF UNITS

Base Quantity		SI Base Unit	
Name	Symbol	Name	Symbol
length	l, x, r (e.t.c)	meter	m
mass	m	kilogram	kg
time, duration	t	second	s
electric current	I or *i*	ampere	A
thermodynamic temperature	T	kelvin	K
amount of substance	n	mole	mol
luminous intensity	I	candela	cd

A. SI Base Units:

In SI *SEVEN* physical quantities are chosen as base and their units are defined, standardized and are called base units. Each SI unit is defined carefully so that it is unique and upon which accurate and reproducible measurements can be made.

TID-BIT : WHY SI?

Before SI units were standardized, Isaac Newton in his book while specifying the length of the pendulum reported not only as '37 whole 7/8 inches long' but '37 whole 7/8 London inches long'. The inch (unit of length) in different cities of England was defined to have different length.

Similarly before SI, we had to deal with odd conversion factors like 16 ounces in a pound or 12 inches in a foot or 5280 feet in a mile. SI came up with decimal notation like 1000 metres was termed as 1 kilometre and 100 centimetres as 1 metre.

B. Derived Units:

Units derived from multiplying and dividing base units are termed as derived units. In SI units for all other physical quantities can be derived from the seven base units. The units for velocity and acceleration are 'm/s' and 'm/s²', respectively. Some derived units were used so often that it became convenient to give them their own names and symbols. For example force has derived units of 'kgms^{-2}' which is given special name as 'newton' and represented as 'N'. Some derived quantities with derived units in terms of base units are given in table 1.3.

POINT TO PONDER

Viruses (about 10^{-7} m long) attacking a cell. How such small lengths can be measured?

TABLE 1.3 DERIVED UNITS FOR 'INTERNATIONAL SYSTEM OF UNITS'

Derived Quantity		Derived Unit	
Name	Symbol	Name	Symbol
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}
density	ρ	kilogram per cubic meter	kgm^{-3}
force	F	newton	$N = kgms^{-2}$
pressure	P	pascal	$Pa = kgm^{-1}s^{-2}$
energy	E, U	joule	$J = kgm^2s^{-2}$
capacitance	C	farad	$F=kg^{-1}m^{-2}s^4A^2$
resistance	R	ohm	$\Omega = kgm^2s^{-3}A^{-2}$

1.4 Standard Form / SCIENTIFIC NOTATION

Scientific notation is a way of writing numbers that are too big or too small to be easily written in decimal form. Standard form or scientific notation has a number of useful properties and is commonly used by scientists, mathematicians and engineers.

In physics we deal with numbers that are either very small or very large, it becomes difficult to write these numbers. For example, the mass of moon is approximately 70,000,000,000,000,000,000,000 kilograms. If we use this number often, we would surely like to have a more compact notation for it. This is exactly what standard form or scientific notation is. It represents a number as the product of a number greater than 1 and less than 10 (called the mantissa) and a power of 10 (termed as exponent):

$$\text{number (N)} = \text{mantissa (M)} \times 10^{\text{exponent (n)}}$$

The mass of moon can thus be written compactly as 7×10^{22} kg, where 7 is the mantissa and 22 is the exponent. Similarly, the diameter of atomic nucleus is about 0.00000000000001m, which in standard form or scientific notation is 1×10^{-14} m.

STEPS FOR CONVERTING NUMBER TO STANDARD FORM

1. In a given number N, move the decimal point and place it after first non-zero digit which will make it mantissa (M).
2. If the decimal is moved towards left from its given initial position then the power of 10 will be positive and whatever is the number of digits through which the decimal point has been moved that will be the value of exponent (power of 10).
3. Similarly, if the decimal point is moved towards right from its given position then the power of 10 will be negative and whatever is the number of digits through which the decimal point has been moved that will be the value of exponent (power of 10).

Example 1.1 AVERAGE DISTANCE BETWEEN EARTH AND MOON

Average distance between earth and moon is 384,400,000 m. Write this number in Standard form / scientific notation.

SOLUTION

For Standard form / scientific notation we can write the term as

$$\text{distance} = \underbrace{384400000.}_{}0 \times 10^0 m$$

For Standard form / scientific notation in order to get mantissa (M) in which the 1st digit before the decimal is non-zero, we have to move the decimal 8 digits towards left. Therefore, the power of 10 will be positive 8, that is

$$\text{distance} = 3.84400000 \times 10^8 m$$ — Answer

EXTENSION EXERCISE 1.1

Why we used the word average in problem statement.

Which is the average distance between earth and moon in standard form or scientific notation.

Assignment 1.1 MASS OF EARTH

The mass of Earth is 5,980,000,000,000,000,000,000,000 kg, write this number in Standard form / scientific notation.

Example 1.2 NUMBER OF SECONDS IN AN YEAR

Find the number of seconds in a year and write the answer in Standard form or scientific notation.

SOLUTION

We know that there are 365 days in a year (y), 24 hours in a day (d), 60 minutes in an hour (h), and 60 seconds (s) in a minute (min). These four relationships are conversion factors. Starting with 1 y and multiplying by these conversion factors, we obtain

$$1y = 1\cancel{y} \times \frac{365\cancel{d}}{1\cancel{y}} \times \frac{24\cancel{h}}{1\cancel{d}} \times \frac{60\cancel{m}}{1\cancel{h}} \times \frac{60\,s}{1\cancel{m}}$$

or $1y = 1 \times 365 \times 24 \times 60 \times 60\,s$

or $1y = 31536000\,s$

For Standard form / scientific notation we can write the term as

$$1y = \underbrace{31536000.}_{}0 \times 10^0 s$$

In order to get mantissa (M) in which the 1st digit before the decimal is non-zero, we have to move the decimal 7 digits towards left. Therefore, the power of 10 will be positive 7, that is

$$1y = 3.1536000 \times 10^7 s$$ — Answer

EXTENSION EXERCISE 1.2

Is this value exact? After each 4 years we have a leap year in which we have 366 days, how would we account for that?

Assignment 1.2 SECONDS IN A WEEK

Calculate the number of seconds in a week. Express The number in power of 10 notation.

Example 1.3 SMALLEST MOLECULE

The smallest molecule is the diatomic hydrogen (H_2), with a bond length of 0.000,000,000,074 m. Write the answer in Standard form.

SOLUTION

In Standard form / scientific notation we can write the term as

$$\text{Bondlength} = 0.\underbrace{000000000074}\times 10^{0} m$$

For Standard form / scientific notation in order to get mantissa (M) in which the 1st digit before the decimal is non-zero, we have to move the decimal 11 digits to the right. Therefore, the power of 10 will be negative 11, that is

$$\text{Bondlength} = 7.4\times 10^{-11} m$$ — Answer

Which is the bond length for diatomic hydrogen in standard form / scientific notation.

Assignment 1.3 AVERAGE MASS OF HOUSE FLY

Adult housefly (Musca domestica) is having a mass of only about 0.000,021,4 kg. Express this number in standard form / scientific notation.

1.5 PREFIXES TO POWER OF TEN

A mechanism through which a very small or very large number is expressed in terms of power of ten by giving a proper name to it is called prefix to the power of ten.

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

The thickness of a paper can be written conveniently in smaller units of millimetre instead of metre. Similarly the long distance between two cities may be expressed better in a bigger unit of distance, i.e., kilometre. A useful set of prefixes in SI to replace powers of 10 are given in table 1.5.

CAN YOU TELL?

Name the convenient unit you will use to measure.

a) width of a book
b) length of a room
c) diameter of a wire
d) mass of candy
e) mass of cricket ball.

TABLE 1.5 PREFIXES

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

ACTIVITY 1.2 ABOUT US

Calculate your height in centimeters and meters and your mass (notice that we do not say weight) in kilograms.

CAN YOU TELL?

Choose the base physical quantities and derived physical quantities from the following.

Temperature, Volume, Time, Area, Density, Length

INFORMATION

The mass of this mosquito can be expressed several different ways: 1×10^{-5} kg, 0.0 1 g, or 10 mg.

Example 1.4 SIZE OF BACTERIUM

A typical bacterium has a mass of 2.0 fg. Express this measurement in terms of kg.

SOLUTION

Given mass m = 2.0 fg

We know that

femtogram $1fg = 1\times 10^{-15} g$

kilogram $1kg = 1\times 10^{3} g$

$m = 2fg$

$$m = 2\,fg = 2\times 10^{-15}\,\cancel{g}\times\frac{1kg}{1\times 10^{3}\,\cancel{g}}$$

therefore $m = 2fg = 2\times 10^{-18}\,kg$ — Answer

Tuberculosis is a respiratory disease (infectious) caused by a bacteria known as Mycobacterium tuberculosis.

Assignment 1.4 SMALLEST BIRD

The smallest bird is the bee hummingbird. Males measure only 0.057 m, Convert this number to standard form and write this number in millimetre.

Example 1.5 PESHAWAR TO LAHORE VIA MOTORWAY

The distance from Peshawar to Lahore through motorway is 489 km, convert this number to megametre (Mm).

SOLUTION

Given Distance d = 489 km

We know that kilometre $1km = 1\times10^{3}\ m$

and megametre $1Mm = 1\times10^{6}\ m$

$$d = 489\,km = 489\times10^{3}\,\not{m}\times\frac{1Mm}{1\times10^{6}\,\not{m}}$$ or $489\,km = 489\times10^{-3}\,Mm$

$d = 489\,km = 0.489\times10^{0}\,Mm$

therefore $489\,km = 0.489\,Mm$ — **Answer**

EXTENSION EXERCISE 1.3

If we go to Lahore by aeroplane, the distance shortens to 376 km, why?

Assignment 1.5 *mm* **TO LAHORE**

Calculate the distance from Peshawar to Lahore in millimetres.

1.6 MEASURING INSTRUMENTS

'Measuring instruments are devices to measure physical quantities'.

Physicists use large number of measuring instruments. These range from simple objects such as rulers and stopwatches to Atomic Force Microscope (AFM) and Scanning Tunneling Electron Microscope (STEM). All measuring instruments have some measuring limitations.

Least count is the minimum value that can be measured on the scale of measuring instrument.

While using a measuring instrument, it is therefore important to take certain precautions in order to obtain an accurate reading.

1.6.1 METRE RULE

This instrument is used to measure the lengths of objects or the distance between two points.

Rulers are made from different materials (wood, plastic, metal) and in a wide range of sizes. Metre rules are one metre long as compared to the standard metre. Metre Rulers usually have 1000 small divisions on them called millimetres. Such metre rulers have least count of 1 mm.

POINT TO PONDER

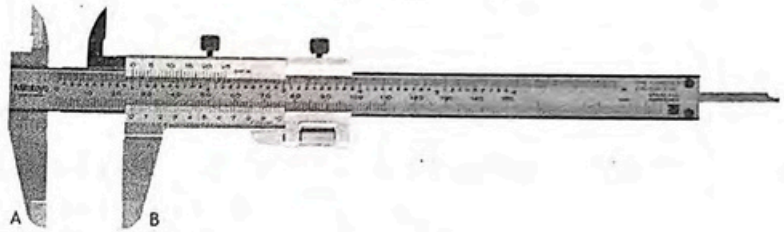
INCHES ON METRE RULE:

Why are inches and feet marked on metre rule? Show the relationship between foot and inch to metre, centimetre and millimetre.

1.6.2 VERNIER CALIPER

'A device used to measure a fraction of smallest scale division by sliding another scale over it is called vernier caliper'. It is a device used to measure small length accurately upto 0.1mm or 0.01cm.

It can be used to measure the thickness, diameter or width of an object and the internal, external diameter of hollow cylinder.



There are two scales on vernier callipers.

Main (fixed) Scale:

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

Vernier (sliding) Scale:

A vernier (sliding) scale which has markings of some multiple of the marking on the main scale. The vernier scale usually has length of 9 mm and is divided equally into 10 divisions (thus separation between two lines on vernier scale is 9/10 mm = 0.9 mm).

Vernier Constant (Least Count of Vernier Callipers):

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

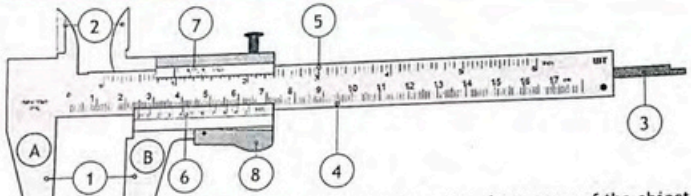
Least count is calculated by two methods:

Method 1:

The difference between the value of one main scale division and the value of one vernier scale division i.e.

Least Count = One Main Scale Division – One Vernier Scale Division

Figure 1.1 Vernier Caliper



1. Outside Jaws: used to take external measures of the object
2. Inside Jaws: used to take internal measures of the object
3. Depth Probe: used to measure depth of the objects
4. Main Scale: Used in centimetre or millimetre measurements
5. Main Scale: Used in inches measurements
6. Vernier Scale: Used in centimetre or millimetre measurements
7. Vernier Scale: Used in inches measurements
8. Retainer: Used to block movable parts

If one main scale division is 1 mm one vernier scale division is 0.9 mm, the least count is 0.1mm.

Method 2:

Mathematically, least count can also be obtained from dividing the value of smallest division on main scale by total number of divisions on vernier scale.

$$\text{Least Count} = \frac{\text{Smallest division on main scale}}{\text{Total number of divisions on vernier scale}}$$

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

$$\text{Least Count} = \frac{1mm}{10} = 0.1mm$$

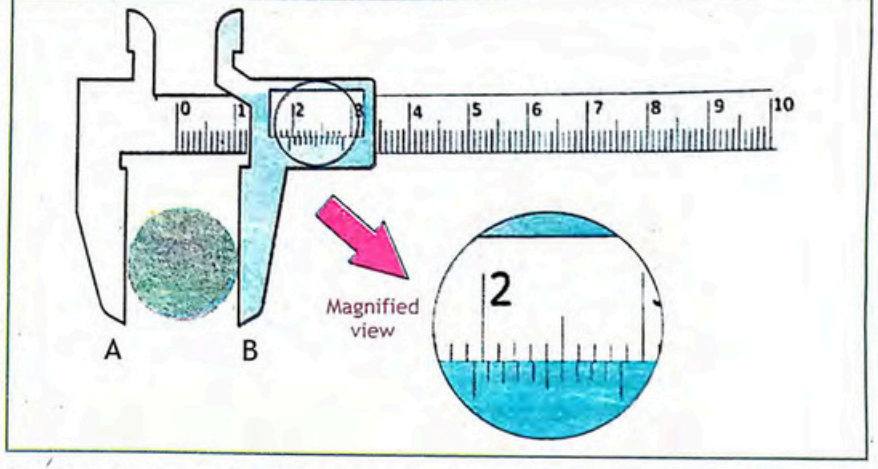
ZERO ERROR IN VERNIER CALIPER

On closing the jaws of the calipers, the zero of the Vernier Scale may or may not coincide with the zero of the main Scale. If their zeros does not coincide, there is zero error in the instrument. The zero error and its correction will be discussed in laboratory work.

Suppose we want to measure the diameter of a small solid cylinder with ernier caliper we will use the following method.

Note the least count of the vernier, (it is usually written on vernier caliper, otherwise we can find it out by method described previously) which in our case is 0.01 cm (0.1 mm).

Figure 1.2 Vernier Caliper



2. Close the jaws fully with no object between the jaws. If the zero line of the vernier scale coincides with the zero line of the main scale then there is no zero error.
3. Now fix the solid cylinder in between the two jaws and tighten the vernier with the help of screw 'S' suppose the zero of the vernier scale is to the right of 1.9 cm the mark and to the left of the 2.0 cm (20 mm) mark as shown in figure 1.2. Thus the required length is somewhat greater than 1.9 cm (19 mm).
4. To find the fraction to be added. We see that division of the vernier scale which coincides (in line) with any division of the main scale. As the 6th division of the vernier scale coincides with one of the main scale divisions as in figure 1.2.
5. Multiply the least count 0.01 cm (0.1 mm) by 6 which gives 0.06 cm (0.6 mm) and add to 1.9 cm (19 mm). The measured length is 1.9 cm + 0.06 cm = 1.96 cm or 19 mm + 0.6 mm = 19.6 mm

   Hence the diameter of solid cylinder is 1.96 cm (19.6 mm).

LAB WORK

- To measure the area of cross section by measuring diameter of a solid cylinder with vernier callipers.
- To measure the volume of a solid cylinder by measuring length and diameter of a solid cylinder with vernier callipers.

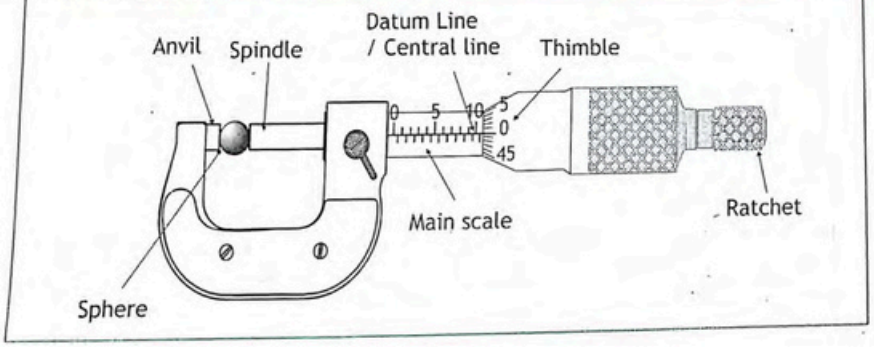
1.6.3 SCREW GAUGE

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

Pitch of Screw Gauge:

The distance traveled by the circular scale on linear scale in one rotation is called the pitch of the screw gauge.

Figure 1.3 Screw Gauge



Least Count of Screw Gauge:

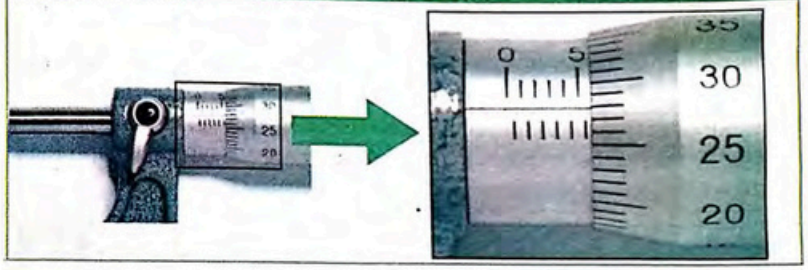
The minimum length which can be measured accurately by a screw gauge is called least count of the screw gauge. The least count of screw gauge is found by dividing its pitch by the total number of circular scale divisions.

$$Least\ Count = \frac{\text{Pitch of Screw Guage}}{\text{Total Number of Divisions on Circular Scale}}$$

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

e.g. $Least\ Count = \frac{0.5mm}{50} = 0.01mm$

Figure 1.4 Screw Gauge



If the pitch of the screw is 0.5 mm and the number of divisions on the circular scale are 50 then the diameter of small sphere is measured by using a screw gauge by the following method.

1. Note the pitch and least count of the screw gauge.
2. Place the object between thimble and anvil. Now turn the thimble until the anvil and spindle gently grip the object. Then turn the ratchet until it starts to click. The ratchet prevents the user from exerting too much pressure on the object.
3. Read the main scale reading. For example, in figure 1.4 the edge of circular scale is lying between 5.5 mm and 6.0 mm, i.e. the diameter of the sphere is more than 5.5 mm and less than 6.0 mm.
4. To know the part more than 5.5 mm. We look for the division of circular scale (Thimble scale) which is in front of the datum line. In figure 1.4 it is 28.
5. Now multiplying 28 by the least count which is 0.01 mm we get 0.28 mm. Add this product to 5.5 mm.

   5.5 mm + 0.28 mm = 5.78 mm

   Thus 5.78 mm is the diameter of the sphere

ZERO ERROR IN SCREW GAUGE

Turn the thimble until the anvil and spindle meet. If the zero mark on the thimble scale does not lie directly opposite the datum line of the main scale we say that there is zero error. The zero error and its correction will be discussed in laboratory work.

LAB WORK

Measure the thickness of a metal strip or a wire by using a screw gauge.

ACTIVITY THICKNESS OF PHYSICS BOOK AND PAGE

With your ruler find the thickness of the book excluding cover, now divide the number by the number of pages in the book also compare the result with the measurement you take with screw gauge.

Assignment 1.6 WHICH INSTRUMENT IS MORE ACCURATE?

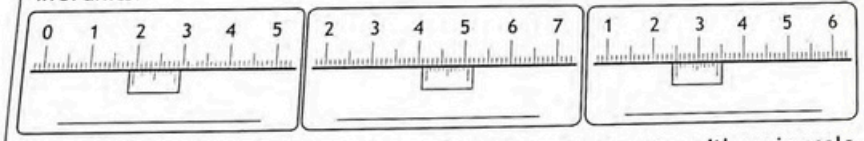
Which of the following is the accurate device for measuring length :

A) a vernier callipers with main scale of 1 mm marking and 50 divisions on the sliding scale

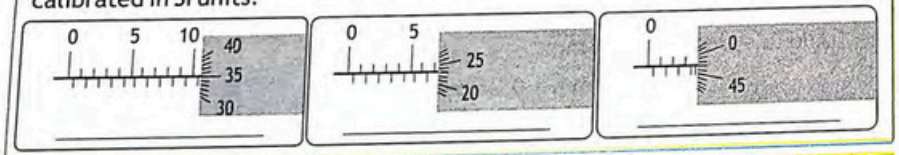
B) a screw gauge of pitch 1 mm and 25 divisions on the circular scale

ACTIVITY READINGS OF VERNIER CALIPERS AND SCREW GAUGE

Read the following Vernier Caliper measurements, with main scale calibrated in SI units.



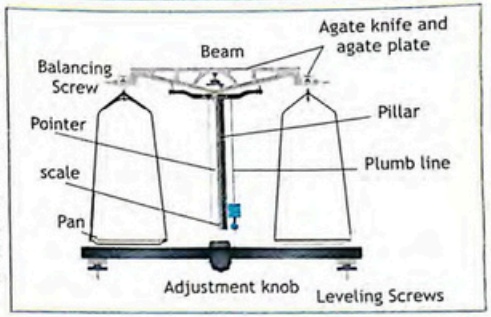
Read the following Micrometer Screw Gauge measurements, with main scale calibrated in SI units.



1.6.4 PHYSICAL BALANCE

The mass of a body is difficult to determine, but it can be compared easily against a body of known mass. This process of comparing the masses of two bodies is commonly known as weighing process. This weighing is carried out through a balance.

Physical balance is just a common balance where there are two pans and you measure weight of an object by putting it in one pan and a known weight in the other.



A physical balance is a very sensitive common balance which can measure weights in milligram order. It is placed in a protective glass case so that even dust and wind can not affect the accuracy of the instrument.

1.6.5 STOP WATCH

The duration of time of specific interval is measured by a stop watch. It has two main types i.e. mechanical and digital.

A) Mechanical / Analogue Stop Watch:

It consists of two hands a small minute hand and a long second hand. Scales for each hand are marked on a circular dial. To note the time both the hands are set at zero by pressing and releasing the knob. As the knob is pressed and released again, the watch starts.

When the second's hand completes two rotaticns of 30 seconds each, the minute hand advances by one division. When it is required to be stopped, again the same knob is pushed, the watch stops, and time can be noted.

B) Digital Stopwatch:

The timing functions in digital stopwatch are usually controlled by two buttons on the case. Pressing the top button starts the timer running, and pressing the button a second time stops it, leaving the elapsed time displayed.

A press of the second button then resets the stopwatch to zero. The second 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

ANALOGUE STOP WATCH

A Mechanical / analogue stop watch can measure up accuracy of 0.1 second, this is the least count of mechanical or analogue stop watch.

DIGITAL STOP WATCH

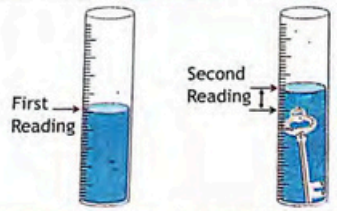
A digital stop watch can measure up accuracy of 0.01 second (centisecond) this is the least count of digital stop watch.

freezes, allowing the elapsed time to that point to be read, but the watch mechanism continues running to record total elapsed time. Pressing the split button a second time allows the watch to resume display of total time.

1.6.6 MEASURING CYLINDER

The volume of a liquid can be found by measuring cylinder which is made of transparent plastic or glass and it has a vertical scale in milliliter (ml) or cubic centimeter (cm^3). Measuring cylinder can be used for measuring the volume of an irregular solid body such as key as shown in figure 1.5.

Figure 1.5 Measuring Cylinder



Volume of the key can be calculated by finding the difference in the rise of water level.

Water is poured into a measuring cylinder until the cylinder is about half full. The volume is measured, and then an irregular shaped object is lowered gently into it.

When the object is completely immersed the volume of the water is read again. The volume of the object is found by subtracting the first reading from the second.

POINT TO PONDER

Why 20 °C is written on Measuring Cylinders?

Example 1.6 ONE LITER MILK IN SI UNITS

A liter (L) is the volume of a cube that is 10 cm by 10 cm. If you drink 1 L of milk, how much volume (a) in cubic centimeters and (b) in cubic meters would it occupy in your stomach?

(a) The volume of a cube of side l is $V = l^3$. The volume in cm^3 is found directly from l = 10 cm. Calculate the volume in cm^3 is

$$V = l^3 = (10\ cm)^3 = 10^3\ cm^3$$

(b) To find the volume in m^3, convert cm^3 to m^3 using the conversion factor 1 cm = 10^{-2} m.

$$10^3\ cm^3 = 10^3\ cm^3 \times \left(\frac{10^{-2}\ m}{1cm}\right)^3$$

or $$10^3\ cm^3 = 10^3\ \cancel{cm^3} \times \frac{10^{-6}\ m^3}{1\cancel{cm^3}}$$

therefore $10^3\ cm^3 = 10^{-3}\ m^3$ — **Answer**

Assignment 1.7 mL CONVERSION

A beaker contains 200 mL of water, what is volume of water in cm^3 and m^3.

1.7 SIGNIFICANT FIGURES

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 metre 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 up to 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.

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

GENERAL RULES FOR WRITING SIGNIFICANT FIGURES

1. NONZERO 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 is 4.
2. ZERO in between two significant digits is always significant. For example the number of significant figures in 32.50063 is 7.
3. ZEROs to the left of significant figures are not significant. For example the number of significant figures in 0.00467 is 3.
4. ZEROs to the right of the significant figure

CALCULATORS DO NOT SHOW CORRECT SIGNIFICANT FIGURES

Some time through calculations the calculator shows more significant digits than required, these numbers should be rounded off to proper number of significant digits.

For example when we want to convert mm to inch (1 mm = 0.0393701 inch), then by multiplying 67.5 mm to inch will give us 2.65748175 inches we have to round off the number to proper significant digits.

may or may not be significant. In decimal fractions zero to the right of a decimal fraction are significant. For example in 7.400 there are 4 significant figures. However if the number is an integer number of significant figures can be found out by accuracy of the measuring instrument. For example in number 80,000 we may have 1, 2 or even 5 significant figures.

5. 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.

RULES FOR ROUNDING OFF SIGNIFICANT FIGURES

1. If the last digit is less than 5 then it will be ignored. e.g. 2.6573 is rounded to 2.657.
2. When the dropping digit is greater than 5 then the last retained digit increases by 1 e.g. 2.6578 is rounded to 2.658.
3. When the dropping digit is 5 and the last retained digit is even then the last digit i.e. 5 will be dropped without affecting the next one. e.g. 2.6585 is rounded to 2.658.
4. If the last digit is 5 and the 2nd last is an odd digit then the 2nd last digit is increased by 1 in order to round off 5, e.g. 2.6575 is rounded to 2.658.

ROUNDING OFF 2.6574818

2.6574818 → 2.657482 → 2.65748 → 2.6575 → 2.658 → 2.66

KEY POINTS

- Physics: The branch of science which deals with the study of properties of matter and energy along with their mutual interaction.
- Physical Quantities: Quantities that can be measured.
- International system of units: The international system of units which consists of seven base units and a number of derived units.
- Seven Base Units: metre, kilogram, second, ampere, candela, Kelvin and mole are base units of system international.
- Scientific Notation: An internationally accepted way of writing numbers in which numbers are recorded using the power of ten and there is only one non zero digit before the decimal.
- Vernier callipers: A device used to measure a fraction of smallest scale division by sliding another scale over it.
- Screw Gauge: A device used to measure a fraction of smallest scale division by rotatory motion of circular scale over it.
- Stop Watch: It is an instrument used for measurement of time interval.
- Significant Figures: The accurately known digits and first doubt full digit in any measurement.

PROJECTS

GROUP - A

NOBEL LAUREATES: Find out who were the Nobel laureates for physics last year, and research their work. Alternatively, explore the history of the Nobel Prizes. Who founded the awards? Why? Who delivers the award? Where? Document your sources and present your findings in a brochure, poster, or presentation.

GROUP - B

STANDARD UNITS: Create a poster, chart or other presentation to be displayed in the classroom depicting standard units for length, mass and time. Depict examples ranging from the very large to the very small.

GROUP - C

PAKISTAN COUNCIL OF SCIENCE AND TECHNOLOGY: Write a publication essay for school library on Pakistan Council of Science and Technology. Define its role and function.

GROUP - D

HISTORY OF SI UNITS: Write an article for school library on how SI units of measurements came into being. Also describe how they are more convenient units.

GROUP - E

METRE RULE: Make a simple length measuring metre rule (from paper or any other easily available material) for use in school laboratory.

EXERCISE

MULTIPLE CHOICE QUESTIONS

1. How many millimeters are there in 10 cm?
   A. 100 mm B. 200 mm C. 50 mm D. 10 mm
2. Which of the following quantity can be measured using a micrometer?
   A. current B. force C. length D. mass
3. The instrument best measures the internal diameter of a pipe is
   A. screw gauge B. vernier caliper
   C. meter rule D. measuring tape
4. Which prefix represents a largest value?
   A. mega B. giga C. peta D. exa
5. Which of the following is the smallest prefix?
   A. atto B. pico C. nano D. femto
6. Which of the following numbers shows one significant digit?
   A. 1.1 B. 6.0 C. 7.1 D. 6×10^2
7. Which of the following numbers shows 4 significant digits?
   A. 900.8 B. 4 C. 5174.00 D. 0.0002
8. A light year is distance traveled by light in one year. It travels about 9.460×10^{15} m. How many significant figures are in this number
   A. 6 B. 2 C. 3 D. 4
9. 0.2 mm in units of meters is
   A. 0.0002m B. 2×10^{-4} m C. none D. both A and B
10. KITAB UL MANAZIR is the name of book written by
    A. Yaqub Kindi B. Ibnal Haitham
    C. Al Beruni D. none

CONCEPTUAL QUESTIONS

Give a brief response to the following questions.

1. How technology is shaped by physics?
2. Physics and biology are considered different branches of science, how physics links with biology?
3. Why are measurements important?
4. Why area is a derived quantity?
5. Name any four derived units and write them as their base units?
6. Why in physics we need to write in scientific notation?
7. What is least count? How least count for vernier calliper and screw gauge are defined?
8. How can we find the volume of a small pebble with the help of measuring cylinder?

COMPREHENSIVE QUESTIONS

Give an extended response to the following questions.

1. Define physics. How physics play a crucial role in science technology and society?
2. What is SI? Name SI base quantities and their units.
3. What are physical quantities? Distinguish between base and derived physical quantities.
4. What is standard form or scientific notation?
5. What are prefixes? Explain with examples.
6. Describe the construction and use for measurement of the following instruments:
   a. Vernier Calipers b. Screw gauge
7. What is meant by the significant figures of measurement? What are the main points to be kept in mind while determining the significant figures of a measurement?