As per the latest ICSE syllabus

9

Revised and Updated

Living Science
PHYSICS

Dhiren M Doshi

Ratna Sagar

Based on the latest syllabus prescribed by the
Council for the Indian School Certificate Examinations

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PHYSICS

9

Dhiren M Doshi

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Dhiren M Doshi is a well-known author of our highly popular series LIVING SCIENCE PHYSICS for ICSE schools for Classes 9 and 10. He has classroom teaching experience in Physics of more than 25 years. As a Physics resource person and a part of the In-service Teachers' Training Programme, he has conducted hundreds of 'Effective Science Teaching' workshops for teachers all over India.

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Preface

It gives me an immense pleasure in presenting this book—**Living Science Physics** for Class IX written strictly in accordance with the latest syllabus prescribed by the Council for the Indian School Certificate Examinations, New Delhi.

My aim and effort while writing this book was to help young readers understand, enjoy and appreciate the fascinating subject of Physics by making the process of learning enjoyable and stimulating. I have attempted to present the subject matter covering the entire prescribed syllabus in a simple language and interesting style with a large number of illustrative examples and practice problems to master the fundamental principles of Physics.

I have presented the various scientific concepts as vital, compelling and meaningful which might otherwise seem dull. Each part of the book has been carefully planned to make it student friendly and present Physics in an interesting, understandable and enjoyable manner. I have tried to stress the applications of what you are learning so that you can relate the facts to the living world.

Salient features of the book are as follows

1. A Structured Programme Learning Approach (SPLA) has been followed in which each chapter is divided into sub-topics followed by **exhaustive exercises** to test knowledge, understanding and application of concepts learnt in that sub-topic.
2. A large number of **solved numerical problems** as examples are given to familiarise the students with the procedure required for solving the numericals.
3. The text has been supplemented with a **large number of well-labelled accurate diagrams, tables and graphs.** The tables and graphs used in the text are capable of standing on their own (self-explanatory).
4. At the end of each sub-topic, **Multiple Choice Questions (MCQ)** have been given. These are very important tools for Competitive Examinations. Going through them will be equivalent to the revision of the whole sub-topic.
5. **Laws, definitions** and **important facts** to be understood are given in bold type.
6. At the end of each chapter, **a brief summary** is provided to highlight the key concepts. The summary is excellent for revision or to gain or overview of the topics covered in the chapter. Important Formulae of all the chapters are also given at the end for quick revision.

7. Additional questions and numerical problems strictly framed in accordance with the **ICSE Examination pattern** have been included at the end of each chapter to give students an ample practice in order to gain confidence and face all kinds of questions.

I sincerely hope that this book will serve its intended purpose and be received enthusiastically by both the students and the teachers. Constructive criticism and valuable suggestions from both teachers and learners are welcome for the improvement of the book.

With warm regards

Delhi **Dhiren M Doshi**

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CHAPTER 1

Measurements and Experimentation

In the present century, we find that science is held in high esteem. The word 'science' comes from a Latin verb '*scientia*' which means 'to know'. Man has always been curious to know more and more about things which surround him and affect him. **The knowledge which man has gained through observations and experiments, when organised systematically is called 'science'.**

Physics is an experimental science. We connect our theoretical description of nature with our experimental observation through quantitative measurements. In physics, we deal with a large number of physical quantities like length, mass, time, velocity, force and pressure. These quantities can give clear understanding only if we can measure them and express our conclusions into these measurements. For this reason, physics is sometimes called **the science of measurement.** For example, when a body is dropped from a height, it falls down to the surface of the earth. To understand this natural phenomenon, we must know why the body falls. With what velocity does it fall? Is this velocity a constant? What is the time taken by the body to reach the ground? Does this time depend upon its mass? And so on. To answer all these questions, measurement of distance, time, etc. are essential.

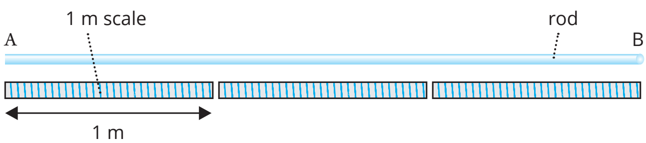

Fig. 1.1 Measurement of the length of the rod AB by using a metre scale

MEASUREMENT

Suppose we want to measure the length of a rod AB and we select metre as the unit of measurement. We place a metre scale successively along rod AB and find that it is contained 3 times in the rod. Thus, 3 is the **numeric value** of the length of rod AB, when **metre** is the unit of measurement. We write length of rod AB = 3 metres

Similarly, if mass of a body is 2 kilograms, it means that the unit of mass is kilogram and this unit is contained 2 times in the mass of the given body.

So for the measurement of a physical quantity, we consider a constant quantity as a standard and then find the number which expresses how many times the standard quantity is contained in the physical quantity. This standard quantity is called the **unit**.

Measurement is, thus, the comparison of unknown physical quantity with a known fixed unit quantity of the same nature.

SYLLABUS

International System of Units and other commonly used system of units – fps and cgs
Measurements using common instruments, Vernier callipers and micrometre screw gauge for length and simple pendulum for time.
Measurement of length using Vernier callipers and micrometre screw gauge. Decreasing least count leads to increase in accuracy; Least count (LC) of Vernier callipers and screw gauge, zero error (basic idea), no numerical problems on callipers and screw gauge; simple pendulum; time period, frequency, graph of length l vs. T^2 only; slope of the graph.
Formula $T = 2 \cdot \pi \cdot \sqrt{l/g}$ [No derivation]. Only simple numerical problems.

Hence to express the magnitude of a physical quantity, we should know two things:

1. The unit in which the quantity is measured.
2. The numeric value which expresses how many times the chosen unit is contained in the given physical quantity.

$$\therefore \quad \begin{bmatrix}\text{Magnitude of} \\ \text{physical quantity}\end{bmatrix} = \begin{bmatrix}\text{Numerical value of physical} \\ \text{quantity} \times \text{Size of its unit}\end{bmatrix}$$

If n is the numerical value of a physical quantity and u is the size of the unit then magnitude Q of the physical quantity is

$$Q = n\,u$$

Thus, when we say that the length of the rod AB is 3 m, i.e. $Q = 3$ m, it means $n = 3$, $u = 1$ m.

Characteristics of a standard unit

The **unit** chosen for measuring any physical quantity must have the following features:

1. It should be of convenient size.
2. It should be well defined.
3. It should be easily reproducible, i.e. replicas of the unit should be available easily.
4. It should not change with time and place.
5. It should not change with the change in physical conditions, e.g. temperature, pressure, etc.
6. It should be easily available and accessible.

Fundamental and derived units

As the number of physical quantities to be measured is very large, it is not feasible to define a separate unit for each quantity. Units are of two kinds.

1. **Fundamental or basic units**
2. **Derived units**

We treat length, mass and time as the three **fundamental** or **basic quantities** which can give full description of the physical world.

The units of measurement of length, mass and time are independent of each other, not definable in terms of other quantities and units of all other physical quantities can be obtained from them. These three units are called the fundamental or basic units.

The units of measurement of all other physical quantities which can be expressed in terms of the fundamental units (i.e. mass, length and time) are called derived units.

For example, the unit of speed is a derived unit.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

$$\therefore \quad \text{Unit of speed} = \frac{\text{Unit of distance (length)}}{\text{Unit of time}}$$

Thus, the unit of speed can be expressed in the fundamental units of length and time, i.e. m/s or m s^{-1}.

Similarly, the unit of acceleration is a derived unit.

$$\text{Acceleration} = \frac{\text{Velocity}}{\text{Time}} = \frac{\text{Displacement}}{(\text{Time})^2}$$

$$\left[\text{Since, Velocity} = \frac{\text{Displacement}}{\text{Time}}\right]$$

$$\therefore \quad \text{Unit of acceleration} = \frac{\text{Unit of displacement (length)}}{(\text{Unit of time})^2}$$

Thus, the unit of acceleration can be expressed in the fundamental units of length and time, i.e. m/s^2 or m s^{-2}.

Similarly, the units of physical quantities like density, momentum, force, work, power and energy can also be expressed in terms of fundamental units of length, mass and time. Their units are all **derived units**.

Old system of units

Different units were assigned for mass and length in different countries. The common systems of units are given below:

1. **CGS system:** It is the Gaussian system, which uses **centimetre, gram** and **second** as the three basic units of length, mass and time respectively.
2. **FPS system:** It is the British engineering system of units, which uses **foot** as the unit of length, **pound** as the unit of mass and **second** as the unit of time.
3. **MKS system:** It uses **metre** as the unit of length, **kilogram** as the unit of mass and **second** as the

unit of time. When MKS system is extended to electricity, then with current as fundamental quantity, ampere (A) is taken as its unit. It is then called MKSA system.

However, the above mentioned systems (CGS, FPS, MKS) had their own **drawbacks** and **problem of coherence** and so, are no longer used. Now, we use the SI system of units which are more scientific, convenient and have been accepted by all the countries for scientific work.

INTERNATIONAL SYSTEM OF UNITS – THE SI UNITS

To make measurements more scientific, convenient and uniform, the French Academy of Science in 1792 designed a metric system of measurement based on the decimal system.

In October 1960, the XIth General Conference on Weights and Measures adopted an international system of units called **SI units**. The name SI is an abbreviation of the "Systeme International d' Unites" in French, which means **International System of Units.**

Base units

In SI system, there are seven base units corresponding to seven base physical quantities. The names of base physical quantities and their corresponding units are given in Table 1.1.

TABLE 1.1 SI base units

S. No.	Base quantity	SI unit	
	Name	Name	Symbol
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Electric current	ampere	A
5.	Temperature	kelvin	K
6.	Luminous intensity	candela	cd
7.	Amount of substance (or quantity of matter)	mole	mol

There are two supplementary quantities in addition to seven fundamental quantities. They are:

1. **Plane angle.** The SI unit of plane angle is radian.
2. **Solid angle.** The SI unit of solid angle is steradian.

Derived units

In addition to the base units, there are a large number of derived units in this system. Some of the derived units with complex names are given in Table 1.2.

TABLE 1.2 Derived units

Derived quantity	Unit	Symbol
Volume	cubic metre	m^3
Density	kilogram per cubic metre	$kg\ m^{-3}$
Velocity	metre per second	$m\ s^{-1}$
Acceleration	metre per second squared	$m\ s^{-2}$
Momentum	kilogram metre per second	$kg\ m\ s^{-1}$

Some derived units are given special names due to their complexity when expressed in terms of the base units, as given in Table 1.3.

TABLE 1.3 Derived units with special names

S. No.	Physical Quantity	Derived Unit	Symbol
1.	Force	newton	N
2.	Pressure	pascal	Pa
3.	Work, Energy	joule	J
4.	Power	watt	W
5.	Frequency	hertz	Hz
6.	Electric charge	coulomb	C
7.	Electric resistance	ohm	Ω
8.	Electromotive force (Potential difference)	volt	V

UNIT OF LENGTH

The SI unit of length is metre. **One metre is defined as the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second.**

Subunits of metre

For the measurement of small lengths, metre is considered too big a unit. The most commonly used subunits of metre are as follows:

- 1 dm (decimetre) = $\frac{1}{10}$ m = 10^{-1} m
- 1 cm (centimetre) = $\frac{1}{100}$ m = 10^{-2} m
- 1 mm (millimetre) = $\frac{1}{1000}$ m = 10^{-3} m
- 1 μm (micrometre) = $\frac{1}{1000000}$ m = 10^{-6} m
- 1 nm (nanometre) = $\frac{1}{1000000000}$ m = 10^{-9} m
- 1 Å (angstrom) = $\frac{1}{10000000000}$ m = 10^{-10} m
- 1 fm (fermi) = $\frac{1}{1000000000000000}$ m = 10^{-15} m

Multiple units of metre

For the measurement of large lengths, metre is considered too small a unit. The most commonly used multiple units of metre are

- 1 dam (decametre) = 10 m
- 1 hm (hectometre) = 100 m = 10^2 m
- 1 km (kilometre) = 1000 m = 10^3 m

Practical units for large distances

In order to measure very large distances, we use the following three units.

- **Astronomical Unit (AU): One astronomical unit is the mean distance between the centres of the earth and the sun**, i.e.

  1 astronomical unit = 1.496×10^{11} m

  or 1 AU = 1.496×10^{11} m

- **Light year (ly): One light year is the distance travelled by light in vacuum in one year**, i.e.

1 light year = Speed of light in vacuum × Time

$= 3 \times 10^8 \text{ m s}^{-1} \times 1 \text{ year}$

$= 3 \times 10^8 \text{ m s}^{-1} \times (365 \times 24 \times 60 \times 60) \text{ s}$

$= 9.46 \times 10^{15}$ m

i.e. 1 ly = 9.46×10^{15} m

- **Parsec: One parsec is 3.26 times the light year,** i.e. 1 parsec = 3.26 light years

$= 3.26 \times (9.46 \times 10^{15} \text{ m})$

1 parsec = 3.08×10^{16} m

UNIT OF MASS

The SI unit of mass is kilogram. **One kilogram is defined as the mass equal to the mass of a standard platinum-iridium alloy cylinder (90% platinum and 10% iridium) kept at 0 °C at the International Bureau of Weights and Measures at Sevres, near Paris in France.**

Subunits of kilogram

For the measurement of smaller masses, kilogram is considered too big a unit. The most commonly used subunits of kilogram are

- 1 g (gram) = $\frac{1}{1000}$ kg = 10^{-3} kg
- 1 mg (milligram) = $\frac{1}{1000000}$ kg = 10^{-6} kg

Multiple units of kilogram

For the measurement of larger masses, kilogram is considered too small a unit. The most commonly used multiples of kilogram are

- 1 quintal = 100 kg = 10^2 kg
- 1 ton or 1 metric ton = 1000 kg = 10^3 kg

Practical units for mass

- For measuring very small masses, the smallest practical unit of mass is atomic mass unit (u).

  1 u (atomic mass unit) = 1.66×10^{-27} kg

  The atomic and nuclear masses are measured in this unit.

- The largest practical unit of mass is **Chandra-shekhar Limit (CSL) or Chandrashekhar mass limit.**

  1 CSL = 1.44 times the mass of the sun

UNIT OF TIME

The SI unit of time second. **One second is the time needed for 9,192,631,770 vibrations of the radiation corresponding to the transition between**

the two hyperfine levels of the ground state of the caesium–133 atom.

Practical units of time

- **Solar day:** It is the time taken by the earth to complete one rotation about its axis with respect to the sun.

$$\begin{aligned} 1 \text{ mean solar day} &= 24 \text{ hours} \\ &= 24 \times 60 \text{ minutes} \\ &= 24 \times 60 \times 60 \text{ seconds} \\ 1 \text{ mean solar day} &= 86400 \text{ seconds} \end{aligned}$$

or $$1 \text{ second} = \frac{1}{86400} \text{ mean solar day}$$

- $$1 \text{ minute (min)} = 60 \text{ s}$$
- $$\begin{aligned} 1 \text{ hour (h)} &= 60 \text{ minutes} \\ &= 60 \times 60 \text{ s} \\ &= 3600 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ common lunar year} &= 354 \text{ days} \\ &= 354 \times 86400 \text{ s} \\ &= 30585600 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ common solar year} &= 365 \text{ days} \\ &= 365 \times 86400 \text{ s} \\ &= 31536000 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ leap year} &= 366 \text{ days} \\ &= 366 \times 86400 \text{ s} \\ &= 31622400 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ decade} &= 10 \text{ years} \\ &= (8 \times 365 + 2 \times 366) \text{ days} \\ &= (2920 + 732) \text{ days} \\ &= 3652 \text{ days} \\ &= 3652 \times 86400 \text{ s} \\ 1 \text{ decade} &= 3.1536 \times 10^8 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ century} &= 100 \text{ years} \\ &= (76 \times 365 + 24 \times 366) \text{ days} \\ &= (27740 + 8784) \text{ days} \\ &= 36524 \text{ days} \\ &= 36524 \times 86400 \text{ s} \\ 1 \text{ century} &= 3.16 \times 10^9 \text{ s} \end{aligned}$$
- $$\begin{aligned} 1 \text{ millennium} &= 1000 \text{ years} \\ &= (760 \times 365 + 240 \times 366) \text{ days} \\ &= (277400 + 87840) \text{ days} \\ &= 365240 \text{ days} \\ &= 365240 \times 86400 \text{ s} \\ 1 \text{ millennium} &= 3.16 \times 10^{10} \text{ s} \end{aligned}$$
- $$1 \text{ millisecond (ms)} = 10^{-3} \text{ s}$$
- $$1 \text{ microsecond } (\mu\text{s}) = 10^{-6} \text{ s}$$
- $$1 \text{ nanosecond (ns)} = 10^{-9} \text{ s}$$
- $$1 \text{ picosecond (ps)} = 10^{-12} \text{ s}$$

SI prefixes

The physical quantities whose magnitudes are either too large or too small can be expressed more compactly by the use of certain prefixes. For example,

1. The height of Mount Everest is 884800 cm. We prefer to say it as 8848 m.
2. The weight of an average man is 60000 g. We prefer to say it as 60 kg.
3. The earth takes 86400 seconds to complete one rotation about its axis with respect to the sun. We prefer to say it as one solar day.

The prefixes we commonly use for powers of 10 are listed in Table 1.4.

Some of the most commonly used units with prefixes are

$$\begin{aligned} 1 \text{ micrometre} &= 1 \ \mu\text{m} = 10^{-6} \text{ m} \\ 1 \text{ millimetre} &= 1 \text{ mm} = 10^{-3} \text{ m} \\ 1 \text{ kilometre} &= 1 \text{ km} = 10^{3} \text{ m and so on.} \end{aligned}$$

Table 1.4 SI prefixes for multiple and submultiples of units

Power of 10	Prefix	Symbol
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h

10^1	deca	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Conventions in writing the SI units and their symbols

The conventions (rules) that should be strictly followed while writing SI units are as follows:

1. In writing the value of a physical quantity, the number and the unit are separated by a space. For example, 100 m is correct but not 100m.
2. No space is to be given between number and °C, degree, minute and second of a plane angle.
3. The symbols for the units of quantities, which are not named after scientists, are written in small letters. For example, the symbol for metre is 'm' and that for kilogram is 'kg'.

Correct	*Incorrect*
m	M
kg	KG
s	S

4. The symbols for the units named after scientists are written with first letter of the name in capital letters. For example, the symbol for the unit of temperature named after scientist Kelvin is written as K. Similarly, the symbol for the unit of force named after scientist Newton is written as N. The symbol for the unit of pressure named after Pascal is written as Pa.

Correct	*Incorrect*
K	k
N	n
J	j

5. To write the full name of a unit, the name is always written in small letters, even if it is the name of a scientist. For example, the full name of unit K is kelvin.

Correct	*Incorrect*
kelvin	Kelvin
joule	Joule
newton	Newton

6. The symbol of a unit is never written in plural but when written in words, plural is used. For example, symbol for 12 kilograms is 12 kg.

Correct	*Incorrect*
12 kg	12 kgs
10 N	10 Ns
5 m	5 ms

7. The symbol for a unit is not followed by a full stop until it appears at the end of a sentence.

Correct	*Incorrect*
kg	kg.
cm	cm.
s	s.

8. In writing units for physical quantities, words and symbols should not be mixed. For example, the unit of speed is metre/second or m s^{-1}.

Correct	*Incorrect*
metre/second	metre/s
m s^{-1}	m/second
newton-metre	newton-m
N m	N-metre

9. A compound unit formed by multiplication of two or more units is written after leaving a space or a middle dot (·) between the symbols. For example, unit of torque is written as N m or N · m.
10. For a compound unit formed by division of units, the division is indicated by a horizontal line or a solidus (oblique stroke, /) or negative powers. For example, the unit of velocity is $\frac{m}{s}$ or m/s or m s^{-1}.
11. For numbers less than unity, zero should be inserted to the left of the decimal point. For example, 0.579 kg is correct but not .579 kg.

CHECK YOUR PROGRESS

A. Choose the most appropriate answer.

1. Physics is sometimes called the science of
   a. electricity. b. heat. c. measurement. d. light.
2. Which one of the following is not a fundamental unit of measurement?
   a. mass b. density c. length d. time
3. The SI unit of temperature is
   a. °C. b. °F. c. K. d. none of these
4. One light year is equivalent to
   a. 9.46×10^{14} m. b. 9.46×10^{15} m. c. 9.46×10^{16} m. d. 9.46×10^{20} m.
5. 1 micrometre is equivalent to
   a. 10^{-3} m. b. 10^{-6} m. c. 10^{-9} m. d. 10^{-12} m.

B. Answer these questions.

1. What is meant by measurement?
2. Define the term 'unit'.
3. Distinguish between fundamental unit and derived unit.
4. Describe the following system of units:
   a. CGS system b. FPS system c. MKS system d. SI system
5. Name the two supplementary physical quantities introduced to the SI system. Write their SI units.
6. Name the SI unit of length and define it.
7. What is the equivalence of the following and the SI unit of length?
   a. 1 cm b. 1 micrometre c. 1 nanometre d. 1 angstrom
8. Name any two units of length bigger than metre.
9. Define the following units:
   a. Astronomical unit b. Light year c. Parsec
10. Name the SI unit of mass and define it.
11. Name the SI unit of time and define it.
12. What is the equivalence of the following and the SI unit of time?
    a. 1 solar day b. 1 solar year c. 1 leap year d. 1 century
    e. 1 microsecond f. 1 nanosecond g. 1 picosecond
13. Name any four conventions that should be strictly followed while writing SI units.

C. Solve these numericals.

1. The radius of proton is 10^{-15} m. Express it in
   a. femtometre b. nanometre c. millimetre d. centimetre
   [**Ans. a.** 1 femtometre **b.** 10^{-6} nanometre **c.** 10^{-12} millimetre **d.** 10^{-13} centimetre]
2. What is the weight of a body of mass 10^6 kg? (Take g = 10 m s^{-2}) (**Hint:** $W = m \times g$) [**Ans.** $W = 10^7$ N]
3. The thickness of a paper is 10^{-4} m. Find the number of papers in 1 metre. [**Ans.** 10^4]
4. What is the distance in km of a star from the earth from which light takes 10 years to reach us?
   [**Ans.** Distance = 9.46×10^{16} km]

MEASUREMENT OF LENGTH

Least count of a measuring instrument

Metre scale is commonly used for measuring lengths. Using it, we can accurately measure lengths up to a minimum of 1 mm because the length of the smallest division made on this metre scale is 1 mm.

The smallest value of a physical quantity which can be measured accurately with an instrument is called the least count (LC) of the measuring instrument. So, the least count of a metre scale is 1 mm.

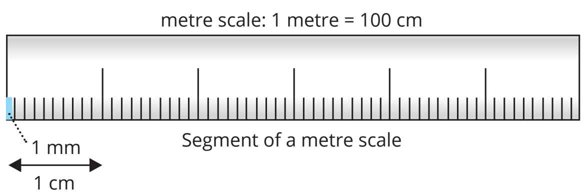

Fig. 1.2 Metre scale

VERNIER CALLIPERS

It is a device used to measure lengths accurately up to $\frac{1}{10}$th of a millimetre. It was designed by a French mathematician **Pierre Vernier**, and hence the instrument is named Vernier.

Principle of a Vernier

Vernier callipers comprise two scales, viz. the **Vernier scale (V)** and the **main scale (S)**. The main scale S is fixed but the Vernier scale V is movable. The Vernier scale slides along the main scale.

The main scale is marked in centimetres and each centimetre is divided into ten parts, that is, millimetres.

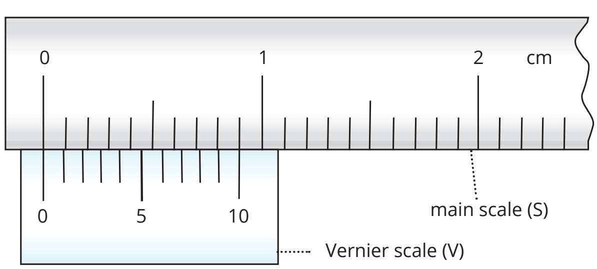

Fig. 1.3 Principle of Vernier

Vernier scale consists of ten divisions that are equal in length to nine millimetres on the main scale. An enlarged view of the same is shown in Figure 1.3.

Vernier constant (Least count of Vernier callipers)

Suppose the size of one main scale division is **S units** and that of one Vernier scale division is **V units**. Also suppose that the length of m Vernier divisions is equal to the length of $(m - 1)$ main scale divisions, since m Vernier divisions coincide with $(m - 1)$ main scale divisions. Therefore, the length of $(m - 1)$ main scale divisions = length of m Vernier scale divisions. Symbolically,

$$(m - 1)S = mV$$

or $$mS - S = mV$$

or $$mS - mV = S$$

or $$m(S - V) = S$$

or $$S - V = \frac{S}{m}$$

or $$S - V = \frac{\text{Value of one main scale division}}{\text{Total number of divisions on the Vernier scale}}$$

The quantity $(S - V)$ represents **the difference between the size of the smallest division on the main scale and the size of one Vernier division**. This quantity $(S - V)$ is called **Vernier constant**.

The Vernier constant of an instrument always remains constant. The Vernier constant of the instrument tells us about the smallest length that can be accurately measured with the instrument. So, Vernier constant is the least count of the Vernier callipers.

Least count of Vernier callipers (Least Count)

$$= \frac{\text{Value of one main scale division}}{\text{Total number of divisions on the Vernier scale}}$$

The least count of Vernier callipers can be calculated by using the principle of Vernier. The length of one small division on the main scale is 1 mm, i.e. S = 1 mm.

$$\therefore \quad \text{Least count} = \frac{S}{m}$$

$$= \frac{1\text{ mm}}{10 \text{ divisions on the Vernier scale}}$$