TOPIC 1 Physical Quantities and Their Units

SQ 1.1.1 On what does the foundation of physics depend?

Answer

The foundation of physics depends on physical quantities, in terms of which the laws of physics are expressed. Therefore these quantities have to be measured accurately.

SQ 1.1.2 Give some examples of physical quantities.

Examples

Mass, length, time, velocity, force, density, temperature and electric current are physical quantities.

SQ 1.1.3 Into how many categories are physical quantities divided?

Categories

Physical quantities are often divided into two categories, base quantities and derived quantities.

SQ 1.1.4 What are base quantities?

Definition

Base quantities are not defined in terms of other physical quantities. They are the independent physical quantities in terms of which the other physical quantities can be defined.

Examples

Length, mass and time are typical examples of base quantities.

SQ 1.1.5 What are derived quantities?

Definition

Derived quantities are those which depend on base quantities.

Examples

Velocity, acceleration and force are examples of derived quantities.

SQ 1.1.6 Differentiate between base quantities and derived quantities.

Base Quantities	Derived Quantities
They are not defined in terms of other physical quantities.	They depend on the base quantities.
They are independent physical quantities.	They are obtained from base quantities.
Length, mass and time are examples.	Velocity, acceleration and force are examples.

SQ 1.1.7 What two steps are involved in the measurement of a base quantity?

First Step

The choice of a standard.

Second Step

The establishment of a procedure for comparing the quantity to be measured with the standard, so that a number and a unit are determined as the measure of that quantity.

SQ 1.1.8 Why must measurements be reliable and accurate?

Reason

Measurements must be reliable and accurate so that they can be used easily and effectively.

SQ 1.1.9 Name any five areas of physics.

Areas

Mechanics, heat and thermodynamics, electromagnetism, optics and sound are areas of physics.

SQ 1.1.10 Name any three interdisciplinary areas of physics.

Interdisciplinary Areas

Astrophysics, biophysics and chemical physics are interdisciplinary areas of physics.

TOPIC 2 International System of Units

SQ 1.2.1 What is the International System of Units?

Answer

In 1960 an international committee agreed on a set of definitions and standards to describe the physical quantities. The system that was established is called the System International (SI).

SQ 1.2.2 Who uses SI units?

Answer

SI units are used by the world's scientific community and by almost all nations.

SQ 1.2.3 Of how many kinds of units does the System International consist?

Answer

The System International consists of two kinds of units, base units and derived units.

SQ 1.2.4 How many base units are there? Name them.

Number

There are seven base units for physical quantities.

Names

Length, mass, time, temperature, electric current, light or luminous intensity and amount of substance.

SQ 1.2.5 Write the SI base units of length, mass and time with their symbols.

Length

metre, symbol m

Mass

kilogram, symbol kg

Time

second, symbol s

SQ 1.2.6 **Write the SI base units of electric current and thermodynamic temperature.**

Electric Current
ampere, symbol A

Thermodynamic Temperature
kelvin, symbol K

SQ 1.2.7 **Write the SI base units of luminous intensity and amount of substance.**

Luminous Intensity
candela, symbol cd

Amount of Substance
mole, symbol mol

SQ 1.2.8 **Why are prefixes used with base units?**

Reason
Prefixes such as milli, micro and kilo may be used with base units to express smaller or larger quantities.

SQ 1.2.9 **What are derived units?**

Definition
Derived units are those units which depend on the base units.

SQ 1.2.10 **Write the derived units of plane angle and solid angle.**

Plane Angle
radian, symbol rad, and it is dimensionless.

Solid Angle
steradian, symbol sr, and it is dimensionless.

SQ 1.2.11 **When were the units of plane angle and solid angle included in the list of derived units?**

Answer
The units of plane angle and solid angle have been included in the list of derived units since 1995.

SQ 1.2.12 **Write the derived unit of force in terms of base units.**

Unit
newton, symbol N

In Base Units
$1\,\mathrm{N} = 1\,\mathrm{kg\,m\,s^{-2}}$

SQ 1.2.13 **Write the derived unit of work in terms of base units.**

Unit
joule, symbol J

In Base Units
$1\,\mathrm{J} = 1\,\mathrm{N\,m} = 1\,\mathrm{kg\,m^2 s^{-2}}$

SQ 1.2.14 **Write the derived unit of power in terms of base units.**

Unit
watt, symbol W

In Base Units
$1\,\mathrm{W} = 1\,\mathrm{J\,s^{-1}} = 1\,\mathrm{kg\,m^2 s^{-3}}$

SQ 1.2.15 **Write the derived unit of electric charge in terms of base units.**

Unit
coulomb, symbol C

In Base Units
$1\,\mathrm{C} = 1\,\mathrm{A\,s}$

SQ 1.2.16 **Write the derived unit of pressure in terms of base units.**

Unit
pascal, symbol Pa

In Base Units
$1\,\mathrm{Pa} = 1\,\mathrm{N\,m^{-2}} = 1\,\mathrm{kg\,m^{-1} s^{-2}}$

SQ 1.2.17 **Which traditional mathematical units of angle does the SI permit?**

Answer
The SI permits the traditional mathematical units for measuring angles, which are the degree, arcminute and arcsecond.

SQ 1.2.18 **Which traditional units of standard time does the SI permit?**

Answer
The SI permits the minute, hour, day and year as traditional units of standard time.

SQ 1.2.19 **Which logarithmic unit does the SI permit?**

Answer
The SI permits the logarithmic unit bel, and its multiples such as the decibel.

SQ 1.2.20 **Which two metric units commonly used in ordinary life does the SI permit?**

Answer
The litre for volume and the tonne (metric ton) for large masses.

SQ 1.2.21 **Name the two non-metric scientific units permitted by the SI.**

Answer
The atomic mass unit (u) and the electron volt (eV).

SQ 1.2.22 **Which units traditionally used at sea and in meteorology does the SI permit?**

Answer
The nautical mile and the knot.

SQ 1.2.23 **Name the common metric units of land area permitted by the SI.**

Answer
The acre and the hectare are common metric units of land area.

SQ 1.2.24 **Where is the bar commonly used as a unit of pressure?**

Answer
The bar is commonly used as the millibar in meteorology and as the kilobar in engineering.

SQ 1.2.25 **In which fields are the angstrom and the barn used?**

Answer
The angstrom and the barn are units used in physics and astronomy.

SQ 1.2.26 **What is scientific notation?**

Definition
Numbers expressed in the standard form which employs powers of ten are said to be in scientific notation.
Practice
The internationally accepted practice is that there should be only <u>one non-zero digit</u> to the left of the decimal.

SQ 1.2.27 **Write 134.7 and 0.0023 in scientific notation.**

Answer
$134.7 = 1.347 \times 10^2$
$0.0023 = 2.3 \times 10^{-3}$

SQ 1.2.28 **Write 143.7 in scientific notation.**

Answer
$143.7 = 1.437 \times 10^2$

SQ 1.2.29 **What is the purpose of prefixes?**

Purpose
Most prefixes indicate order of magnitude in steps of 1000. They provide a convenient way to express large and small numbers and to eliminate <u>non-significant digits</u>.

SQ 1.2.30 **Name the four prefixes included in the SI to accommodate earlier usage.**

Prefixes
The four prefixes are centi (10^{-2}), deci (10^{-1}), deca (10^1) and hecto (10^2).

SQ 1.2.31 **Write the prefixes for the factors 10^{-12}, 10^{-9} and 10^{-6}.**

Answer
10^{-12} is pico (p)
10^{-9} is nano (n)
10^{-6} is micro (μ).

SQ 1.2.32 **Write the prefixes for the factors 10^3, 10^6 and 10^9.**

Answer
10^3 is kilo (k)
10^6 is mega (M)
10^9 is giga (G).

SQ 1.2.33 **Why is each SI unit represented by a symbol and not an abbreviation?**

Reason
Each SI unit is represented by a symbol, not an abbreviation, because these symbols are the <u>same in all languages</u>. Hence correct use of the symbol is very important.
Example
For ampere we should use “A” not “amp”, and for seconds “s” not “sec”.

SQ 1.2.34 **Does the full name of a unit begin with a capital letter?**

Answer
No. The full name of a unit does not begin with a capital letter.
Example
We write newton and metre, with the exception of Celsius.

SQ 1.2.35 **In which case do symbols appear in lower case?**

Answer
Symbols appear in lower case, such as “m” for metre and “s” for second, with the exception of “L” for litre.

SQ 1.2.36 **Which symbols have initial capital letters?**

Answer
Symbols named after scientists have initial letters capital, such as “N” for newton, “Pa” for pascal and “W” for watt.

SQ 1.2.37 **In which style are symbols and prefixes printed?**

Answer
Symbols and prefixes are printed in upright (roman) style, regardless of the type style in the surrounding text.

SQ 1.2.38 **Do symbols take the plural form?**

Answer
No. Symbols do not take the plural form. For example we write 1 mm
100 mm
1 kg and 60 kg.

SQ 1.2.39 **Is a full stop placed after a unit symbol?**

Answer
No full stop or dot is placed after the symbol, except at the <u>end of the sentence</u>.

SQ 1.2.40 **How is a prefix written with a base unit?**

Answer
A prefix is written before and without space to the base unit. For example we write “mL” and not “m L”.

SQ 1.2.41 **How are base units written in an expression?**

Answer
Base units are written one space apart, and a space is left even between the number and the symbol, as in 1 kg and $10\ \mathrm{m\ s^{-1}}$.

SQ 1.2.42 **Are compound prefixes allowed?**

Answer
No, compound prefixes are not allowed. For example, 1 $\mu\mu$F should be written as 1 pF.

SQ 1.2.43 **When a base unit with a multiple is raised to a power, to what does the power apply?**

Rule
The power applies to the whole multiple and not to the base unit alone.
Example
$1\ \mathrm{km}^2 = (10^3\ \mathrm{m})^2 = 1 \times 10^6\ \mathrm{m}^2$

SQ 1.2.44 **Which notation should be used instead of the solidus?**

Answer
Negative index notation such as $\mathrm{m\,s^{-1}}$ should be used instead of the solidus $\mathrm{m/s}$.

SQ 1.2.45 **Can symbols and names be mixed in the same expression?**

Answer
No. We should write metre per second or $\mathrm{m\,s^{-1}}$, and not metre/sec or m/second.

SQ 1.2.46 **In which units should practical work be recorded?**

Answer
Practical work should be recorded in the most convenient units, depending upon the instruments being used. The final results must be recorded in the appropriate base units.

SQ 1.2.47 **Which former CGS units are not allowed in the System International?**

Answer
The System International does not allow the use of former CGS system units such as dyne, erg, gauss, poise and torr.

TOPIC 3 Uncertainty in Measurement

SQ 1.3.1 **Why does every measured quantity have some uncertainty?**

Reason
Every instrument is calibrated to a certain smallest division mark on it, and this fact puts a limit regarding its accuracy. Hence every measured quantity has some uncertainty about its value.

SQ 1.3.2 **What is the limit of measurement of an instrument?**

Answer
When a reading is taken with an instrument, its limit of measurement is the smallest division or graduation on its scale.

SQ 1.3.3 **What is absolute uncertainty?**

Definition
The maximum uncertainty estimated as being one smallest division of the instrument is called absolute uncertainty.

Example
It is one millimetre on a metre rule that is graduated in millimetres.

SQ 1.3.4 **To what is the absolute uncertainty of an instrument equal?**

Answer
The absolute uncertainty is in fact equal to the least count of the instrument.

SQ 1.3.5 **One edge of a book coincides with the 10.0 cm mark and the other with 33.5 cm. Find its length with uncertainty.**

Solution
$(33.5 \pm 0.05) - (10.0 \pm 0.05)$

Result
$\text{Length} = (23.5 \pm 0.1)\,\text{cm}$

Meaning
The true length of the book lies between $23.4\,\text{cm}$ and $23.6\,\text{cm}$.

SQ 1.3.6 **Define fractional uncertainty.**

Definition
Fractional uncertainty is the ratio of the uncertainty to the measured value.

Formula
$$\text{Fractional uncertainty} = \frac{\text{Uncertainty}}{\text{Measured value}}$$

SQ 1.3.7 **Define percentage uncertainty.**

Definition
Percentage uncertainty is the fractional uncertainty expressed as a percentage.

Formula
$$\text{Percentage uncertainty} = \frac{\text{Uncertainty}}{\text{Measured value}} \times 100\%$$

SQ 1.3.8 **How is uncertainty indicated in a digital instrument?**

Answer
With a digital scale one digit beyond what is certain is estimated, and this is reflected in some fluctuations of the last digit.

SQ 1.3.9 **What should be done if the last digit of a digital instrument fluctuates by 1 or 2?**

Answer
If the last digit fluctuates by 1 or 2, then that last digit should be written down.

SQ 1.3.10 **What does a large fluctuation in the last digit of a digital instrument mean?**

Answer
If the fluctuation is more than 2 or so, the reading may be influenced by some factor such as air currents. A large fluctuation may mean that the displayed digit is not really significant.

SQ 1.3.11 **How has the indication of uncertainty in a recorded value been simplified?**

Answer
The indication of uncertainty in a recorded value has been simplified by using significant figures.

SQ 1.3.12 **What does the last digit of a value recorded with significant figures indicate?**

Answer
Its last digit, which is an estimation, is an indication of the accuracy of the recorded value.

SQ 1.3.13 **What is meant by least count of an instrument?**

Definition

The least count of an instrument is the smallest division or graduation on its scale, and it is equal to the absolute uncertainty of that instrument.

SQ 1.3.14 **What is the least count of a metre rule graduated in millimetres?**

Answer

The least count of a metre rule graduated in millimetres is one millimetre, i.e. 0.1 cm.

SQ 1.3.15 **What is the least count of Vernier Callipers?**

Answer

The least count of Vernier Callipers is 0.01 cm.

SQ 1.3.16 **What is the least count of a micrometer screw gauge?**

Answer

The least count of a micrometer screw gauge is 0.001 cm.

SQ 1.3.17 **How is the uncertainty found for an average of many readings?**

Answer

For the average value of many readings, the uncertainty is the mean deviation from the average.

SQ 1.3.18 **How is the uncertainty found in a timing experiment?**

Answer

For a periodic uncertainty, the least count of the timing device is divided by the number of vibrations measured.

TOPIC 4 Use of Significant Figures

SQ 1.4.1 **What are significant figures?**

Definition

The number of digits of a measurement about which we do feel reasonably sure are called significant figures.

Statement

In any measurement, the accurately known digits and the first estimated or doubtful digit are called significant figures.

SQ 1.4.2 **What do significant figures reflect?**

Answer

Significant figures in fact reflect the use of the actual instrument used for that measurement.

SQ 1.4.3 **Why must the result of a calculator be rounded off?**

Reason

While using a calculator the result of any calculation contains many digits after the decimal point. These additional digits may mislead another person into believing them, so they are to be rounded off to the correct number of significant figures.

SQ 1.4.4 **What should be kept in view while recording observations?**

Answer

The uncertainty or the least count of the instrument should be kept in view while recording observations and while quoting the results of any calculations.

SQ 1.4.5 **Why is it better to quote a result in scientific notation?**

Reason

It is better to quote the result in scientific notation to avoid any ambiguity regarding the number of significant figures.

SQ 1.4.6 **What does proper use of significant figures ensure?**

Answer

Proper use of significant figures ensures that we correctly represent the uncertainty of our measurements.

SQ 1.4.7 **Why is a reported mass of 3.145 g more accurate than 3.1 g?**

Reason

The reported mass 3.145 g has more significant figures, which reflects the use of a better or more precise instrument.

SQ 1.4.8 **What happens as the quality of measuring instruments improves?**

Answer

As we improve the quality of our measuring instrument and techniques, we extend the result to more and more significant figures and correspondingly improve the experimental accuracy of the result.

SQ 1.4.9 **Which digits are always significant?**

Rule

All digits 1, 2, 3, 4, 5, 6, 7, 8, 9 are significant. However, zeros may or may not be significant.

SQ 1.4.10 **Is a zero between two significant figures significant?**

Rule

Yes. A zero between two significant figures is itself significant.

SQ 1.4.11 **Are zeros to the left of the leftmost significant figure significant?**

Rule

No. Zeros to the left of the most significant figure are not significant.

Example

None of the zeros in 0.00467 or 02.59 are significant.

SQ 1.4.12 **Are zeros to the right of a significant figure in a decimal fraction significant?**

Rule

Yes. In a decimal fraction, zeros to the right of a significant figure are significant.

Example

All the zeros in 3.570 or 7.4000 are significant.

SQ 1.4.13 **How is the number of significant zeros determined in an integer such as 8000 kg?**

Rule

In integers, the number of significant zeros is determined by the precision of the measuring instrument.

Example

If the least count is 1 kg there are four significant figures, written as 8.000×10^3 kg; if it is 10 kg there are three, written as 8.00×10^3 kg.

SQ 1.4.14 **Which figures are significant in a measurement recorded in scientific notation?**

Rule

When a measurement is recorded in scientific notation or standard form, the figures other than the powers of ten are significant figures.

Example

8.70×10^4 kg has three significant figures.

SQ 1.4.15 **How many significant figures are retained while multiplying or dividing numbers?**

Rule

Keep a number of significant figures in the product or quotient not more than that contained in the least accurate factor, i.e. the factor containing the least number of significant figures.

SQ 1.4.16 **How many decimal places are retained while adding or subtracting numbers?**

Rule

The number of decimal places retained in the answer should be equal to the smallest number of decimal places in any of the quantities being added or subtracted.

Note

In this case it is the position of the decimal that matters, not the number of significant figures.

SQ 1.4.17 **What is the rule when the first digit dropped is less than 5?**

Rule

If the first digit dropped is less than 5, the last digit retained should remain unchanged.

SQ 1.4.18 **What is the rule when the first digit dropped is more than 5?**

Rule

If the first digit dropped is more than 5, the digit to be retained is increased by one.

SQ 1.4.19 **What is the rule when the digit to be dropped is exactly 5?**

Rule

If the digit to be dropped is 5, the previous digit which is to be retained is increased by one if it is odd, and retained as such if it is even.

SQ 1.4.20 **Round off 43.75 and 56.8546 to three significant figures.**

Answer

43.75 is rounded off as 43.8

56.8546 is rounded off as 56.9.

SQ 1.4.21 **Round off 73.650 and 64.350 to three significant figures.**

Answer

73.650 is rounded off as 73.6, because the retained digit 6 is even.

64.350 is rounded off as 64.4, because the retained digit 3 is odd.

SQ 1.4.22 **Add 72.1 m, 3.42 m and 0.003 m to the correct number of decimal places.**

Solution

The sum is 75.523 m.

Rounding

The number 72.1 has the smallest number of decimal places, so the answer is rounded to the same position.

Result

75.5 m

SQ 1.4.23 **Add 2.7643 m, 4.10 m and 1.273 m to the correct number of decimal places.**

Solution

The sum is 8.1373 m.

Rounding

The number 4.10 has the smallest number of decimal places, so the answer is rounded to the same position.

Result

8.13 m

SQ 1.4.24 **What are the limitations of significant figures?**

Limitation

Significant figures deal with only one source of uncertainty, that inherent in reading the scale.

Other Sources

Real experimental uncertainties have many contributions, including personal errors and sometimes hidden systematic errors, so the total uncertainty may well be more than the significant figures suggest.

SQ 1.4.25 **How many significant figures are there in 37 km and 0.002953 m?**

Answer

37 km has two significant figures.

0.002953 m has four significant figures.

SQ 1.4.26 **How many significant figures are there in 7.50034 cm and 200.0 m?**

Answer

7.50034 cm has six significant figures.

200.0 m has four significant figures.

SQ 1.4.27 **The length, breadth and thickness of a sheet are 2.03 m, 1.22 m and 0.95 cm. Find its volume to the appropriate significant digits.**

Solution

$V = 2.03 \times 1.22 \times 0.95 \times 10^{-2}$

Rounding

The factor 0.95 cm has the minimum number of significant figures, which is two.

Result

$V = 2.4 \times 10^{-2}\,\mathrm{m}^3$

SQ 1.4.28 **A box of mass 3.25 kg has two coins of masses 10.01 g and 10.02 g added to it. Find the total mass to the appropriate precision.**

Solution

$3.25 + 0.01001 + 0.01002 = 3.27003\,\mathrm{kg}$

Rounding

The least precise mass 3.25 kg has two decimal places.

Result

$\text{Total mass} = 3.27\,\mathrm{kg}$

SQ 1.4.29 **Round off 0.02055 and 4656.5 to three significant figures in scientific notation.**

Answer

$0.02055 = 2.06 \times 10^{-2}$

$4656.5 = 4.66 \times 10^{3}$

TOPIC 5 Precision and Accuracy

SQ 1.5.1 **What determines the precision of a measurement?**

Answer

The precision of a measurement is determined by the instrument or device being used. The smaller the least count, the more precise is the measurement.

SQ 1.5.2 **Define accuracy of a measurement.**

Definition

Accuracy is defined as the closeness of a measurement to the exact or accepted value of a physical quantity.

Expression

It is expressed by the fractional or percentage uncertainty.

SQ 1.5.3 **How does percentage uncertainty affect accuracy?**

Answer

The smaller the fractional or percentage uncertainty, the more accurate is the measurement.

SQ 1.5.4 **Define a precise measurement and an accurate measurement.**

Precise Measurement

A precise measurement is the one which has less precision or absolute uncertainty.

Accurate Measurement

An accurate measurement is the one which has less fractional or percentage uncertainty.

SQ 1.5.5 **Differentiate between precision and accuracy.**

Precision	Accuracy
It is determined by the instrument being used.	It is the closeness of a measurement to the accepted value.
It is indicated by the absolute uncertainty or least count.	It is expressed by the fractional or percentage uncertainty.
The smaller the least count, the more precise the measurement.	The smaller the percentage uncertainty, the more accurate the measurement.

SQ 1.5.6 **A length is recorded as 25.5 cm with a metre rule of least count 0.1 cm. Find its fractional and percentage uncertainty.**

Solution

$$\text{Fractional uncertainty} = \frac{0.1}{25.5} = 0.004$$

$$\text{Percentage uncertainty} = \frac{0.1}{25.5} \times 100\% = 0.4\%$$

SQ 1.5.7 **A length is recorded as 0.45 cm with Vernier Callipers of least count 0.01 cm. Find its fractional and percentage uncertainty.**

Solution

$$\text{Fractional uncertainty} = \frac{0.01}{0.45} = 0.02$$

$$\text{Percentage uncertainty} = \frac{0.01}{0.45} \times 100\% = 2\%$$

SQ 1.5.8 **Why is the reading 25.5 cm less precise but more accurate?**

Reason

It is taken by a metre rule whose least count 0.1 cm is larger, so it is less precise. However its percentage uncertainty is only 0.4%, so it is more accurate.

SQ 1.5.9 **Why is the reading 0.45 cm more precise but less accurate?**

Reason

It is taken by Vernier Callipers whose least count 0.01 cm is smaller, so it is more precise. However its percentage uncertainty is 2%, so it is less accurate.

SQ 1.5.10 **Which instrument should be used for a small physical quantity?**

Answer

The smaller a physical quantity, the more precise the instrument should be used. It is in fact the relative measurement which is important.

SQ 1.5.11 **Can we ever make an exact measurement?**

Answer

No. We can never make an exact measurement. The best we can do is to come as close as possible within the limitation of the measuring instrument.

TOPIC 6 Assessment of Total Uncertainty in the Final Result

SQ 1.6.1 **How is the total uncertainty assessed for addition and subtraction?**

Rule

For addition and subtraction, the absolute uncertainties are added.

SQ 1.6.2 **Two positions are recorded as 15.4 ± 0.1 cm and 25.6 ± 0.1 cm. Find the distance between them.**

Solution

$\Delta x = x_2 - x_1 = (25.6 - 15.4)$

Result

$\Delta x = (10.2 \pm 0.2)\,\text{cm}$

SQ 1.6.3 **Two lengths are 8.5 ± 0.1 cm and 12.6 ± 0.1 cm. Find their sum.**

Solution

$\ell = \ell_1 + \ell_2 = (8.5 + 12.6)$

Result

$\ell = (21.1 \pm 0.2)\,\text{cm}$

SQ 1.6.4 **How is the total uncertainty assessed for multiplication and division?**

Rule

For multiplication and division, the percentage uncertainties are added.

SQ 1.6.5 **A conductor has V = 5.2 ± 0.1 V and I = 0.84 ± 0.05 A. How is the uncertainty in R estimated?**

Method

The percentage uncertainty in V and the percentage uncertainty in I are calculated separately and then added, because

$$R = \frac{V}{I}$$

involves division.

SQ 1.6.6 **For V = 3.4 ± 0.1 V and I = 0.68 ± 0.05 A, find the total percentage uncertainty in R.**

Solution

$$\backslash\%\text{age uncertainty in } V = \frac{0.1}{3.4} \times 100\% = 3\%$$

$$\backslash\%\text{age uncertainty in } I = \frac{0.05}{0.68} \times 100\% = 7\%$$

Result

The total percentage uncertainty in R is

$3 + 7 = 10\%$

SQ 1.6.7 **For V = 3.4 V and I = 0.68 A with 10% uncertainty, write the value of the resistance.**

Solution

$$R = \frac{V}{I} = \frac{3.4}{0.68} = 5.0\,\Omega$$

Result

$R = (5.0 \pm 0.5)\,\Omega$

The uncertainty, being an estimate only, is recorded by one significant figure.

SQ 1.6.8 **How is the total uncertainty assessed for a power factor?**

Rule

The percentage uncertainty is multiplied by the power factor in the formula.

SQ 1.6.9 **Why does a power factor increase the precision demand of a measurement?**

Reason

As the uncertainty is multiplied by the power factor, the total uncertainty becomes larger. Therefore it increases the precision demand of the measurement.

SQ 1.6.10 **The radius of a sphere is 1.25 ± 0.01 cm. Find the percentage uncertainty in its area A = πr².**

Solution

$$\backslash\%\text{age uncertainty in } r = \frac{0.01}{1.25} \times 100\% = 0.8\%$$

Result

Since

$A = \pi r^2$

the total percentage uncertainty is

$2 \times 0.8 = 1.6\%$

SQ 1.6.11 **For a sphere of radius 1.25 cm with 1.6% uncertainty, write the area with its uncertainty.**

Solution

$A = \pi r^2 = 3.14 \times (1.25)^2 = 4.906\,\text{cm}^2$

Result

$A = (4.91 \pm 0.08)\,\text{cm}^2$

SQ 1.6.12 **A cylinder has diameter 1.25 cm and length 3.35 cm, each measured with least count 0.01 cm. Find the percentage uncertainty in each.**

Solution

$$\backslash\%\text{age uncertainty in length} = \frac{0.01}{3.35} \times 100\% = 0.3\%$$

$$\backslash\%\text{age uncertainty in diameter} = \frac{0.01}{1.25} \times 100\% = 0.8\%$$

SQ 1.6.13 **Find the total percentage uncertainty in the volume of a cylinder of diameter 1.25 cm and length 3.35 cm.**

Method

Since

$$V = \frac{\pi d^2 \ell}{4}$$

the total uncertainty is twice the percentage uncertainty in diameter plus the percentage uncertainty in length.

Solution

$2 \times 0.8\% + 0.3\%$

Result

The total uncertainty in V is 1.9%.

SQ 1.6.14 **Calculate the volume of a cylinder of diameter 1.25 cm and length 3.35 cm with its uncertainty.**

Solution

$$V = \frac{\pi d^2 \ell}{4} = \frac{3.14 \times (1.25)^2 \times 3.35}{4}$$

Result

$V = (4.11 \pm 0.08)\,\text{cm}^3$

TOPIC 7 Dimensions of Physical Quantities

SQ 1.7.1 **What are dimensions of a physical quantity?**

Definition

Any physical quantity can be described by certain familiar properties such as length, mass, time, temperature and electric current. These measurable properties are called dimensions.

Nature

Dimensions deal with the qualitative nature of a physical quantity in terms of fundamental quantities.

SQ 1.7.2 Why are length, depth, height, diameter and light year given the same dimension?

Reason

All of them are measured in metre, so they are denoted by the same dimension, basically known as length and given the symbol $[L]$ written within square brackets.

SQ 1.7.3 Write the symbols used for the dimensions of the fundamental quantities.

Symbols

Length is $[L]$, mass is $[M]$, time is $[T]$, electric current is $[A]$ and temperature is $[\theta]$.

SQ 1.7.4 Why have these five dimensions been chosen as basic?

Reason

These five dimensions have been chosen as being basic because they are easy to measure in experiments.

SQ 1.7.5 What do the dimensions of other quantities indicate?

Answer

The dimensions of other quantities indicate how they are related to the basic quantities, and they are a combination of fundamental dimensions.

SQ 1.7.6 Write the dimensions of speed.

Derivation

Speed is measured in metres per second, so it has the dimensions of length divided by time.

Formula

$$[v] = \frac{[L]}{[T]} = [LT^{-1}]$$

SQ 1.7.7 Write the dimensions of acceleration.

Derivation

Since

$$a = \frac{\Delta v}{\Delta t}$$

the dimensions are

$$[a] = \frac{[LT^{-1}]}{[T]}.$$

Formula

$$[a] = [LT^{-2}]$$

SQ 1.7.8 Write the dimensions of force.

Derivation

Since

$$F = ma$$

the dimensions are

$$[F] = [M][LT^{-2}].$$

Formula

$$[F] = [MLT^{-2}]$$

SQ 1.7.9 What are the two main uses of dimensional analysis?

Uses

By the use of dimensionality we can check the homogeneity or correctness of a physical equation.

We can also derive a formula for a physical quantity.

SQ 1.7.10 State the principle of homogeneity of physical equations.

Statement

The correctness of an equation can be checked by showing that the dimensions of the quantities on both sides of the equation are the same. This is known as the principle of homogeneity.

SQ 1.7.11 Why can numerical factors be ignored in dimensional analysis?

Reason

Numerical factors like $\frac{1}{2}$ have no dimensions, so they can be ignored.

SQ 1.7.12 Show that the equation S = ½at² is dimensionally correct.

Solution

Putting the dimensions of both sides,

$[S] = [a][t^2] = [LT^{-2}][T^2]$.

Result

$[L] = [L]$

Since the dimensions on both sides are the same, the equation is dimensionally correct.

SQ 1.7.13 How can dimensionality be used to derive a formula?

Answer

Dimensionality can be used to derive a possible formula for a physical quantity by correct estimation of the various factors on which the quantity depends.

SQ 1.7.14 On which quantities does the centripetal force depend?

Answer

The centripetal force depends on the mass m of the object, the radius r of the circle and the uniform speed v.

SQ 1.7.15 Derive the formula for centripetal force using dimensional analysis.

Assumption

Let

$$F = (\text{constant})\, m^a v^b r^c$$

Dimensions

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

Comparing

Comparing the powers gives

$a = 1$

$b = 2$

and

$c = -1$

Result

$$F = \frac{mv^2}{r}$$

SQ 1.7.16 Can dimensional analysis determine the numerical value of a constant?

Answer

No. The numerical value of the constant cannot be determined by dimensional analysis. However, it can be found by experiments.

SQ 1.7.17 **What are the limitations of dimensional analysis?**

Limitation

The dimensional method cannot identify where an equation is wrong. Even if an equation is proved correct, we can only say that the equation might be correct.

Reason

The method does not provide a check on any numerical factor or constant, which can only be determined by experiments or by plotting a suitable graph.

SQ 1.7.18 **Write the dimensions of kinetic energy.**

Derivation

Since

$KE = \frac{1}{2}mv^2$

the dimensions are

$[KE] = [M][LT^{-1}]^2$.

Formula

$[KE] = [ML^2T^{-2}]$

SQ 1.7.19 **Write the dimensions of angular velocity.**

Derivation

Angular velocity is angle divided by time, and angle is dimensionless.

Formula

$[\omega] = [T^{-1}]$

SQ 1.7.20 **Write the dimensions of Planck's constant.**

Derivation

Since

$E = hu$

therefore

$h = \frac{E}{u}$

where energy has dimensions $[ML^2T^{-2}]$ and frequency has $[T^{-1}]$.

Formula

$[h] = [ML^2T^{-1}]$

SQ 1.7.21 **What is meant by a dimensionless quantity? Give one example.**

Definition

A dimensionless quantity is one which has no dimensions of the fundamental quantities.

Example

Plane angle measured in radian is a dimensionless quantity.

SQ 1.7.22 **If P = Q + R and both Q and R have dimensions [MLT^{-1}], what are the dimensions and SI unit of P?**

Dimensions

By the principle of homogeneity all terms must have the same dimensions, so

$[P] = [MLT^{-1}]$.

SI Unit

The SI unit of P is $\mathrm{kg\,m\,s^{-1}}$.