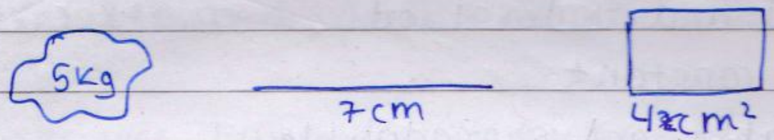
PHYSICAL QUANTITIES

Properties that can be measured and expressed in terms of number and unit (if required). Eg:-

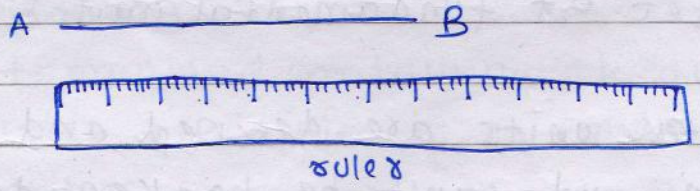


The quantities mass and length are measured directly but the area is measured indirectly by first measuring the sides (Length and breadth).

Measurement is the process of comparing a physical quantity with a certain standard quantity of the same time and expressing the quantity in terms of numbers.

The standard quantity used for comparison in measurement is called the unit.

For eg:- when we want to measure a line AB, we need a certain standard quantity (cm), so we use a ruler (not scale as scale is calibrated into a measuring device), and compare the length of AB with the ruler to find the length to be ~~3 cm~~ 7 cm.



The length of AB is found to be 7 times more than the length of the standard 1 cm, so its length is 7 cm. We express it in terms of number (7) and unit (cm).

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Characters of standard unit

* A ~~stard~~ standard unit of mearusement must be :-

+ Well defined and understood.
+ Should be a constant
+ Easily available and reproducible.
+ Universally accepted
+ Suitable in size.

Systems - CGS, FPS, MKS, SI system

SI System (Le Systeme International d' Unites)

+ Introduced in 1960 by 11th ~~co~~ Intl. conference on weight and measures held in France, to bring the uniformity in the units to cover all branches of Physics
+ It is internationally accepted, metric system (multiples and sub multiples can be expressed as powers of Ten), is rational (same unit is assigned for a particular physical quantity, eg:- for all types of energy, Joule is the unit), coherent (logical, consistent units of different physical quantities are based on certain set of fundamental units)

Fundamental units are defined and understood by themselves and can't be broken down into other smaller quantities are fundamental / base units. Eg:- luminous intensity, length, mass, amount of substance, time, temperature, Electric current.

Units of those physical quantities defined and expressed in terms of other fundamental units are called derived units.

SI prefixes and power of 10.

- Prefixes like nano, kilo, micro etc. are used to express ~~sor~~ units based on the power of 10.

1 µm (micrometer) = 1×10^{-6} m.

pico	p	10^{-12}
nano	n	10^{-9}
micro	µ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}

Finding SI base units of derived quantities

- know the quantity
- Write a formula containing the quantity.
- Convert other quantities in formula in terms of base quantities.
- Express in terms of powers of SI base units.

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Find SI base unit of work done

- Work done is a physical quantity
- $W = Fs$
- ~~$W = m.a.s = m \times \frac{V}{t}$~~ $\times s$
- $W = m.a.s = m \times \frac{\Delta v}{\Delta t} \times s$

where Δv is change in velocity in time Δt

- $W = kg \times \frac{ms^{-1}}{s} \times m$

$= kgm^{2} s^{-2}$

SI unit of work is Joule but SI base unit is $kgm^2 s^{-2}$.

PRINCIPLE OF HOMOGENEITY OF UNITS IN PHYSICAL EQUATIONS

The units of each of the terms of a correct physical equation on both sides should be the same.
If $A = B + C$ is a correct equation, then,
Unit of A = Unit of B = Unit of C

$S = ut + \frac{1}{2}at^2$
Here, there are three terms, s, ut and $\frac{1}{2}at^2$. The units are separated by arithmetic operators.

$m = ms^{-2} . \cancel{s} + 1/2\ m\cancel{s^{-2}} . s^2$

$m = m + 1/2 m$

$\therefore$ Unit of s = Unit of ut = Unit of $1/2\ at^2$

Application of Homogeinity.

A simple pendulum has mass m and length l at a place where g is the acceleration due to gravity. which formula must be correcte.

$t = 2\pi \sqrt{l/g}$ (π is unitless because it is the ratio of two lengths (C/d).)

Use of SI base units.

Convert 2.5 J into erg.

SI base unit of Word done = $kg\,m^2 s^{-2}$

$1J = 1kg \times (1m)^2 \times (1s)^{-2}$ --- (i)

$= 1000\,g \times (100\,cm)^2 \times (1s)^{-2}$

$= 1000\,g \times 10000\,cm^2 \times 1s^{-2}$

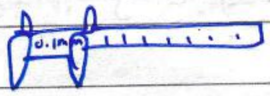
$= 10000000\,g\,cm^2 s^{-2}$

$= 1 \times 10^7$ erg.

$\therefore 2.5\,J = 2.5 \times 10^7$ erg.

Significant figures in measurement.

- The meaningful digits in a number are called significant figures.
- For eg:- when measuring the diameter of a ~~ruler~~ marble using a ruler, we can say that it is 2.2 cm but not 2.24 cm. because the least count (minimum value a device can measure) is only 1mm in a ruler. So meaningful digits are only 2 and 2 in 2.2 cm.
- If we measure a line using the same ruler, and get reading 5cm, we must write 5.0 cm because we are ~~confixed~~ confirmed that first decimal place is 0. Also 5cm has 1 significant figure while 5.0 has two.

Using vernier calipers: 

- Vernier calipers' least count is 0.1 mm.
- So, any reading must be expressed as 0.00 cm.

Using micrometer screw gauge

- It has a least count of 0.01 mm.
- So, any reading must be expressed as 0.000 cm.
- ~~The lea~~

- The least count of measuring device are more uncertain. Even whole number can be made very uncertain by it. Eg:- Reading can be 4.9 cm but we may perceive it as 5.0 cm. But ~~it only seems~~ the uncertain actually lies in the 0.9 decimal place.

- So, the first whole number is certain but the least count is uncertain.
- As we measure ~~device wi~~ with device of lower least count, we get uncertain.
- So, in a given reasing the least count is always uncertain.

Rules to identify significant figures.

- All non-zero digits are significant.
  324, 19842, 23.45
  three significant digits
- Leading zeroes before the first non zero digits are not significant.
  023, 0.0023
  significant
  These numbers are not equal in magnitude but in terms of no. of significant figures, they are same (2 significant figures.
- All zeroes between the non-zero digits are significant
  10025, 3001.02
  significant
- Trailing zeroes are significant if there is decimal anywhere in the number
  50.0, 505.3200, 500, 50000
  not trailing

50.0 mm must be written as 5.00 cm when converting due to two significant 0s in 50.0 mm

PHYSICAL QUANTITIES . . .

Rules to identify significant figures . . .

+ If there are trailing zeroes without decimal in the number, it is not clear wether they're significant or not.

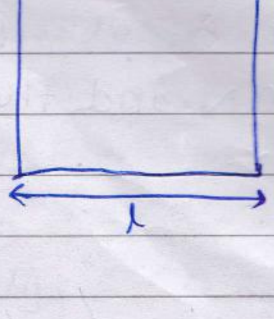
  56000

In such situations they are expressed in terms of powers of 10 to identify significant figures

5.6×10^4
5.60×10^4
5.6000×10^4

More about significant figures.

0,10.1205 (First 0 insignificant)
0.00750 (first 3 0s insignificant)
20.50 (All are significant)
10.0075 (All are significant)
401.0 (All are significant)
5.060×10^7 (All are significant)
501.071×10^4 (All six significant)
400 (~~we~~ only sure that 4 is significant)



Area = $l \times l$ (4.0×10^2)
Ruler, $l = \underline{20}$ mm (Ruler's least count is 1 mm)
Area = $400 mm^2$ (~~All figures significant~~ Only 2 significant)
($\because$ Ruler can measure upto 1 mm. ~~20 mm~~
both 2 & 0 are significant. So while converting it must be written as 2.0 cm

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Vernier calipers, $l = 20.0$ mm

$A = 20.0 \times 20.0$

$= 400$ mm^2 (All figures significant) (4.00×10^2)

In multiplication & least no. of significant figures is to be written.

$\overbrace{3.2}^{2sf} \times \overbrace{7.50}^{3sf}$

$= 24$ (2sf)

$\overbrace{3.20}^{3sf} \times \overbrace{7.50}^{3sf}$

$= 24.0$ (3 sf)

Micrometer screw gauge, $l = 20.00$ mm

$A = 20.00 \times 20.00$

$= 400.0$ mm^2 (All 4 figures significant) (4.000×10^2)

Accuracy ~~or~~ and Precision in measurement.

→ Accuracy refers to the degree to which a measurement approaches the true value.

→ The equipment used ~~determines~~ and the skill of the experimenter determines the accuracy.

→ If repeated measurements are taken accurately, their average approaches very close to the true value.

→ Precision refers to the measurement taken in more significant figures.

→ With the increase in number of significant figures quoted in the measurement, the precision increases.

$d = 2.2$ cm → less precise.

$d = 2.20$ cm

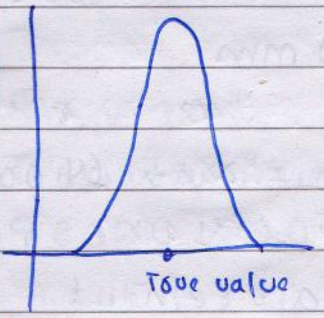
$d = 2.204$ cm → more precise

→ If repeated measurements are taken precisely, the readings are all close together.

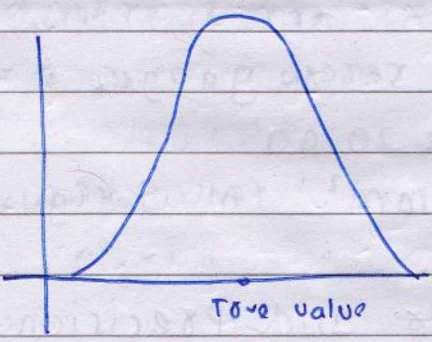
If true height is 1.71 m and following are measurements by A & B

A - 1.90 m, 1.91 m, 1.90 m
[Precise but not accurate]
B - 1.71 m, 1.65 m, 1.76 m
[Accurate but not precise]

Let x-axis be value and y-axis be No. of measurements



high accuracy
high precision



high accuracy
low precision

A - 9.81, 9.79, 9.84, 9.83
B - 9.81, 10.12, 9.89, 9.13
C - 9.45, 9.21, 8.99, 8.76
D - 8.45, 8.46, 8.50, 8.41

	Avg	Δg_{max} (Max - least)	Accuracy	(Range) Precision
A	9.82	9.84 - 9.79 = 0.05	Most (1)	Most (1)
B	9.74	0.99	2	Least (4)
C	9.10	0.69	3	3
D	8.46	0.09	Least (4)	2

In measurement, accuracy is prioritized over precision.

Errors and Uncertanities in measurement.

- Measurement is done to find the true value of a physical quantity.
- True value is obtained if measurement is perfect
- In practice, it is almost impossible to have perfect measurements.
- Hence, every measurement has uncertanity.
- Uncertanity represents an actual range of values around the measurement, within which we expect the true value to lie.
- Uncertanity is an actual number with an unit.
- Diameter = 2.2 cm, here 0.1 cm is the uncertanity. The actual value ~~can~~ lies between 2.1 cm to 2.3 cm.
- If we have a measurement 4.0 ± 0.1 cm, it means the true value lies between 3.9 cm and 4.1 cm.
- Error in the measurement is just a problem that causes the reading to be different from the true value.
- Errors are caused by poor technique while measuring and / or less than perfect equipment.
- Two important errors causing uncertanities are Systematic errors & Random errors.

- Systematic errors are the errors that cause all the measurements to be either below or above the accepted value.
- Eg: zero error is error in the measuring device that gives non-zero reading when the true reading is zero. (The zero in a ruler might not be at the very beginning of the ruler.

- Errors in calibration of measuring device
- Error in timing by slow or fast running watch.

Random errors

- Error that causes measurements to be scattered around the accepted value. (below ~~or~~ and above the accepted value).
- Eg: Reaction time error when taking time with stop watch.
- Errors due to careless experimenter.
- Errors while taking readings of quantities that varies with time.
- These errors can be minimized by repeated measurements and taking their average.

Parallax error

- Error introduced by incorrect use of measuring instruments.
- By positioning eye in incorrect position.
- Can be minimized by opposite of of errors.
- It can be both random and systematic.

Representing uncertanities.

- Uncertanity represents actual range of values around measurement where we expect true value to lie.
- Measured value of x which uncertanity is expressed as: $x = x_b \pm \Delta x$.

measured value of x = best estimate of x $\pm$ uncertanity of x.

Δx is also known as absolute uncertanity.

Rules.

- Uncertanity are almost rounded to one significant figure.

$g = 9.81 \pm 0.02\ ms^{-2}$.

but not as $g = 9.81 \pm 0.023\ ms^{-2}$.

- The last significant figure in any stated answer should be of the same order of magnitude (in the same decimal position) in uncertanity.

$g = 9.\underbrace{81} \pm 0.\underbrace{02}\ ms^{-2}$

~~2-g~~ 2-decimal places

$l = \cancel{9.}\ 8.34 \pm 0.111$ cm [Incorrect]

$= 8.34 \pm 0.10$ (Also incorrect)

$= 8.3 \pm 0.1$ [correct]

$v = 6051.78 \pm 30 ms^{-1}$ [Incorrect]

$= 6050 \pm 30\ ms^{-1}$ [correct]

The answer 92.82 with uncertanity 0.323 is expressed as: 92.8 ± 0.3

The answer 92.82 with uncertanity 3.764 is expressed as: 93 ± 4

with uncertanity 33.7 : ~~93 ± 30~~ 90 ± 30.

(Matching place value of uncertanity & number).

- Answer to a measured or calculated value and uncertanity should be expressed in the same form (power of 10).

$q = 1.61 \times 10^{-19} \pm 5 \times 10^{-21}$ ... not appropriate.

$= 1.61 \times 10^{-19} \pm 0.05 \times 10^{-19}$ .. (correct)

$= 161 \times 10^{-21} \pm 5 \times 10^{-21}$ [Technically correct but ~~not adv~~ better to go with the above one]

PHYSICAL QUANTITIES EXERCISE

1. Name six SI base units as suggested in the syllabus.

Ans. Six SI base units are :- kilogram, metre, Ampere, second, mole, kelvin.

2. Find the SI base units of the physical quantities.

a) Area

Area = l^2 [Area of square]

$= m \times m$

$= m^2$,,

∴ SI base unit of Area is m^2 ,,

b) Volume

Volume = l^3 (volume of cube)

$= m \times m \times m$

$= m^3$

∴ SI base unit of volume is m^3 ,,

c) Speed

Speed = Distance / time

$= m/s$

$= ms^{-1}$,,

∴ SI base unit of speed is ms^{-1} ,,

d) Velocity

Velocity = Displacement / time

$= m/s$

$= ms^{-1}$,,

∴ SI base unit of velocity is ms^{-1} ,,

e) Acceleration

Acceleration = $^{\text{Velocity}}/_{\text{time}}$ $[^{dv}/_{dt}]$

$= {}^{ms^{-1}}/_{s}$

$= ms^{-2}$,,

∴ SI base unit of ~~velocity is~~ acceleration is ms^{-2} ,,

f) Force

Force = mass × acceleration $[^{dp}/_{dt} = m\,^{dv}/_{dt} = ma]$

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

$= kgms^{-2}$,,

∴ SI base unit of force is $kg\,ms^{-2}$,,

g) Work done

Work done = Force × displacement × $\cos\theta$

= mass × acceleration × displacement

$= kgms^{-2} \times m = kgm^2s^{-2}$

∴ SI base unit of work done is kgm^2s^{-2}

h) Power

Power = $^{\text{work done}}/_{\text{time}}$

$= {}^{kgm^2s^{-2}}/_{s}$

$= kgm^2s^{-3}$

∴ SI base unit of power is kgm^2s^{-3} ,,

i) Density

Density = $^{\text{mass}}/_{\text{volume}}$

$= {}^{kg}/_{m^3}$

$= kgm^{-3}$

∴ SI base unit of density is kgm^{-3} ,,

j) Pressure

Pressure = Force/Area

$= \text{kgms}^{-2}/\text{m}^{2}$

$= \text{kg m}^{-1}\text{s}^{-2}$

∴ SI base unit of pressure is $\text{kg m}^{-1}\text{s}^{-2}$ //.

k) Energy

Energy = mass × speed of light^2 [From einstein's relativistic eqⁿs in electrodynamics of moving bodies.]

$= \text{kg} \times (\text{ms}^{-1})^2$

$= \text{kg} \times \text{m}^2\text{s}^{-2}$

$= \text{kgm}^2\text{s}^{-2}$

∴ SI base unit of energy is $\text{kg m}^2\text{s}^{-2}$ //.

l) Gravitational constant

Force = $G.m_1.m_2/r^2$ [from Newton's gravity definition]

or, $N = G\,\text{kg}^2/\text{m}^2$

or, $G = \text{kgms}^{-2}/\text{kg}^2\text{m}^{-2}$ ∴ $G = \text{m}^3\text{kg}^{-1}\text{s}^{-2}$

∴ SI base unit of gravitational constant is $\text{m}^3\text{kg}^{-1}\text{s}^{-2}$

m) Frequency

Speed = Frequency × wavelength

or, $\text{ms}^{-1} = f \times \text{m}$

∴ $f = \text{s}^{-1}$

∴ SI base unit of frequency is s^{-1}.

n) Specific heat capacity

$Q = m.s.dt$

or, $\text{kgm}^2\text{s}^{-2} = \text{kg}\,{}^\circ\text{K}.s$

∴ $s = \text{m}^2\text{s}^{-2}\,{}^\circ\text{K}^{-1}$

∴ The SI base unit of specific heat capacity is $\text{m}^2\text{s}^{-2}\,{}^\circ\text{K}^{-1}$ //.

o) Electric charge

current = $\text{charge} / \text{time}$

$Q = A.S$

$\therefore$ The SI ~~unit o~~ base unit of electric charge is As.

p) Potential difference

Power = Voltage x current

$V = \text{kg}\,m^2 s^{-3} / A$

$\therefore V = \text{Kg}m^2 s^{-3} A^{-1}$

$\therefore$ SI base unit of potential difference is $\text{Kg}m^2 s^{-3} A^{-1}$.

q) Electric resistance

$V = IR$

$R = \text{kg}m^2 s^{-3} A^{-1} / A$

$\therefore R = \text{Kg}m^2 s^{-3} A^{-2}$

$\therefore$ SI base unit of electric resistance is $\text{Kg}m^2 s^{-3} A^{-2}$.

3. Find the ratio of 1Gm to 1 μm

$$\frac{1Gm}{1\mu m} = \cancel{10}\ \frac{1 \times 10^9\, m}{1 \times 10^{-6}\, m}$$

$$\frac{1Gm}{1\mu m} = 1 \times 10^{15}$$

$\therefore 1 \times 10^{15}\ \mu m = 1Gm$.

4. Check wether the given eq^n is correct or not.

a) ~~$v = \sqrt{P/q}$~~ $V = \sqrt{P/\rho}$, where P is the pressure, V is the velocity of sound in air, and ρ is the density of air.

Changing both sides to their base units,

$$V = \sqrt{\frac{P}{\rho}}$$

or, $$S/t = \sqrt{\frac{F/A}{m/V}}$$

or, $$ms^{-1} = \sqrt{\frac{ma/m^2}{kg/m^3}}$$

or, $$ms^{-1} = \sqrt{\frac{kg\,ms^{-2}}{m^2} \times \frac{m^3}{kg}}$$

or, $$ms^{-1} = \sqrt{m^2 s^{-2}}$$

$\therefore$ $ms^{-1} = ms^{-1}$

$\therefore$ The eq^n is correct.

b) The average density ρ of the earth is written as $\rho = \frac{3g^2}{4\pi RG}$, where g is acceleration due to gravity, R is earth's radius and G is universal gravitational const.

$$\rho = 3g^2/4\pi RG$$

or, $kgm^{-3} = 3 \times (ms^{-2})^2 / 4\pi . m . Nm^2kg^{-2}$ [we remove 3 and 4π]

or, $kgm^{-3} = m^2s^{-4} / m.a.m^3kg^{-2}$

or, $kgm^{-3} = m^2s^{-4} / kg.ms^{-2}.m^3kg^{-2}$

or, $kgm^{-3} = m^2s^{-4} / kg^{-1}m^4s^{-2}$

or, $kgm^{-3} = kgm^{-2}s^{-4}.s^2$

or, $kgm^{-3} = kgm^{-2}s^{-2}$

$\therefore$ It is not correct.

5. A sphere of radius 'r' moving through a fluid of density ρ with a velocity v experiences an opposing force given by $F = k r^x \rho^y v^z$ where k is non dimensional constant. Find x, y and z.

Comparing the units by removing constant 'k'

$F = r^x \rho^y v^z$

or, $m.a = m^x . (kg/m^3)^y . (ms^{-2})^2$

or, $kgms^{-2} = m^x . (kgm^{-3})^y . (ms^{-1})^2$

or, $kgms^{-2} = m^x . kg^y . m^{-3y} . m^2 s^{-2}$

or, $kgms^{-2} = kg^y m^{x-3y+2} s^{-2}$

∴ To make the ~~units equa~~ eq^n correct, the degree of units in both sides must be the same.

∴ $y = 1$ ∴ $z = 2$

∴ $\cancel{x - 3y = 1}$ $x - 3y + 2 = 1$

or, $\cancel{x - 3 = 1}$ $x - 3 + 2 = 1$

∴ $\cancel{x = 4}$ $x = 2$ 2

∴ The values of x, y and z are ~~4~~, 1 and 2.

6. The force F between ~~the~~ two point charges ~~Q~~ is given by $F = \frac{Q_1 . Q_2}{4\pi r^2 \varepsilon}$

where Q_1 and Q_2 are charges, r is the distance between the charges and ε is a constant that depends on medium. Find base units of ε.

~~Comparing~~

Comparing units, by removing constant 4π

$$F = \frac{Q_2 . Q_1}{4\pi . r^2 . \epsilon}$$

or $$m.a = \frac{A.s.A.s}{m^2.\epsilon}$$

or $$kgms^{-2} = A^2 s^2 m^{-2} \epsilon$$

or $$\epsilon = \frac{kgms^{-2}}{A^2 s^2 m^{-2}}$$

or $$\epsilon = kg m^3 s^{-4} A^{-2}$$

$\therefore$ The SI base units of ϵ is $kg m^3 A^{-2} s^{-4}$,,

MCQ A

1. A sheet of gold leaf has a thickness of 0.125 μm. A gold atom has a radius of 174 pm. Approximately how many atoms are in the sheet.

$1 \mu m = 10^{-6} m$ $\therefore$ $0.125 \mu m = 0.125 \times 10^{-6} m$,,
$1 pm = 10^{-12} m$ $\therefore$ $174 pm = 174 \times 10^{-12} m$,,

Approx. no. of gold atoms $= \frac{0.125 \times 10^{-6} m}{174 \times 10^{-12} m}$
$= 718.39$
≈ 700

$\therefore$ Answer = 700 ,,

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2. The drag coefficient C_d is a nomber with no units. It is used to compare drag on differont cars at different speeds. C_d is given by the eq^n.
$C_d = \frac{2F}{v^n \rho A}$, where F is drag force, ρ is Air density, A is cross-sectional area of car and v is the car's speed. What is the value of n.

$C_d = 2F / v^n \rho A$

or, $1 = 2ma / v^n . kgm^{-3} . m^2$

or, $(ms^{-1})^n . kgm^{-2} = 2kgms^{-2}$

or, $m^n s^{-n} . kg m^{-1} = 2kg ms^{-2}$

or, $kg m^{n-1} . s^{-n} = kg ms^{-2}$

or, $n-1 = 1$

$\therefore n = 2$

$\therefore$ Answer = 2

3. What correctly expresses force in terms of SI base units.

Electric power = Voltage x current

or, work done / time = A.V

or, $fd/t = A.V$

or, $m.a.m/s = A.V$

or, $kgms^{-2}.m/s = A.V$

or, $A.V = Kgm^2s^{-3}$

$\therefore V = Kgm^2s^{-3}A^{-1}$

$\therefore$ Answer = $Kgm^2s^{-3}A^{-1}$

4. Which formula could be correct for speed v of ocean waves in terms of density ρ of sea water, the acceleration of free fall g, the depth h of ocean and wavelength λ

Answer = $v = \sqrt{g\lambda}$

$ms^{-1} = \sqrt{ms^{-2} . m}$

Or, $ms^{-1} = \sqrt{(ms^{-1})^2}$

$\therefore ms^{-1} = ms^{-1}$ //.

MEASUREMENT....

Fractional and percentage uncertanity..

$x = x_b + \Delta x$

Fractional uncertanity $= \dfrac{\Delta x}{x_b}$

Percentage uncertanity $= \dfrac{\Delta x}{x_b} \times 100\%$

Example:-

$l = 50 \pm 1$ cm,

[50 has two significant figures because uncertanity lies in onth place].

Fractional uncertanity $= \dfrac{\Delta l}{l_0} = \dfrac{1}{50} = 0.02$..

Percentage uncertanity $= 0.02 \times 100\% = 2\%$

The length can also be expressed as:.

$l = 50 \pm 2\%$

Fractional uncertanity is also called relative uncertanity.

Uncertanity $\geq 10\%$ is rough measurement.

Uncertanity $< 2\%$ is good measurement.

These uncertanities can be expressed in more than one significant figure.

Uncertanity in derived quantity

The measured value of x with uncertanity is expressed as :- $x = x_b \pm \Delta x$

From this expression,

The max. value of x is :- $x_{max} = x_b + \Delta x$ --- (i)

The min. value of x is :- $x_{min} = x_b - \Delta x$ --- (ii)

Subtracting 2 from 1,

$x_{max} - x_{min} = 2\Delta x$

$\therefore \Delta x = \dfrac{x_{max} - x_{min}}{2}$

If $x = 10.2 \pm 0.2$ and $y = 3.0 \pm 0.1$, find with uncertanity the value of the following. And find fractional & percentage uncertanity.

a) ~~$x+y$~~ $a = x + y$

$a_b = x_b + y_b$

$= 10.2 + 3.0$

$= 13.2$

~~$\Delta a = 0.3\ (0.2 + 0.1)$~~

$\Delta a = \dfrac{a_{max} - a_{min}}{2}$

$= \dfrac{(x_{max} + y_{max}) - (x_{min} + y_{min})}{2}$

$= \dfrac{(10.4 + 3.1) - (10.0 + 2.9)}{2}$

$= 0.3$

$\therefore a = 13.2 \pm 0.3$

Fractional $= \dfrac{0.3}{13.2} = 0.0227$

Percent $= 2.27\%$

b) $b = x - y$

$b_b = x_b - y_b$

$= 10.2 - 3.0$

$= 7.2$

~~$\Delta b =$~~

$\Delta b = \dfrac{b_{max} - b_{min}}{2}$

$= \dfrac{(x_{max} \cancel{+ y_{max}} - y_{min}) - (x_{min} - y_{max})}{2}$

$= \cancel{\dfrac{(10.4 + 3.1) - (10.0 + 2.9)}{2}}$

$= \cancel{0.3}\ 0.3$

$\therefore b = 7.2 \pm \cancel{0.3}\ 0.3$

Fractional $= \dfrac{\cancel{0.3}}{7.2} = 0.0416$

Percent $=$ ~~4.16%~~

c) $c = xy$

$c_b = x_b \times y_b$

$= 10.2 \times 3.0$

$= 30.6$

$$\Delta c = \frac{c_{max} - c_{min}}{2}$$

$$= \frac{(x_{max} \cdot y_{max}) - (x_{min} \cdot y_{min})}{2}$$

$$= \frac{(10.4 \times 3.1) - (10.0 \times 2.9)}{2}$$

$= 1.62 = \cancel{1.6}\ 2.0$

$\therefore c = \cancel{30.6}\ 31 \pm 2$ $\quad \frac{1.62}{30.6} = 0.0529$

Fractional $= \frac{2}{31} = \cancel{0.0645}$

Percentage $= \cancel{6.45\%}\ 5.29\%$

d) $d = x/y$

$d_b = x_b / y_b$

$= 10.2 / 3.0$

$= 3.4$

$$\Delta d = \frac{d_{max} - d_{min}}{2}$$

$$= \frac{\left(\frac{x_{max}}{y_{min}}\right) - \left(\frac{x_{min}}{y_{max}}\right)}{2}$$

$$= \frac{\left(10.4/2.9\right) - \left(10.0/3.1\right)}{2}$$

$= \cancel{1.667} = \cancel{1.10}\ 0.18 = 0.1$

$\therefore d = \cancel{3.4 \pm 1.2}\ 3.4 \pm 0.2$ $\quad \frac{0.1802}{3.4} = 0.053$

Fractional $= \cancel{0.667}\ 0.0294$

Percentage $= \cancel{66.7\%}\ \cancel{2.94\%}\ 5.3\%$

e) $e = 4x$

$e_b = 4 \cdot x_b$

$= 4 \times 10.2$

$= 40.8$

$$\Delta e = \frac{e_{max} - e_{min}}{2}$$

$$= \frac{4 \times 10.4 - 4 \times 10.0}{2}$$

$= \cancel{0.4}\ 0.8$

$\therefore e = 40.8 \pm 0.8$

Fractional $= \frac{0.8}{40.8} = \cancel{0.0098}\ 0.0196$

Percentage $= \cancel{0.98\%}\ 1.96\%$

f) $f = x^3$

$f_b = x_b^3$

$= 10.2^3$

$= 1061.208$

$$\Delta f = \frac{f_{max} - f_{min}}{2}$$

$$= \frac{(10.4)^3 - (10.0)^3}{2}$$

$= 62.432 = 60$

$\therefore f = 1060 \pm 60$ $\quad \frac{62.432}{1061.208} = 0.0588$

Fractional $= \cancel{0.566}\ \cancel{0.0566}$

Percentage $= \cancel{5.66\%}\ 5.88\%$

- Absolute uncertanities are added in addition and in subtraction.
- Fractional / percentage uncertanities are added to get fractional / percentage uncertanity in multiplication / division.
- When a no. is multiplied by a constant, abcolute uncertanity is multiplied by constant & fractional and percentage uncertanity remain same.
- When a number is raised to a power n, fractional and/or percentage uncertanities are multiplied by n.

\# $\rho = (13600 \pm 100)\ Kg\ m^{-3}$

$g = (9.81 \pm 0.02)\ ms^{-2}$

$h = (0.762 \pm 0.005)\ m.$

$P = \rho g h$

$= (1.02 \pm 0.02) \times 10^{5}\ Pa$ [only answer with 1 SF]

\# V = 2.05 V, accuracy is ± 1% and ± 1 digit.

$\Delta V = 1\%$ of 2.05

$= 0.0205\ V$

$= 0.2V$

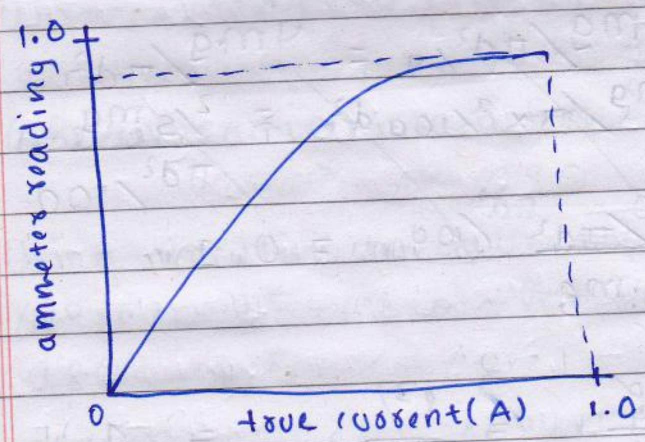
$= \pm 0.2 \pm 0.1$ (1 digit)

$= \pm 0.3$ //.

MEASUREMENT...

Use of calibration curves

- Measuring device sometimes may not have accurate scale. So the device can't give the correct value.
- In such cases, we use calibration curves, where we have a plot of reading and true value.



- In case of two different physical quantities A and B (one depending on another), we sometimes have to predict A by direct measurement of B. We can use calibration curves in these cases.

PHYSICAL QUANTITIES EXERCISE

1. The potential difference across a resistor is measured as 5.0 V ± 0.1 V. The resistor is labelled as having resistance 125 Ω ± 3%.

i) Calculate power dissipated by the resistor.

Potential difference = 5.0 V ± 0.1 V

Resistance = 125 Ω ± 2.4 Ω = 125 Ω ± 2 Ω.

$I = V/R$

$I_b = V_b / R_b = 5.0/125 = 0.04\ A$

$\Delta I = \dfrac{I_{max} - I_{min}}{2}$

$= \dfrac{(5.1/123) - (4.9/127)}{2}$

$= 1.44 \times 10^{-3}\ A = 0.00144\ A = 0.001\ A$

$\therefore I = 0.040 \pm 0.001\ A$

Power dissipated = IR

Power dissipated = V. I

or $P = V.V/R$ $= V.V/R$ [$\because I = V/R$]

$\therefore P = V^2/R$ $= V^2/R$

$P_b = V_b^2 / R_b = 5.0^2/125 = 0.2\ W$

$\Delta P = \dfrac{P_{max} - P_{min}}{2}$

$= \dfrac{(5.1^2/121) - (4.9^2/129)}{2}$ [$\because R = 125 \pm 4\ \Omega$]

$= 0.0112\ W = 0.01\ W$ $0.0144\ W = 0.01\ W$

$\therefore$ Power dissipated $= 0.20 \pm 0.01\ W$

$\left[\dfrac{\Delta P}{P} = 2\dfrac{\Delta V}{V} + \dfrac{\Delta R}{R} \right]$ $\dfrac{\Delta P}{P} \times 100\% = \dfrac{2\Delta V}{V} \times 100\% + \dfrac{\Delta R}{R} \times 100\%$

$= \dfrac{2 \times 0.1}{5.0} \times 100\% + 3\%$

$= 7\%$

ii) Calculate percentage uncertanity in the power.

Percentage uncertanity = $\dfrac{0.01\cancel{12}^{\,44}}{0.2} \times 100\%$ = 5/6%

7.2%

iii) Determine the value of power, with its absolute uncertanity rounded to appropriate sig. figures.

Power dissipated = 0.20 ± 0.01 W.

2. One end of a wire is connected to a fixed pt. A load is attached to the other end so that the wire hangs vertically.
The wire's diameter and load F are measured in,
$d = 0.40 \pm 0.02$ mm , $F = 25.0 \pm 0.5$ N.

a) For the measurement of diameter of the wire, state

(i) The name of a suitable measuring instrument.
→ Micrometer screw gauge

(ii) How random errors may be reduced when using the instrument.
→ By conducting careful experiment.
→ Taking multiple measurements then taking their average.

b) The stress σ of the wire is given by:

$$\sigma = \frac{4F}{\pi d^2}$$

i) Show that the value of σ is 1.99×10^8 Nm^{-2}.

" " " ")

$F_b = 25.0\,N$, $d_b = 0.40\,mm = \frac{0.40}{10 \times 100}\,m = 4 \times 10^{-4}\,m.$

$$\sigma = \frac{4F}{\pi d^2} = \frac{4 \times 25}{3.14 \times (4 \times 10^{-4})^2} = \frac{100}{5.024 \times 10^{-7}} = 199044586$$

$$= 1.99 \times 10^{8}\ Nm^{-2}$$ //.

[As stress is restoring force per unit cross-sectional area, its unit is Nm^{-2}.]

ii) Determine percentage uncertanity in σ.

$$\Delta\sigma = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$= \frac{\left(\frac{4 \times 25.5}{3.14 \times (4 \times 10^{-4} - 2 \times 10^{-5})^2}\right) - \left(\frac{4 \times 24.5}{3.14 \times (4 \times 10^{-4} + 2 \times 10^{-5})^2}\right)}{2}$$

$$= 24015228.6 = 2 \times 10^{7}\ Nm^{-2} = 0.2 \times 10^{8}\ Nm^{-2}$$

Percentage uncertanity $= \frac{24015228.6}{199044586} \times 100\%$

$= 12.06\%$

iii) Determine value of σ with its absolute uncertanity rounded to appropriate no. of significant figures.

$$\sigma = 2.0 \times 10^{8} \pm 0.2 \times 10^{8}\ Nm^{-2}$$ //.

3. In an experiment to determine acceleration of free fall g, the period of oscillation T and length l of a simple pendulum were measured. The uncertanity in measurement of l is estimated to be 4% and that of T is estimated to be 1%.
The value of T is given by $T = 2\pi\sqrt{\frac{l}{g}}$

What is uncertanity in value of g.

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

or, $T/2\pi = \sqrt{l/g}$

or, $(T/2\pi)^2 = (\sqrt{l/g})^2$

or, $T^2/4\pi^2 = l/g$

$\cancel{\therefore g = \frac{T^2}{4\pi^2 l}}$ $\quad \therefore g = \frac{4\pi^2 l}{T^2}$

Let l be 1m and T be 1s,

$\Delta g = \frac{g_{max} - g_{min}}{2}$

$= \frac{\left(\frac{4\pi^2(1 + 4/100)}{(1 - 1/100)^2}\right) - \left(\frac{4\pi^2(1 - 4/100)}{(1 + 1/100)^2}\right)}{2}$

$= \frac{4\pi^2\left(\frac{1 + 4/100}{(1 - 1/100)^2} - \frac{1 - 4/100}{(1 + 1/100)^2}\right)}{2}$

$= \cancel{2\pi^2 \times 0.12}$ $\quad 4\pi^2 \times 0.12/2$

$= \cancel{2.366304}$ $\quad \cancel{4\pi^2.0}$ $\quad 4\pi^2 \times 0.06$

$g_b = \frac{4\pi^2 l_b}{T_b^2} = \frac{4\pi^2 \times 1}{1^2} = 4\pi^2$

Uncertanity in g $= \frac{\cancel{4\pi^2} \times 0.06}{\cancel{4\pi^2}} \times 100\% = 6\%$

$\therefore$ The uncertanity in g is approximately 6%.

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1. A student measures the current through a resistor and the potential difference across it. There is 4% uncertanity in current reading and 1% in p.d reading. The student calculates the resistance of the resistor. What is the percentage uncertanity in the calculated resistance?

$V = IR$

$R = V/I$

Let $V = 1\,V$ and $I = 1\,A$

$R_b = V_b/I_b = 1/1 = 1\,\Omega$

$$\Delta R = \frac{R_{max} - R_{min}}{2}$$

$$= \frac{\left(\frac{1 + 1/100}{1 - 4/100}\right) - \left(\frac{1 - 1/100}{1 + 4/100}\right)}{2}$$

$= 0.05008\,\Omega$

Percentage uncertanity $= \frac{0.5008}{1} \times 100 \approx 5\%$

$\therefore$ Answer = D (5%)

2. A student applies a p.d of $4.0 \pm 0.1\,V$ across a resistor of resistance R of $10.0 \pm 0.3\,\Omega$ for a time of $(50 \pm 1)\,s$. The student calculates the Energy dissipated using the eq^n $E = \frac{V^2 t}{R} = 80\,J$

What is the absolute uncertanity in the calculated energy value.

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$$\Delta E = \frac{E_{max} - E_{min}}{2}$$

$$= \frac{\left(\frac{(4.1)^2 \times 51}{9.7}\right) - \left(\frac{(3.9)^2 \times 49}{10.3}\right)}{2}$$

$$= 8.012\ J \approx 8\ J$$

$\therefore$ Answer = D (8J)

3. The diagram shows the stem of a Celsius thermometer marked to show initial and final temperature values.
What is the temperature change expressed to appropriate number of significant figures.

Final temperature (t_2) = 14°C
Initial temperature (t_1) = −6.5°C
Change in temperature (dt) = $t_2 - t_1$
= 14°C − (−6.5°C)
= 20.5°C
= ~~21°C [Rounding up]~~

$\therefore$ Answer = ~~C (21°C)~~ B (20.5°C)
As least count of thermometer is 0.5°C.