DAY ONE

Units and Measurement

Learning & Revision for the Day

- Physics
- Units
- Significant Figures
- Accuracy and Precision
- Errors in Measurement
- Dimensions of Physical Quantities

Physics

Physics is the study of matter and its motion, as well as space and time using concepts such as energy, force, mass and charge. It is an experimental science, creating theories that are tested against observation.

Scope and Excitement

Scope of Physics is very vast, as it deals with a wide variety of disciplines such as mechanics, heat, light, etc.

It also deals with very large magnitude of astronomical phenomenon as well as very small magnitude involving electrons, protons, etc.

Nature of Physical Laws

Physics is the study of nature and natural phenomena. All observations and experiments in physics lead to certain facts. These facts can be explained on the basis of certain laws.

Physics, Technology and Society

Connection between physics, technology and society can be seen in many examples like working of heat engines gave rise to thermodynamics. Wireless communication technology arose from basic laws of electricity and magnetism. Lately discovery of silicon chip triggered the computer revolution.

Units

Measurement of any physical quantity involves comparison with a certain basic, widely accepted reference standard called **unit**.

Fundamental and Derived Units

Fundamental units are the units which can neither be derived from one another, nor they can be further resolved into more simpler units.

These are the units of fundamental quantity. However, **derived units** are the units of measurement of all physical quantities which can be obtained from fundamental units.

System of Units

A complete set of these units, both fundamental and derived unit is known as the **system of units**. The common systems are given below:

1. **CGS System** (Centimetre, Gram, Second) are often used in scientific work. This system measures, Length in centimetre (cm), Mass in gram (g), Time in second (s).
2. **FPS System** (Foot, Pound, Second) It is also called the British Unit System. This unit measures, Length in foot (foot), Mass in gram (pound), Time in second (s).
3. **MKS System** In this system also length, mass and time have been taken as fundamental quantities and corresponding fundamental units are metre, kilogram and second.
4. **International System (SI) of Units** It is an extended version of the MKS (Metre, Kilogram, Second) system. It has seven base units and two supplementary units. Seven base quantities and two supplementary quantities, their units along with definitions are tabulated below.

Base Quantity	Basic Units	
	Name and Symbol	Definintion
Length	metre (m)	The metre is the length of path travelled by light in vacuum during a time interval of 1/299,792,458 part of a second.
Mass	kilogram (kg)	It is the mass of the international prototype of the kilogram (a platinum iridium alloy cylinder) kept at International Bureau of Weights and Measures, at Sevres (France).
Time	second (s)	The second is the duration of 9,192, 631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of cesium-133 atom.
Electric current	Ampere (A)	The ampere is that constant current, which if maintained in two straight, parallel conductors of infinite length placed 1 m apart in vacuum would produce a force equal to 2×10^{-7} Nm^{-1} on either conductor.
Thermodyn-amic temperature	Kelvin (K)	The kelvin is $\frac{1}{273.16}$ th fraction of the thermodynamic temperature of the triple point of water.
Amount of substance	mole (mol)	The mole is the amount of substance of a system, which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12.
Luminous intensity	candela (cd)	The candela is the luminous intensity in a given direction of a source emitting monochromatic radiation of frequency 540×10^{12} Hz and having a radiant intensity of $\frac{1}{683}$ W sr^{-1} in that direction.

Supplementary Units		
Supplementary Quantity	Name and Symbol	Definition
Plane angle	radian (rad)	It is angle subtended at the centre by an arc of a circle having a length equal to the radius of the circle.
Solid angle	steradian (sr)	It is the solid angle which is having its vertex at the centre of the sphere, it cuts-off an area of the surface of sphere equal to that of a square with the length of each side equal to the radius of the sphere.

NOTE
- Angle subtended by a closed curve at an inside points is 2π rad.
- Solid angle subtended by a closed surface at an inside point is 4π steradian.

Significant Figures

In the measured value of a physical quantity, the digits about the correction of which we are sure, plus the last digits which is doubtful, are called the significant figures.

Larger the number of significant figures obtained in a measurement, greater is the accuracy of the measurement.

Rules for Counting Significant Figures

- All the non-zero digits are significant. In 2.738 the number of significant figures is 4.
- All the zeros between two non-zero digits are significant, no matter where the decimal point is. As examples 209 and 3.002 have 3 and 4 significant figures, respectively.
- If the measured number is less than 1, the zero (s) on the right of decimal point and to the left of the first non-zero digit are non-significant. In $\underline{0}.\underline{00}807$, first three underlined zeros are non-significant and the number of significant figures is only 3.

- The terminal or trailing zero (s) in a number without a decimal point are not significant. Thus, 12.3 m $= 1230$ cm $= 12300$ mm has only 3 significant figures.
- The trailing zero(s) in number with a decimal point are significant. Thus, 3.800 kg has 4 significant figures.
- A choice of change of units does not change the number of significant digits or figures in a measurement.
- To remove ambiguities in determining number of significant figures, a measurement is usually expressed as '$a \times 10^b$', where $1 \le a \le 10$ and b is the order of magnitude.

Rules for Arithmetic Operations with Significant Figures

- In addition or subtraction, the final results should retain as many decimal places as there are in the number with the least decimal place. As an example sum of 423.5 g, 164.92 g and 24.381 g is 612.801 g, but it should be expressed as 612.8 g only because the least precise measurement (423.5 g) is correct to only one decimal place.
- In multiplication or division, the final result should retain as many significant figures as there are in the original number with the least significant figures.
  For example Suppose an expression is performed like

$$(24.3 \times 1243) / (44.65) = 676.481522$$

Rounding the above result upto three significant figures result would become 676.

Rules for Rounding off the Uncertain Digits

- The preceding digit is raised by 1 if the insignificant digit to be dropped is more than 5 and is left unchanged if the latter is less than 5. e.g. 18.764 will be rounded off to 18.8 and 18.74 to 18.7.
- If the insignificant figure is 5 and the preceding digit is even, then the insignificant digit is simply dropped. However, if the preceding digit is odd, then it is raised by one so as to make it even. e.g. 17.845 will be rounded off to 17.84 and 17.875 to 17.88.

Accuracy and Precision

The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity. However, precision tells us to what resolution or limit, the quantity is measured by a measuring instrument.

Least Count

The least count of a measuring instrument is the least value, that can be measured using the instrument. It is denoted as LC.

(i) **Least count of vernier callipers**

$$\text{LC} = \frac{\text{Value of 1 main scale division}}{\text{Total number of vernier scale division}}$$

(ii) **Least count of screw gauge**

$$\text{LC} = \frac{\text{Value of 1 pitch scale reading}}{\text{Total number of head scale division}}$$

Errors in Measurement

The difference in the true value (mean value) and measured value of a quantity is called error of measurement. Different types of error are given below:

(i) Absolute error,

$$a_{\text{mean}} = a_0 = \frac{a_1 + a_2 + a_3 + \dots a_n}{n} = \frac{1}{n}\sum_{i=1}^{i=n} a_i$$

$$\begin{aligned}
\Delta a_1 &= \text{mean value} - \text{observed value}\\
\Delta a_1 &= a_0 - a_1\\
\Delta a_2 &= a_0 - a_2\\
\vdots \quad & \quad \vdots \quad \vdots\\
\Delta a_n &= a_0 - a_n
\end{aligned}$$

(ii) Mean absolute error,

$$\Delta a_{\text{mean}} = \frac{[\,|\Delta a_1| + |\Delta a_2| + |\Delta a_3| + \dots + |\Delta a_n|\,]}{n} = \frac{\sum_{i=1}^{n} |\Delta a_i|}{n}$$

(iii) Relative or fractional error $= \dfrac{\Delta a_{\text{mean}}}{a_{\text{mean}}}$

(v) Percentage error,

$$\delta_a = \text{Relative error} \times 100\,\% = \frac{\Delta a_{\text{mean}}}{a_{\text{mean}}} \times 100\%$$

Combination of Errors

(i) If $X = A + B$, then $(\Delta X) = \pm(\Delta A + \Delta B)$

(ii) If $X = ABC$, then $\left(\dfrac{\Delta X}{X}\right)_{\text{max}} = \pm\left[\dfrac{\Delta A}{A} + \dfrac{\Delta B}{B} + \dfrac{\Delta C}{C}\right]$

(iii) If $X = A^k B^l C^n$, then $\left(\dfrac{\Delta X}{X}\right) = \pm\left[k\dfrac{\Delta A}{A} + l\dfrac{\Delta B}{B} + n\dfrac{\Delta C}{C}\right]$

Dimensions of Physical Quantities

The dimensions of a physical quantity are the powers to which the fundamental (base) quantities are raised, to represent that quantity.

Consider the physical quantity force.

'Force $=$ mass $\times$ acceleration $=$ mass $\times$ length $\times$ (time)$^{-2}$'

Thus, the dimension of force are 1 in mass [M]

1 in length [L] and -2 in time $[\text{T}^{-2}]$, that is $[\text{MLT}^{-2}]$.

- Dimensions of a physical quantity do not depend on its magnitude or the units in which it is measured.

Principle of Homogeneity of Dimensions and Applications

According to this principle, a correct dimensional equation must be homogeneous, i.e. dimensions of all the terms in a physical expression must be same.

LHS (dimension) = RHS (dimension)

Uses of Dimensions

(i) To check the correctness of a given physical equation.

(ii) Derivation of formula.

(iii) Dimensional formula is useful to convert the value of a physical quantity from one system to the other. Physical quantity is expressed as a product of numerical value and unit. In any system of measurement, this product remains constant.

Let dimensional formula of a given physical quantity be $[M^a L^b T^c]$.If in a system having base units $[M_1 L_1 T_1]$ the numerical value of given quantity be n_1 and numerical value n_2 in another unit system having the base units $[M_2, L_2, T_2]$, then

$$Q = n_1 u_1 = n_2 u_2$$

$$n_1 [M_1^a L_1^b T_1^c] = n_2 [M_2^b L_2^b T_2^c]$$

$$\boldsymbol{n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c}$$

Dimensions of Important Physical Quantities

Physical Quantity	SI Unit	Dimensional Formula
Power	Watt (W)	$[ML^2 T^{-3}]$
Pressure, stress, coefficient of elasticity (ρ, σ, η)	Pascal (Pa) or Nm^{-2}	$[ML^{-1} T^{-2}]$
Frequency, angular frequency	Hz or s^{-1}	$[T^{-1}]$
Angular momentum	kg $m^2 s^{-1}$	$[ML^2 T^{-1}]$
Torque	Nm	$[ML^2 T^{-2}]$
Gravitational constant (G)	N m^2 kg^{-2}	$[M^{-1} L^3 T^{-2}]$
Moment of inertia	kg m^2	$[ML^2]$
Acceleration, acceleration due to gravity	ms^{-2}	$[LT^{-2}]$
Force, thrust, tension, weight	Newton (N)	$[MLT^{-2}]$
Linear momentum, impulse	kg ms^{-1} or Ns	$[MLT^{-1}]$
Work, energy, KE, PE, thermal energy, internal energy, etc.	Joule (J)	$[ML^2 T^{-2}]$
Surface area, area of cross-section	m^2	$[L^2]$
Electric conductivity	Sm^{-1}	$[M^{-1} L^{-3} T^3 A^2]$
Young's modulus, Bulk modulus	Pa	$[ML^{-1} T^{-2}]$
Compressibility	m^2 N^{-1}	$[M^{-1} LT^2]$
Magnetic Flux	Wb	$[ML^2 T^{-2} A^{-1}]$
Magnetic Flux density (σ)	Wb / m^2	$[MT^{-2} A^{-1}]$
Intensity of a wave	Wm^{-2}	$[MT^{-3}]$
Photon flux density	m^{-2} s^{-1}	$[L^{-2} T^{-1}]$
Luminous energy	Lm s	$[ML^2 T^{-2}]$
Luminance	Lux	$[MT^{-3}]$
Specific heat capacity	$Jkg^{-1} K^{-1}$	$[L^2 T^{-2} K^{-1}]$
Latent heat of vaporisation	Jkg^{-1}	$[L^2 T^{-2}]$
Coefficient of Thermal conductivity	$Wm^{-1} K^{-1}$	$[MLT^{-3} K^{-1}]$
Electric voltage	JC^{-1}	$[ML^2 T^{-3} A^{-1}]$
Magnetisation	Am^{-1}	$[L^{-1} A]$
Magnetic induction	T	$[MT^{-2} A^{-1}]$
Planck's constant	J-s	$[ML^2 T^{-1}]$
Radioactive decay constant	Bq	$[T^{-1}]$
Binding energy	MeV	$[ML^2 T^{-2}]$

DAY PRACTICE SESSION 1

FOUNDATION QUESTIONS EXERCISE

1 In which of the following systems of units, a Weber is the unit of magnetic flux?

(a) CGS (b) MKS (c) SI (d) FPS

2 In an experiment, the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (0.5°), then the least count of the instrument is → **AIEEE 2009**

(a) one minute (b) half minute
(c) one degree (d) half degree

3 A student measured the length of a rod and wrote it as 3.50 cm.Which instrument did he use to measure it?

(a) A meter scale → **JEE Main 2014**
(b) A vernier calliper where the 10 divisions in vernier scale matches with 9 divisions in main scale and main scale has 10 divisions in 1 cm
(c) A screw gauge having 100 divisions in the circular scale and pitch as 1 mm
(d) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm

4 N division on main scale of a vernier callipers coincide with $(N+1)$ division of the vernier scale if each division on main scale is of "a" units, least count of instrument is

(a) $\frac{N+1}{a}$ (b) $\frac{a}{N+1}$ (c) $\frac{N-1}{a}$ (d) $\frac{a}{N-1}$

5 One 8 centimetre on the main scale of a vernier calliper is divided into 10 equal parts. If 10 of the divisions of the vernier coincide with small divisions on the main scale, the least count of the callipers is

(a) 0.005 cm (b) 0.02 cm
(c) 0.01 cm (d) 0.05 cm

6 The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are

(a) 5, 1, 2 (b) 5, 1, 5 (c) 5, 5, 2 (d) 4, 4, 2

7 A bee of mass 0.000087 kg sits on a flower of mass 0.0123 kg. What is the total mass supported by the stem of the flower up to appropriate significant figures?

(a) 0.012387 kg (b) 0.01239 kg
(c) 0.0124 kg (d) 0.012 kg

8 The radius of a uniform wire is $r = 0.021$ cm. The value of π is given to be 3.142. What is the area of cross-section of the wire up to appropriate significant figures?

(a) $0.0014\ \text{cm}^2$ (b) $0.00139\ \text{cm}^2$
(c) $0.001386\ \text{cm}^2$ (d) $0.0013856\ \text{cm}^2$

9 A man runs 100.5 m in 10.3 s. Find his average speed up to appropriate significant figures.

(a) $9.71\ \text{ms}^{-1}$ (b) $9.708\ \text{ms}^{-1}$
(c) $9.7087\ \text{ms}^{-1}$ (d) $9.70874\ \text{ms}^{-1}$

10 If the length of rod A is 3.25 ± 0.01 cm and that of B is 4.19 ± 0.01 cm, then the rod B is longer than rod A by

(a) (0.94 ± 0.00) cm (b) (0.94 ± 0.01) cm
(c) (0.94 ± 0.02) cm (d) (0.094 ± 0.005) cm

11 You measure two quantities as $A = 1.0\ \text{m} \pm 0.2\ \text{m}$, $B = 2.0\ \text{m} \pm 0.2\ \text{m}$. We should report correct value for $\sqrt{AB}$ as

(a) $1.4\ \text{m} \pm 0.4\ \text{m}$ (b) $1.41\ \text{m} \pm 0.15\ \text{m}$
(c) $1.4\ \text{m} \pm 0.3\ \text{m}$ (d) $1.4\ \text{m} \pm 0.2\ \text{m}$

12 A student measured the length of the pendulum 1.21 m using a metre scale and time for 25 vibrations as 2 min 20 sec using his wrist watch, absolute error in g is

(a) $0.11\ \text{ms}^{-2}$ (b) $0.88\ \text{ms}^{-2}$
(c) $0.44\ \text{ms}^{-2}$ (d) $0.22\ \text{ms}^{-2}$

13 The absolute error in density of a sphere of radius 10.01 cm and mass 4.692 kg is

(a) $3.59\ \text{kgm}^{-3}$ (b) $4.692\ \text{kgm}^{-3}$
(c) 0 (d) $1.12\ \text{kgm}^{-3}$

14 A sphere has a mass of $12.2\ \text{kg} \pm 0.1$ kg and radius $10\ \text{cm} \pm 0.1$ cm, the maximum % error in density is

(a) 10% (b) 2.4% (c) 3.83% (d) 4.2%

15 If error in measurement of radius of sphere is 1%, what will be the error in measurement of volume?

(a) 1% (b) $\frac{1}{3}\%$ (c) 3% (d) 10%

16 What is the percentage error in the measurement of the time period T of a pendulum, if the maximum errors in the measurements of l and g are 2% and 4%, respectively?

(a) 6% (b) 4% (c) 3% (d) 5%

17 The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1% , the maximum error in determining the density is → **JEE Main 2018**

(a) 2.5% (b) 3.5%
(c) 4.5% (d) 6%

18 Which one of the following represents the correct dimensions of the coefficient of viscosity?

(a) $[ML^{-1}T^{-2}]$ (b) $[MLT^{-1}]$
(c) $[ML^{-1}T^{-1}]$ (d) $[ML^{-2}T^{-2}]$

19 Which of the following sets share different dimensions?

(a) Pressure, Young's modulus, stress
(b) Emf, potential difference, electric potential
(c) Heat, work done, energy
(d) Dipole moment, electric flux, electric field

20 Out of the following pairs, which one does not have identical dimensions?

(a) Angular momentum and Planck's constant
(b) Impulse and momentum
(c) Moment of inertia and moment of a force
(d) Work and torque

21 The dimensions of $\dfrac{e^2}{4\pi\varepsilon_0 hc}$, where e, ε_0, h and c are the electronic charge, electric permittivity, Planck's constant and velocity of light in vacuum respectively, are

(a) $[M^0L^0T^0]$ (b) $[ML^0T^0]$ (c) $[M^0LT^0]$ (d) $[M^0L^0T]$

22 In the relation $X = 3YZ^2$, X and Z represent the dimensions of capacitance and magnetic induction respectively, dimensions of Y are

(a) $[MT^{-1}Q^{-1}]$ (b) $[M^{-3}T^4L^{-2}Q^4]$
(c) $[M^{-3}T^{-1}L^{-1}Q^4]$ (d) $[ML^2T^{-2}A^{-2}]$

23 The dimensions of magnetic field in M,L,T and C (coulomb) is given as

(a) $[MLT^{-1}C^{-1}]$ (b) $[MT^2C^{-2}]$ (c) $[MT^{-1}C^{-1}]$ (d) $[MT^{-2}C^{-1}]$

24 Dimensions of $\dfrac{1}{\mu_0\varepsilon_0}$, where symbols have their usual meaning, are

(a) $[L^{-1}T]$ (b) $[L^2T^2]$ (c) $[L^2T^{-2}]$ (d) $[LT^{-1}]$

25 If the acceleration due to gravity is 10 ms^{-2} and units of length and time are changed to kilometre and hours respectively, the numerical value of acceleration is

(a) 360000 (b) 72000 (c) 36000 (d) 129600

26 If E = energy, G = gravitational constant, I = impulse and M = mass, then dimensions of $\dfrac{GIM^2}{E^2}$ are same as that of

(a) time (b) mass (c) length (d) force

27 Let $[\varepsilon_0]$ denotes the dimensional formula of the permittivity of vacuum. If M = mass, L = length, T = time and A = electric current, then **→ JEE Main 2013**

(a) $[\varepsilon_0] = [M^{-1}L^{-3}T^2A]$ (b) $[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$
(c) $[\varepsilon_0] = [M^{-2}L^2T^{-1}A^{-2}]$ (d) $[\varepsilon_0] = [M^{-1}L^2T^{-1}A^2]$

28 With the usual notations, the following equation

$$s = u + \frac{1}{2}a(2t-1) \text{ is}$$

(a) only numerically correct
(b) only dimensionally correct
(c) Both numerically and dimensionally correct
(d) Neither numerically nor dimensionally correct

29 The dimensions of $\dfrac{a}{b}$ in the equation $p = \dfrac{a-t^2}{bx}$ where, p is pressure, x is distance and t is time, are

(a) $[M^2LT^{-3}]$ (b) $[MT^{-2}]$ (c) $[ML^3T^{-2}]$ (d) $[LT^{-3}]$

30 The velocity of a particle is given as $v = a + bt + ct^2$. If the velocity is measured in ms^{-1}, then units of a and c are

(a) ms^{-1} and ms^{-3} (b) ms^{-2} and ms
(c) m^2s and ms^2 (d) ms and ms^{-1}

31 In the following dimensionally consistent equation, we have, $F = \dfrac{X}{\text{Linear density}} + Y$, where F = force.

The dimensional formula for X and Y are

(a) $[M^2L^0T^{-2}]$; $[MLT^{-2}]$ (b) $[M^2L^{-2}T^{-2}]$; $[MLT^{-2}]$
(c) $[MLT^{-2}]$; $[ML^2T^{-2}]$ (d) $[M^0L^0T^0]$; $[ML^0T^0]$

32 The dimensions of self-inductance are

(a) $[ML^{-2}T^{-2}A^{-2}]$ (b) $[ML^2T^{-2}A^{-2}]$
(c) $[ML^2T^{-2}A^{-1}]$ (d) $[ML^{-2}T^{-2}A^{-1}]$

33 Match List I with List II and select the correct answer using the codes given below the lists. **→ 2013 Main**

	Column I		Column II
A.	Boltzmann constant	p.	$[ML^2T^{-1}]$
B.	Coefficient of viscosity	q.	$[ML^{-1}T^{-1}]$
C.	Planck constant	r.	$[MLT^{-3}K^{-1}]$
D.	Thermal conductivity	s.	$[ML^2T^{-2}K^{-1}]$

Codes

	A	B	C	D		A	B	C	D
(a)	p	q	r	s	(b)	s	q	p	r
(c)	s	r	p	q	(d)	r	s	q	p

Direction (Q. Nos. 34-37) *Each of these questions contains two statements : Statement* I (*Assertion*) *and Statement* II (*Reason*). *Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes* (*a*), (*b*), (*c*), (*d*) *given below*

(a) Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I
(b) Statement I is true, Statement II is true; Statement II is not the correct explanation for Statement I
(c) Statement I is true; Statement II is false
(d) Statement I is false; Statement II is true

34 **Statement I** The order of accuracy of measurement depends on the least count of the measuring instrument.

Statement II The smaller the least count, the greater is the number of significant figures in the measured value.

35 **Statement I** The dimensional method cannot be used to obtain the dependence of the work done by a force F on the angle θ between force F and displacement x.

Statement II Angle can be measured in radians but it has no dimensions.

36 **Statement I** The mass of an object is 13.2 kg in the measurement there are 3 significant figures.

Statement II The same mass when expressed in grams as 13200 g has five significant figures.

37 **Statement I** Method of dimensions cannot be used for deriving formula containing trigonometrical ratios.

Statement II This is because trigonometrical ratios have no dimensions.

DAY PRACTICE SESSION 2

PROGRESSIVE QUESTIONS EXERCISE

1 The dimensions of angular momentum, latent heat and capacitance are, respectively. → **JEE Main (Online) 2013**

(a) $[ML^2T^1A^2]$, $[L^2T^{-2}]$, $[M^{-1}L^{-2}T^2]$
(b) $[ML^2T^{-2}]$, $[L^2T^2]$, $[M^{-1}L^{-2}T^4A^2]$
(c) $[ML^2T^{-1}]$, $[L^2T^{-2}]$, $[ML^2TA^2]$
(d) $[ML^2T^{-1}]$, $[L^2T^{-2}]$, $[M^{-1}L^{-2}T^4A^2]$

2 The speed (v) of ripples on the surface of water depends on surface tension (σ), density (ρ) and wavelength (λ). The square of speed (v) is proportional to

(a) $\frac{\sigma}{\rho\lambda}$ (b) $\frac{\rho}{\sigma\lambda}$ (c) $\frac{\lambda}{\sigma\rho}$ (d) $\rho\lambda\sigma$

3 Dimensions of resistance in an electrical circuit, in terms of dimensions of mass M, length L, time T and current I, would be

(a) $[ML^2T^{-3}I^{-1}]$ (b) $[ML^2T^{-2}]$
(c) $[ML^2T^{-1}I^{-1}]$ (d) $[ML^2T^{-3}I^{-2}]$

4 In the relation $p = \frac{\alpha}{\beta} e^{-\frac{\alpha z}{k\theta}}$, p is pressure, z is distance, k is Boltzmann constant and θ is the temperature. The dimensional formula of β will be

(a) $[M^0L^2T^0]$ (b) $[ML^2T]$
(c) $[ML^0T^{-1}]$ (d) $[M^0L^2T^{-1}]$

5 The dimensions of σb^4 (σ = Stefan's constant and b = Wien's constant) are

(a) $[M^0L^0T^0]$ (b) $[ML^4T^{-3}]$ (c) $[ML^{-2}T]$ (d) $[ML^6T^{-3}]$

6 If Planck's constant (h) and speed of light in vacuum (c) are taken as two fundamental quantities, which one of the following can, in addition,be taken to express length, mass and time in terms of the three chosen fundamental quantities?

(i) Mass of electron (m_e)
(ii) Universal gravitational constant (G)
(iii) Charge of electron (e)
(iv) Mass of proton (m_p)

(a) (i),(ii) and (iii) (b) (i) and (iii)
(c) (i), (ii) and (iv) (d) (i) only

7 The length and breadth of a rectangular sheet are 16.2 cm and 10.1 cm , respectively. The area of the sheet in appropriate significant figures and error is

(a) 164 ± 3 cm^2 (b) 163.62 ± 2.6 cm^2
(c) 163.6 ± 2.6 cm^2 (d) 163.62 ± 3 cm^2

8 Resistance of a given wire is obtained by measuring the current flowing in it and the voltage difference applied across it. If the percentage errors in the measurement of the current and the voltage difference are 3% each, then error in the value of resistance of the wire is

(a) 6% (b) zero (c) 1% (d) 3%

9 A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm
Circular scale reading : 52 divisions
Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.
The diameter of wire from the above data is

(a) 0.052 cm (b) 0.026 cm
(c) 0.005 cm (d) 0.52 cm

10 A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a thin sheet of aluminium. Before starting the measurement, it is found that when the two jaws of the screw gauge are brought in contact, the 45th division coincides with the main scale line and that the zero of the main scale is barely visible. What is the thickness of the sheet, if the main scale reading is 0.5 mm and the 25th division coincides with the main scale line?

(a) 0.75 mm (b) 0.80 mm
(c) 0.70 mm (d) 0.50 mm

11 The following observations were taken for determining surface tension T of water by capillary method. Diameter of capillary, $d = 1.25 \times 10^{-2}$ m rise of water, $h = 1.45 \times 10^{-2}$m. Using $g = 9.80$ m/s^2 and the simplified relation $T = \frac{dhg}{4} \times 10^3$N/m, the possible error in surface tension is closest to → **JEE Main 2017 (Offline)**

(a) 1.5% (b) 2.4% (c) 10% (d) 0.15%

12 A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90s, 91s, 92s and 95s. If the minimum division in the measuring clock is 1s, then the reported mean time should be

➔ **JEE Main 2016 (Offline)**

(a) (92 ± 2) s (b) (92 ± 5) s (c) (92 ± 1.8) s (d) (92 ± 3) s

13 The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. Measured value of L is 20.0 cm known to 1mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of resolution.The accuracy in the determination of g is

➔ **JEE Main 2015**

(a) 2% (b) 3% (c) 1% (d) 5%

14 The current voltage relation of diode is given by $I = (e^{1000V/T} - 1)$ mA, where the applied voltage V is in volt and the temperature T is in kelvin. If a student makes an error measuring ± 0.01V while measuring the current of 5 mA at 300K, what will be the error in the value of current in mA? ➔ **JEE Main 2013**

(a) 0.2 mA (b) 0.02 mA (c) 0.5 mA (d) 0.05 mA

Direction (Q. Nos. 15-16) *Each of these questions contains two statements : Statement* I (*Assertion*) *and Statement* II (*Reason*). *Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes* (*a*), (*b*), (*c*), (*d*) *given below*

(a) Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I
(b) Statement I is true, Statement II is true; Statement II is not the correct explanation for Statement I
(c) Statement I is true; Statement II is false
(d) Statement I is false; Statement II is true

15 **Statement I** The value of velocity of light is 3×10^8 ms^{-1} and acceleration due to gravity is 10 ms^{-2} and the mass of proton is 1.67×10^{-27} kg.

Statement II The value of time in such a system is 3×10^7 s.

16 **Statement I** The distance covered by a body is given by $s = u + \frac{1}{2}\frac{a}{t}$, where the symbols have usual meaning.

Statement II We can add, substract or equate quantities which have same dimensions.

ANSWERS

SESSION 1

1 (c)	**2** (a)	**3** (b)	**4** (b)	**5** (b)	**6** (a)	**7** (d)	**8** (a)	**9** (a)	**10** (c)
11 (d)	**12** (d)	**13** (a)	**14** (c)	**15** (c)	**16** (c)	**17** (c)	**18** (c)	**19** (d)	**20** (c)
21 (a)	**22** (b)	**23** (c)	**24** (c)	**25** (d)	**26** (a)	**27** (b)	**28** (d)	**29** (b)	**30** (a)
31 (a)	**32** (b)	**33** (b)	**34** (b)	**35** (a)	**36** (c)	**37** (a)			

SESSION 2

1 (d)	**2** (a)	**3** (d)	**4** (a)	**5** (b)	**6** (a)	**7** (a)	**8** (a)	**9** (a)	**10** (b)
11 (a)	**12** (a)	**13** (b)	**14** (a)	**15** (b)	**16** (d)				

Hints and Explanations

SESSION 1

1 A weber is the unit of magnetic flux in SI system.

2 Least count

$$= \frac{\text{Value of main scale division}}{\text{Number of divisions on vernier scale}}$$

$$= \frac{1}{30}\text{ MSD} = \frac{1}{30} \times \frac{1^\circ}{2} = \frac{1^\circ}{60} = 1\text{ min}$$

3 If student measures 3.50cm, it means that there is an uncertainly of $\frac{1}{100}$ cm.

For vernier scale with $1\text{ MSD} = 1\text{ mm}$ and $9\text{MSD} = 10\text{ VSD}$

LC of vernier calliper $= 1\text{ MSD} - 1\text{VSD}$

$$= \frac{1}{10}\left(1 - \frac{9}{10}\right) = \frac{1}{100}\text{cm}$$

4 $(N + 1)\text{ VSD} = N\text{ MSD}$

$\therefore \quad 1\text{ VSD} = \frac{N}{N+1}\text{ MSD}$

Least count

$= (1\text{ MSD} - 1\text{VSD})$ (value of MSD)

$$= \left(1 - \frac{N}{N+1}\right) \times a = \frac{a}{N+1}$$

5 $1\text{ MSD} = \frac{1}{10}\text{ cm} = 0.1\text{ cm},$

$10\text{ VSD} = 8\text{ MSD}$

Hence, we get

$1\text{ VSD} = \frac{8}{10}\text{ MSD} = \frac{8}{10} \times (0.1) = 0.08\text{ cm}$

Thus, the least count $= 1\text{ MSD} - 1\text{VSD}$

$= 0.1 - 0.08 = 0.02\text{ cm}$

6 Number of significant figures in $23.023 = 5$

Number of significant figures in $0.0003 = 1$

Number of significant figures in $2.1 \times 10^{-3} = 2$

7 The mass of the bee has 2 significant figures in kg, whereas the mass of the flower has three significant figures. Hence, the sum (0.012387) must be rounded off to the third decimal place. Therefore, the correct significant figure is 0.012.

8 $A = \pi r^2 = 3.142 \times (0.021)^2$

$= 0.00138562\text{ cm}^2.$

Now, there are only two significant figures in 0.021 cm. Hence, the result must be rounded off to two significant figures as $A = 0.0014\text{ cm}^2$.

9 Average speed $= \frac{100.5\text{ m}}{10.3\text{ s}}$

$= 9.75728\text{ ms}^{-1}$

The distance has four significant figures but the time has only three. Hence, the result must be rounded off to three significant figure to 9.71 ms^{-1}.

10 As, $\quad A = 3.25 \pm 0.01\text{ cm}$

and $\quad B = 4.19 \pm 0.01\text{ cm}$

$\therefore \quad Y = B - A$

$= 4.19 - 3.25 = 0.94\text{ cm}$

and $\Delta Y = \Delta B + \Delta A$

$= 0.01\text{ cm} + 0.01\text{ cm} = 0.02\text{ cm}$

$\therefore \quad Y = (0.94 \pm 0.02)\text{ cm}$

11 Here, $A = 1.0\text{ m} \pm 0.2\text{ m},$

$B = 2.0\text{ m} \pm 0.2\text{ m}$

$x = \sqrt{AB} = \sqrt{(1.0)(2.0)} = 1.414\text{ m}$

Rounding off to two significant digits,

$x = \sqrt{AB} = 1.4\text{ m}$

Now, $\frac{\Delta x}{x} = \frac{1}{2}\left[\frac{\Delta A}{A} + \frac{\Delta B}{B}\right]$

$$= \frac{1}{2}\left[\frac{0.2}{1.0} + \frac{0.2}{2.0}\right] = \frac{0.6}{2 \times 2.0}$$

$$\Delta x = \frac{0.6\,x}{2 \times 2.0} = 0.15 \times 1.414$$

$= 0.2121$

Rounding off to one significant digit,

$\Delta x = 0.2\text{ m}$

Hence, $\sqrt{AB} = x \pm \Delta x = (1.4 \pm 0.2)\text{ m}$

12 As, $T = 2\pi\sqrt{\frac{l}{g}}$ or $g = \frac{4\pi^2 l}{T^2}$

$$\Rightarrow \quad \left(\frac{\Delta g}{g} = \frac{\Delta L}{L} + \frac{2\Delta T}{T}\right)$$

So, absolute error in g is

$$\Delta g = \left(\frac{\Delta L}{L} + \frac{2\Delta T}{T}\right) g$$

$$= \left(\frac{0.01}{1.21} + \frac{2 \times 1}{140}\right) \times 9.8$$

$= (0.0227 \times 9.8) = 0.22\text{ ms}^{-2}$

13 $\therefore \rho = \frac{M}{\frac{4}{3}\pi r^3} = \frac{4.692 \times 3}{4 \times 3.14 \times (10.01)^3 \times 10^{-6}}$

$\rho = 1.12 \times 10^3\text{ kg - m}^{-3}$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta r}{r}$$

$$\therefore \Delta\rho = \left(\frac{0.001}{4.692} + \frac{3 \times 0.01}{10.01}\right) \times 1.12 \times 10^3$$

$= 3.59\text{ kgm}^{-3}$

14 $\therefore$ Density, $\rho = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi r^3},$

$$\frac{d\rho}{\rho} \times 100 = \left(\frac{\Delta M}{M} + \frac{3\Delta r}{r}\right) \times 100$$

$$= \left(\frac{0.1}{12.2} + 3 \times \frac{0.1}{10}\right) \times 100$$

$= 3.83\%$

15 As, $V = \frac{4}{3}\pi r^3$

Hence, $\frac{\Delta V}{V} \times 100 = 3\frac{\Delta r}{r} \times 100$

$= 3 \times 1\% = 3\%$

16 Since, the time period,

$$T = \frac{1}{2\pi}\sqrt{\frac{l}{g}}$$

Thus, for calculating the error, we get

$$\frac{\Delta T}{T} = \pm\left[\frac{1}{2}\frac{\Delta l}{l} + \frac{1}{2}\frac{\Delta g}{g}\right]$$

$$= \pm\left[\frac{1}{2} \times 2\% + \frac{1}{2} \times 4\%\right] = \pm 3\%$$

17 $\because$ Density, $\rho = \frac{\text{Mass}}{\text{Volume}} = \frac{M}{L^3}$ or $\rho = \frac{M}{L^3}$

$\Rightarrow$ Error in density $\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{3\Delta L}{L}$

So, maximum % error in measurement of ρ is

$$\frac{\Delta\rho}{\rho} \times 100 = \frac{\Delta M}{M} \times 100 + \frac{3\Delta L}{L} \times 100$$

or % error in density $= 1.5 + 3 \times 1$

% error $= 4.5\%$

18 By Newton's formula $\eta = \frac{F}{A\,(\Delta V / \Delta Z)}$

$\therefore \quad$ Dimensions of η

$$= \frac{\text{Dimensions of force}}{(\text{Dimensions of area} \times \text{Dimensions of velocity gradient})}$$

$$= \frac{[\text{MLT}^{-2}]}{[\text{L}^2][\text{T}^{-1}]} = [\text{ML}^{-1}\text{T}^{-1}]$$

19 Dipole moment = charge × distance

Electric flux = electric field × area

20 $I = mr^2$

$\therefore \quad [I] = [\text{ML}^2]$

τ moment of force $= r \times F$

$\therefore \quad [\tau] = [\text{L}][\text{MLT}^{-2}] = [\text{ML}^2\text{T}^{-2}]$

21 $\left[\frac{e^2}{4\pi\varepsilon_0 hc}\right]$

$$= \frac{[\text{AT}]^2}{[\text{M}^{-1}\text{L}^{-3}\text{T}^4\text{A}^2] \cdot [\text{ML}^2\text{T}^{-1}] \cdot [\text{LT}^{-1}]}$$

$= [\text{M}^0\text{L}^0\text{T}^0]$

22 $X = [C] = [M^{-1} L^{-2}T^2Q^2]$,
$Z = [B] = [MT^{-1}Q^{-1}]$
$$Y = \frac{X}{Z^2} = \frac{[M^{-1}T^2L^{-2}Q^2]}{[MT^{-1}Q^{-1}]^2} = [M^{-3}T^4L^{-2}Q^4]$$

23 From the relation $F = qvB$
$\Rightarrow \quad [MLT^{-2}] = [C][LT^{-1}][B]$
$\Rightarrow \quad [B] = [MC^{-1}T^{-1}]$

24 As we know that, formula of velocity is
$v = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow v^2 = \frac{1}{\mu_0\varepsilon_0} = [LT^{-1}]^2 \quad \therefore$
$\frac{1}{\mu_0\varepsilon_0} = [L^2T^{-2}]$

25 $n_2 = n_1\left[\frac{L_1}{L_2}\right]\left[\frac{T_1}{T_2}\right]^{-2}$
$= 10\left[\frac{\text{metre}}{\text{km}}\right]\left[\frac{\text{sec}}{\text{h}}\right]^{-2}$
$n_2 = 10\left[\frac{\text{m}}{10^3\,\text{m}}\right]\left[\frac{\text{sec}}{3600\text{sec}}\right]^{-2}$
$=129600$

26 $$\left[\frac{GIM^2}{E^2}\right] = \frac{[M^{-1}L^3T^{-2}]\times[MLT^{-1}]\times[M]^2}{[ML^2T^{-2}]^2}$$
$= [M^0L^0T]$

So, dimensions of $\frac{GIM^2}{E^2}$ are same as that of time.

27 Electrostatic force between two charges,
$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1\,q_2}{R^2}$$
$$\Rightarrow \quad \varepsilon_0 = \frac{q_1 q_2}{4\pi FR^2}$$
Substituting the units.
Hence, $\varepsilon_0 = \frac{C^2}{N\text{ - }m^2} = \frac{[AT\;]^2}{[MLT^{-2}]\;[L^2]}$
$= [M^{-1}\;L^{-3}\;T^4\;A^2]$

28 s = distance travelled, u = velocity.
So, dimensionally it is not a correct equation.

29 $p = \frac{a - t^2}{bx}$
$\Rightarrow \quad pbx = a - t^2$
$\Rightarrow \quad [pbx] = [a] = [T^2]$
or $\quad [b] = \frac{[T^2]}{[p][x]} = \frac{[T^2]}{[ML^{-1}T^{-2}][L]}$
$= [M^{-1}T^4]$
$\therefore \quad \left[\frac{a}{b}\right] = \frac{[T^2]}{[M^{-1}T^4]} = [MT^{-2}]$

30 Unit of a = unit of v = m/s = ms^{-1}
and unit of c = unit of $\frac{v}{t^2}$
$= \frac{\text{m /s}}{\text{s}^2} = \text{m / s}^3 = \text{ms}^{-3}$

31 $[F] = \left[\frac{X}{\text{Linear density}}\right] + [Y]$.
So, the dimensions of Y are the same as that of F, i.e. $[Y] = [F] = [MLT^{-2}]$
Now, $[MLT^{-2}] = \left[\frac{X}{ML^{-1}}\right]$
$\Rightarrow \quad X = [M^2\; L^0T^{-2}]$

32 The self-inductance L of a coil in which the current varies at a rate $\frac{dI}{dt}$ and is given by $e = -L\,\frac{dI}{dt}$, where e is the electromotive force (emf) induced in the coil.
Now, the dimensions of emf are the same as that of the potential difference,
i.e. $[ML^2T^{-3}I^{-1}]$
Now, $L = \frac{-e}{dI/dt}$.
Hence, the dimensions of L are
$$[L] = \frac{\text{dimensions of}\,e}{\text{dimensions of}\,I\,/\,\text{dimensions of}\,t}$$
$= \frac{[ML^2\;T^{-3}\;I^{-1}]}{[I\;/\;T]}$
$= [ML^2T^{-2}I^{-2}]$

33 (A) $U = \frac{1}{2}\,kT$
$\Rightarrow [ML^2T^{-2}] = [k]\;K$
$\Rightarrow \quad [K] = [ML^2T^{-2}K^{-1}]$
(B) $F = \eta A\,\frac{dv}{dx}$
$\Rightarrow [\eta] = \frac{[MLT^{-2}]}{[L^2LT^{-1}L^{-1}]} = [ML^{-1}\;T^{-1}]$
(C) $E = h\nu \Rightarrow [ML^2T^2] = [h]\;[T^{-1}]$
$\Rightarrow \quad [h] = [ML^2T^{-1}]$
(D) $\frac{dQ}{dt} = \frac{k\,A\Delta\theta}{l}$
$\Rightarrow [k] = \frac{[ML^2T^{-3}L]}{[L^2K]} = [MLT^{-3}K^{-1}]$

34 The least count of a measuring device is the least distance (resolution/accuracy), that can be measured using the device.
Greater is the number of significant figures obtained in a measurement, greater is its precision and for this the least count of the measuring instrument should be smaller.

35 Work done is $W = Fx\cos\theta$. Since, θ is dimensionless, the dependence of W on θ cannot be determined by the dimensional method.

36 The degree of accuracy (and hence the number of significant figures) of a measurement cannot be increased by changing the unit.

37 It is true that trigonometrical ratios do not have dimensions. Therefore, method of finding dimensions cannot be utilized for deriving formula involving trigonometrical ratio.

SESSION 2

1 Angular momentum $= r \times P = [LM\,LT^{-1}]$
$= [ML^2T^{-1}]$
Latent heat, $\quad L = \frac{Q}{M} = [L^2T^{-2}]$
Capacitance, $C = \frac{q}{V} = \frac{(AT)^2}{W}$
$\left(\text{as, } V = \frac{W}{q}\right)$
$= [A^2T^2M^{-1}L^{-2}T^{+2}]$
$= [M^{-1}L^{-2}T^4A^2]$

2 Let $v \propto \sigma^a\rho^b\lambda^c$. Equating dimensions on both sides
$[M^0\,L^1\,T^{-1}] = k\;[MT^{-2}]^a\,[ML^{-3}]^b\,[L]^c$
$[M^0LT^{-1}] = k\;[M]^{a+b}[L]^{-3b+c}\;[T]^{-2a}$
Equating the powers of M, L, T on both sides, we get
$a + b = 0$ and $-3b + c = 1; -2a = -1$
Solving, we get $a = \frac{1}{2}, b = -\frac{1}{2}, c = -\frac{1}{2}$
$\therefore\; v \propto \sigma^{1/2}\rho^{-1/2}\lambda^{-1/2} \qquad \therefore\; v^2 \propto \frac{\sigma}{\rho\lambda}$

3 Resistance, $R = \frac{\text{Potential difference}}{\text{Current}}$
$= \frac{V}{I} = \frac{W}{qI}$
($\because$ Potential difference is equal to work done per unit charge)
So, dimensions of R
$$= \frac{[\text{Dimensions of work}]}{[\text{Dimensions of charge}]\;[\text{Dimensions of current}]}$$
$= \frac{[ML^2T^{-2}]}{[IT]\;[I]} = [ML^2T^{-3}I^{-2}]$

4 In the given equation, $\frac{\alpha z}{k\theta}$ should be dimensionless
$\therefore\; [\alpha] = \left[\frac{k\theta}{z}\right]$
$\Rightarrow [\alpha] = \frac{[ML^2\;T^{-2}\;K^{-1}\times K]}{[L]} = [MLT^{-2}]$
and $[p] = \left[\frac{\alpha}{\beta}\right]$
$\Rightarrow \quad [\beta] = \left[\frac{\alpha}{p}\right] = \frac{[MLT^{-2}]}{[ML^{-1}T^{-2}]} = [M^0L^2T^0]$

5 $\lambda_m T = b$ or $b^4 = \lambda_m^4 T^4$
and $\frac{\text{energy}}{\text{area}\times\text{time}} = \sigma T^4$
or $\quad \sigma = \frac{\text{energy}}{(\text{area}\times\text{time})\,T^4}$

$$\sigma b^4 = \left(\frac{\text{energy}}{\text{area}\times\text{time}}\right)\lambda_m^4$$

or $[\sigma b^4] = \frac{[ML^2T^{-2}]}{[L^2][T]}[L^4] = [ML^4T^{-3}]$.

6 $h = [ML^2T^{-1}]$; $c = [LT^{-1}]$, $m_e = [M]$, $G = [M^{-1}L^3T^{-2}]$, $e = AT$; $m_p = M$,

$$\frac{hc}{G} = \frac{[M^1L^2T^{-1}][LT^{-1}]}{[M^{-1}L^3T^{-2}]} = [M^2]$$

$$\Rightarrow \quad M = \sqrt{\frac{hc}{G}}$$

$$\frac{h}{c} = \frac{[ML^2T^{-1}]}{[LT^{-1}]} = [ML]$$

$$\Rightarrow \quad L = \frac{h}{cM} = \frac{h}{c}\sqrt{\frac{G}{hc}} = \frac{\sqrt{Gh}}{c^{3/2}}$$

From $c = [LT^{-1}]$,

$$T = \frac{L}{c} = \frac{\sqrt{Gh}}{c^{3/2}c} = \frac{\sqrt{Gh}}{c^{5/2}}$$

Hence, out of (i), (ii) and (iii) any one can be taken to express L, M, T in terms of three chosen fundamental quantities.

7 Here, $l = (16.2 \pm 0.1)$ cm ;

$b = (10.1 \pm 0.1)$ cm

$A = l \times b = 16.2 \times 10.1 = 163.62$

Rounding off to three significant digits, $A = 164\ \text{cm}^2$

$$\frac{\Delta A}{A} = \left(\frac{\Delta l}{l} + \frac{\Delta b}{b}\right) = \frac{0.1}{16.2} + \frac{0.1}{10.1}$$

$$= \frac{1.01 + 1.62}{16.2 \times 10.1} = 2.63\ \text{cm}^2$$

Rounding off to one significant figure, $\Delta A = 3\text{cm}^2$

$\therefore \quad A = (164 \pm 3)\ \text{cm}^2$

8 From Ohm's law, $R = \frac{V}{I}$

$\Rightarrow \ln R = \ln V - \ln I$

$\Rightarrow \frac{\Delta R}{R} = \frac{\Delta V}{V} + \frac{\Delta I}{I} = 3\% + 3\% = 6\%$

9 Diameter of wire, $d = \text{MSR} + \text{CSR} \times \text{LC}$

$= 0 + 52 \times \frac{1}{100} = 0.52\ \text{mm} = 0.052\ \text{cm}$

10 Least count $= \frac{\text{pitch}}{\text{(number of division on circular scale)}}$

$= \frac{0.5}{50}$ mm

$\therefore \quad \text{LC} = 0.01$

Negative zero error $= -5 \times \text{LC} = -0.005$ mm

Measured value = main scale reading + screw guage reading – zero error

$= 0.5\ \text{mm} + \{25 \times 0.01 - (-0.05)\}$ mm

$= 0.80$ mm

11 By given formula, we have surface tension,

$$T = \frac{dhg}{4} \times 10^3\ \frac{N}{m} \qquad \left(\because r = \frac{d}{2}\right)$$

$\Rightarrow \frac{\Delta T}{T} = \frac{\Delta d}{d} + \frac{\Delta h}{h}$ [given, g is constant]

So, percentage error is

$$= \frac{\Delta T}{T} \times 100$$

$$= \left(\frac{\Delta d}{d} + \frac{\Delta h}{h}\right) \times 100$$

$$= \left(\frac{0.01 \times 10^{-2}}{1.25 \times 10^{-2}} + \frac{0.01 \times 10^{-2}}{1.45 \times 10^{-2}}\right) \times 100$$

$= 1.5\%$

$\therefore \frac{\Delta T}{T} \times 100 = 1.5\%$

12 Arithmetic mean time of a oscillating simple pendulum $= \frac{\Sigma x_i}{N}$

$$= \frac{90 + 91 + 92 + 95}{4} = 92\ \text{s}$$

Mean error is

$$= \frac{\Sigma|\bar{x} - x_i|}{N} = \frac{2 + 1 + 3 + 0}{4} = 1.5$$

Given, minimum division in the measuring clock, is 1 s. Thus, the reported mean time of a oscillating simple pendulum $= (92 \pm 2)$ s.

13 Given, time period, $T = 2\pi\sqrt{\frac{L}{g}}$

Thus,changes can be expressed as

$$= \frac{2T}{T} = \pm\frac{\Delta L}{L} \pm \frac{\Delta g}{g}$$

According to the question, we can write

$$\frac{\Delta L}{L} = \frac{0.1\text{cm}}{20.0\text{cm}} = \frac{1}{200}$$

Again time period $T = \frac{90}{100}$ s

and $\Delta T = \frac{1}{200}$ s $\Rightarrow \frac{\Delta T}{T} = \frac{1}{90}$

Now, $\quad T = 2\pi\sqrt{\frac{L}{g}}$

$\therefore \frac{\Delta g}{g} = \frac{\Delta L}{L} + \frac{2\Delta T}{T}$ or $\frac{\Delta g}{g} \times 100\%$

$$= \left(\frac{\Delta L}{L}\right) \times 100\% + \left(\frac{2\Delta T}{T}\right) \times 100\%$$

$$= \left(\frac{1}{200} \times 100\right)\% + 2 \times \frac{1}{90} \times 100\%$$

$= 2.72\% = 3\%$

Thus, accuracy in the determination of g is approx 3 %.

14 Given, $I = (e^{1000V/T} - 1)$ mA

$dV = \pm 0.01\text{V}$, $T = 300$ K, $I = 5$ mA,

$I = e^{1000V/T} - 1$, $I + 1 = e^{1000V/T}$

Taking log on both sides, we get

$$\log (I + 1) = \frac{1000V}{T}$$

$$\Rightarrow \quad \frac{d(I+1)}{I+1} = \frac{1000}{T}\,dV$$

$$\frac{dI}{I+1} = \frac{1000}{T}\,dV$$

$$\Rightarrow \quad dI = \frac{1000}{T} \times (I + 1)\,dV$$

$$dI = \frac{1000}{300} \times (5 + 1) \times 0.01$$

$= 0.2$ mA

So, error in the value of current is 0.2 mA.

15 $[c] = [LT^{-1}] = 3 \times 10^8\ \text{ms}^{-1}$

and $[g] = [LT^{-2}] = 10\ \text{ms}^{-2}$

So, $\quad \frac{c}{g} = \frac{[LT^{-1}]}{[LT^{-2}]} = T$

$\therefore \quad T = \frac{3 \times 10^8}{10} = 3 \times 10^7$ s

16 The physical quantities can be equated, added or subtracted only when they have same dimensions. The distance covered by a body is $s = u + \frac{1}{2}\frac{a}{t}$

$$[L] = [LT^{-1}] + \frac{[LT^{-2}]}{[T]}$$

$$[L] = [LT^{-1}] + [LT^{-3}]$$

As every term of equation is not is not having same dimensions, so it is a wrong expression for distance.