# 1 Physical World and Measurement

## QUICK LOOK

Neither the names nor the symbols used for the physical quantities are international standards. Some quantities are known as several different names such as the magnetic *B-field* which known as the *magnetic flux density*, the *magnetic induction* or simply as the *magnetic field* depending on the context. Similarly, surface tension can be denoted by $\sigma, \gamma$ or $T$. The table usually lists only one name and symbol. The final column lists some special properties some of the quantities have such as their scaling behavior (i.e. whether the quantity is intensive or extensive), their transformation properties (i.e. whether the quantity is a scalar, vector or tensor) or whether the quantity is conserved.

**Table 1.1:** Base Quantities

| Base quantity | Symbol | Description | SI unit | Symbol for dimension | Comments / Definition |
|---|---|---|---|---|---|
| length | $l$ | The one-dimensional extent of an object. | metre (m) | $L$ | **1 metre =** the length of the path traveled by light in vacuum during a time interval of 1 / 299 792 458 of a second. (17th CGPM, 1983, Resolution 1) |
| Mass | $m$ | The amount of matter in an object. | kilogram (kg) | $M$ | Extensive/**1 kilogram =** the mass of the international prototype of the kilogram. (3rd CGPM, 1901) |
| Time | $t$ | The duration of an event. | second (s) | $T$ | **1 second =** 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 the cesium 133 atom. (13th CGPM, 1967, Resolution 1) |
| Electric current | $I$ | Rate of flow of electrical charge. | ampere (A) | $I$ | **1 ampere =** that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vaccum, would produce between these conductors a force equal to $2 \cdot 10^{-7}$ newton per metre of length. (9th CGPM, 1948) |
| Temperature | $T$ | Average energy per degree of freedom of a system. | kelvin (K) | $\theta$ | Intensive/**1 kelvin =** the fraction 1 /273.16 of the thermodynamic temperature of the triple point of water. (13th CGPM, 1967) |
| Amount of substance | $n$ | Number of particles compared to the number of atoms in 0.012 kg of $^{12}C$. | mole (mol) | $N$ | Extensive/**1 mole =** the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon – 12. (14th CGPM, 1971) |
| Luminous intensity | $L$ | Amount of energy emitted by a light source in a particular direction. | candela (cd) | $J$ | **1 candela =** the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency $540 \cdot 10^{12}$ hertz and that has a radiant intensity in that direction of 1 / 683 watt per steradian. (16th CGPM, 1948) |

To convert a physical quantity from one system to the other $n_2 = n_1 \left[\frac{M_1}{M_2}\right]^a \left[\frac{L_1}{L_2}\right]^b \left[\frac{T_1}{T_2}\right]^c$

**Table: 1.2** Physical Quantities

| Derived quantity | Symbol | Description | SI units | Dimension | Comments |
|---|---|---|---|---|---|
| Plane angle | $\theta$ | Measure of a change in direction or orientation. | radian (rad) | 1 | |
| Solid angle | $\Omega$ | Measure of the size of an object as projected on a sphere. | steradian (sr) | 1 | |
| Absorbed dose rate | | Absorbed dose received per unit of time. | Gy $s^{-1}$ | $L^2\,T^{-3}$ | |
| Angular momentum | $L$ | Measure of the extent and direction and object rotates about a reference point. | kg $m^2\,s^{-1}$ | $M\,L^2\,T^{-1}$ | conserved quantity, pseudovector |
| Area | $A$ | The two-dimensional extent of an object. | $m^2$ | $L^2$ | |
| Area density | $\rho_A$ | The amount of mass per unit area of a two-dimensional object. | kg $m^{-2}$ | $M\,L^{-2}$ | |

| | | | | | |
|---|---|---|---|---|---|
| Capacitance | $C$ | Measure for the amount of stored charge for a given potential. | Fara ($F = A^2$) $s^4$ kg$^{-1}$ $m^{-2}$) | $I^2 T^4 M^{-1} L^{-2}$ | |
| Catalytic activity | | Change in reaction rate due to presence of a catalyst. | katal (kat = mol s$^{-1}$) | $N T^{-1}$ | |
| Catalytic activity concentration | | Change in reaction rate due to presence of a catalyst per unit volume of the system. | kat m$^{-3}$ | $N L^{-3} T^{-1}$ | |
| Chemical potential | $M$ | The amount of energy needed to add a particle to a system. | J mol$^{-1}$ | $M L^2 T^{-2} N^{-1}$ | intensive |
| Molar concentration | $C$ | Amount of substance per unit volume. | mol $m^{-3}$ | $N L^{-3}$ | intensive |
| Current density | $\bar{J}$ | Amount of electric current flowing through a surface. | A $m^{-2}$ | $I L^{-2}$ | vector |
| Dose equivalent | $H$ | Measure for the received amount of radiation adjusted for the effect of different types of radiant on biological tissue. | sievert (Sv = m$^2$ s$^{-2}$) | $L^2 T^{-2}$ | |
| Dynamic Viscosity | $H$ | Measure for the resistance of an incompressible fluid to stress. | Pa s | $M L^{-1} T^{-1}$ | |
| Electric Charge | $Q$ | Amount of electric charge. | coulomb ($C$ = A s) | I T | extensive, conserved quantity |
| Electric charge density | $\rho_Q$ | Amount of electric charge per unit volume. | $C$ m$^{-3}$ | $I T L^{-3}$ | intensive |
| Electric displacement | $D$ | Strength of the electric displacement. | $C$ m$^{-2}$ | $I T L^{-2}$ | vector field |
| Electric field strength | $\bar{E}$ | Strength of the electric field. | $V$ $m^{-1}$ | $M L T^{-3} I^{-1}$ | vector field |
| Electrical conductance | $G$ | Meausure for how easily current flows through a material. | siemens (S = A$^2$ s$^3$ kg$^{-1}$ m$^{-2}$) | $L^{-2} M^{-1} T^3 I^2$ | scalar |
| Electric potential | $V$ | The amount of work required to bring a unit charge into an electric field from infinity. | volt (V = kg m$^2$ A$^{-1}$ s$^{-3}$) | $L^2 M T^{-3} I^{-1}$ | scalar |
| Electrical resistance | $R$ | The degree to which an object opposes the passage of an electric current. | ohm (Ω = kg m$^2$ A$^{-2}$ s$^{-3}$) | $L^2 M T^{-3} I^{-2}$ | scalar |
| Energy density | $\rho_E$ | Amount of energy per unit volume. | J m$^{-3}$ | $M L^{-1} T^{-2}$ | intensive |
| Entropy | $S$ | Measure for the amount of available states for a system. | J K$^{-1}$ | $M L^2 T^{-2} \Theta^{-1}$ | extensive, scalar |
| Impulse | $\bar{p}$ | The cause of a change in momentum, acting on an object. | kg m s$^{-1}$ | $M L T^{-1}$ | vector |
| Frequency | $F$ | The number of times something happens in a period of time. | hertz (Hz = s$^{-1}$) | $T^{-1}$ | |
| Half-life | $t_{1/2}$ | The time needed for a quantity to decay to half its original value. | S | T | |
| Heat | $Q$ | Amount of energy transferred between systems due to temperature difference. | J | $M L^2 T^{-2}$ | |
| Heat capacity | $C_p$ | Amount of energy needed to raise the temperature of a system by one degree. | J K$^{-1}$ | $M L^2 T^{-2} \Theta^{-1}$ | extensive |
| Heat flux density | $\phi_Q$ | Amount of heat flowing through a surface per unit area. | W m$^{-2}$ | $M T^{-3}$ | |
| Illuminance | $E_v$ | Total luminous flux incident to a surface per unit area. | lux (lx = cd sr m$^{-2}$) | $J L^{-2}$ | |
| Impedance | $Z$ | Measure for the resistance of an electrical circuit against an alternating current. | ohm (Ω = kg m$^2$ A$^{-2}$ s$^{-3}$) | $L^2 M T^{-3} I^{-2}$ | complex scalar |
| Index of refraction | $n$ | The factor by which the speed of light is reduce in a medium. | | 1 | intensive |
| Inductance | $L$ | Measure for the amount of magnetic flux generated for a certain current run through a circuit. | henry (H = kg m$^2$ A$^{-2}$ s$^{-2}$) | $M L^2 T^{-2} I^{-2}$ | |
| Irradiance | $E$ | Power of electromagnetic radiation flowing through a surface per unit area. | W m$^{-2}$ | $M T^{-2}$ | |
| Linear density | $\rho_l$ | Amount of mass per unit length of a one-dimensional object. | | $M L^{-1}$ | |
| Luminous flux (or *luminous power*) | $F$ | Perceived power of a light source. | lumen (lm = cd sr) | J | |
| Magnetic field strength | $H$ | Strength of a magnetic field in a material. | A m$^{-1}$ | $I L^{-1}$ | vector field |
| Magnetic flux | Φ | Measure of quantity of magnetism, taking account of | weber (Wb = kg m$^2$ A$^{-1}$ | $M L^2 T^{-2} I^{-1}$ | scalar |

| | | | | | |
|---|---|---|---|---|---|
| | | the strength and the extent of a magnetic field. | $s^{-2}$) | | |
| Magnetic flux density | *B* | Measure for the strength of the magnetic field. | tesla (T = kg $A^{-1}$ $s^{-2}$) | M $T^{-2}$ $I^{-1}$ | pseudovector field |
| Magnetization | *M* | Amount of magnetic moment per unit volume. | A $m^{-1}$ | I $L^{-1}$ | vector field |
| Mass fraction | *X* | Mass of a substance as a fraction of the total mass. | kg/kg | 1 | intensive |
| (Mass) Density (volume density) | $\rho$ | The amount of mass per unit volume of a three-dimensional object. | kg $m^{-3}$ | M $L^{-3}$ | intensive |
| Mean lifetime | $\tau$ | Average time needed for a particle to decay. | S | T | intensive |
| Molar energy | | Amount of energy present is a system per unit amount of substance. | J $mol^{-1}$ | M $L^2$ $T^{-2}$ $N^{-1}$ | intensive |
| Molar entropy | | Amount of entropy present in a system per unit amount of substance. | J $K^{-1}$ $mol^{-1}$ | M $L^2$ $T^{-2}$ $\Theta^{-1}$ $N^{-1}$ | intensive |
| Molar heat capacity | *c* | Heat capacity of a material per unit amount of substance. | J $K^{-1}$ $mol^{-1}$ | M $L^2$ $T^{-2}$ $N^{-1}$ | intensive |
| Moment of inertia | *I* | Inertia of an object with respect to angular acceleration. | kg $m^2$ | M $L^2$ | Tensor (Not specified by magnitude, unit and direction) |
| Momentum | $\vec{p}$ | Product of an object's mass and velocity. | N s | M L $T^{-1}$ | vector, extensive |
| Permeability | $\mu$ | Measure for how the magnetization of material is affected by the application of an external magnetic field. | H $m^{-1}$ | M $L^{-1}$ $I^{-2}$ | intensive |
| Permittivity | *E* | Measure for how the polarization of a material is affected by the application of an external electric field. | F $m^{-1}$ | $I^2$ $M^{-1}$ $L^{-3}$ $T^4$ | intensive |
| Power | *P* | The rate of change in energy over time. | watt (W) | M $L^2$ $T^{-3}$ | extensive |
| Pressure | *p* | Amount of force per unit area. | pascal (Pa = kg $m^{-1}$ $s^{-2}$) | M $L^{-1}$ $T^{-2}$ | intensive |
| (Radioactive) Activity | *A* | Number of particles decaying per unit time. | becquerel (Bq = $s^{-1}$) | $T^{-1}$ | extensive |
| (Radioactive) Dose | *D* | Amount of energy absorbed by biological tissue from ionizing radiation per unit mass. | gray (unit) (Gy = $m^2$ $s^{-2}$) | $L^2$ $T^{-2}$ | |
| Radiance | *L* | Power of emitted electromagnetic radiation per solid angle and per projected source area. | W $m^{-2}$ $sr^{-1}$ | M $T^{-3}$ | |
| Radiant intensity | *I* | Power of emitted electromagnetic radiation per solid angle. | W $sr^{-1}$ | M $L^2$ $T^{-3}$ | scalar |
| Reaction rate | *R* | Measure for speed of a chemical reaction. | mol $m^{-3}$ $s^{-1}$ | N $L^{-3}$ $T^{-1}$ | intensive |
| Speed | *v* | Rate of change of the position of an object. | m $s^{-1}$ | L $T^{-1}$ | scalar |
| Specific energy | | Amount of energy present per unit mass. | J $kg^{-1}$ | $L^2$ $T^{-2}$ | intensive |
| Specific heat capacity | *c* | Heat capacity per unit mass. | J $kg^{-1}$ $K^{-1}$ | $L^2$ $T^{-2}$ $\Theta^{-1}$ | intensive |
| Specific volume | *v* | The volume occupied by a unit mass of material (reciprocal of density). | $m^3$ $kg^{-1}$ | $L^3$ $M^{-1}$ | intensive |
| Spin | *S* | Intrinsic property of particles, roughly to be interpreted as the intrinsic angular momentum of the particle. | kg $m^2$ $s^{-1}$ | M $L^2$ $T^{-1}$ | |
| Stress | $\sigma$ | Amount of force exerted per surface area. | Pa | M $L^{-1}$ $T^{-2}$ | 2-tensor. (or scalar) |
| Surface tension | $\gamma$ | Amount of work needed to change the surface of a liquid by a unit surface area. | N $m^{-1}$ or J $m^{-2}$ | M $T^{-2}$ | |
| Thermal conductivity | *k* | Measure for the ease with which a material conducts heat. | W $m^{-1}$ $K^{-1}$ | M L $T^{-3}$ $\theta^{-1}$ | intensive |
| Torque | $\tau$ | Product of a force and the perpendicular distance of the force from the point about which it is exerted. | N m | M $L^2$ $T^{-2}$ | pseudovector |
| Velocity | $\vec{v}$ | Speed of an object in a chosen direction. | m $s^{-1}$ | L $T^{-1}$ | vector |
| Volume | *V* | The three dimensional extent of an object. | $m^3$ | $L^3$ | extensive |
| Wavelength | $\lambda$ | Distance between repeating units of a propagating wave. | m | L | |
| Wavenumber | *k* | Reciprocal of the wavelength. | $m^{-1}$ | $L^{-1}$ | |

**Limitations of Dimensional Analysis:** Although dimensional analysis is very useful it cannot lead us too far as,

- If dimensions are given, physical quantity may not be unique as many physical quantities have same dimensions. For example if the dimensional formula of a physical quantity is $[ML^2T^{-2}]$ it may be work or energy or torque.
- Numerical constant having no dimensions [*K*] such as (1/2), 1 or $2\pi$ *etc.* cannot be deduced by the methods of dimensions.
- The method of dimensions cannot be used to derive relations other than product of power functions. For example, $s = ut + (1/2)at^2$ or $y = a\sin\omega t$ cannot be derived by using this theory (try if you can). However, the dimensional correctness of these can be checked.
- The method of dimensions cannot be applied to derive formula if in mechanics a physical quantity depends on more than 3 physical quantities as then there will be less number (= 3) of equations than the unknowns (> 3). However still we can check correctness of the given equation dimensionally. For example $T = 2\pi\sqrt{1/mgl}$ can not be derived by theory of dimensions but its dimensional correctness can be checked.
- Even if a physical quantity depends on 3 physical quantities, out of which two have same dimensions, the formula cannot be derived by theory of dimensions, *e.g.*, formula for the frequency of a tuning fork $f = (d/L^2)v$ cannot be derived by theory of dimensions but can be checked.

**Accuracy:** Accuracy of a result or experimental procedure can refer to the percentage difference between the experimental result and the accepted value. The stated uncertainty in an experimental result should always be greater than this percentage accuracy.

- Accuracy is also associated with the inherent uncertainty in a measurement. We can express the accuracy of a measurement explicitly by stating the estimated uncertainty or implicitly by the number of significant figures given. For example, we can measure a small distance with poor accuracy using a metre rule, or with much greater accuracy using a micrometer.
- Another term you will hear in relation to experiments and experimental results is the term precision. Precision is the degree of exactness with which a quantity is measured.

**Nature and Use of Errors:** Errors occur in all physical measurements. When a measurement is used in a calculation, the error in the measurement is therefore carried through into the result. The two different types of error that can occur in a measured value are:

- **Systematic error:** This occurs to the same extent in each one of a series of measurements eg zero error, where for instance the needle of a voltmeter is not correctly adjusted to read zero when no voltage is present.
- **Random error:** This occurs in any measurement as a result of variations in the measurement technique (eg parallax error, limit of reading, etc).
- **Experimental Errors:** The variations in different readings of a measurement are usually referred to as "experimental errors". They are not to be confused with "mistakes". Such variations are normal.

**Precise Measurement:** Least count = one division value of main scale / Total number of divisions on vernier or circular scale

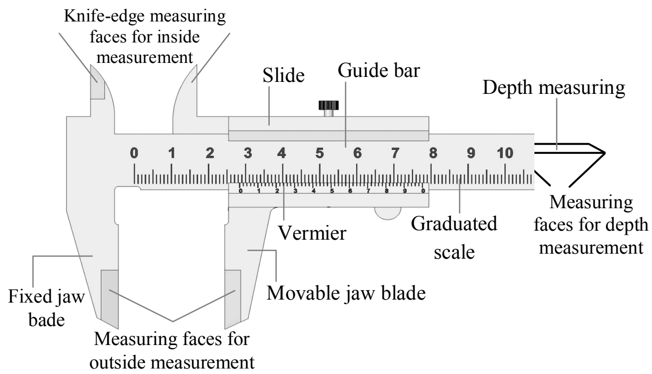


**Figure 1.1**

- Least count of vernier calipers, $LC = \dfrac{s}{n}$

  Least count of screw guaze $= \dfrac{p}{n}$

  Error in a measurement = Least count.
- Percentage error in a formula $y = \dfrac{p^a q^b}{r^c}$ is

  $$\left(a\frac{\Delta p}{p} + b\frac{\Delta q}{q} + c\frac{\Delta r}{r}\right) \times 100\%$$
- The last figure in a measurement is doubtful, the error in last figure is ± 1. (Keeping position with respect to decimal place fixed.)

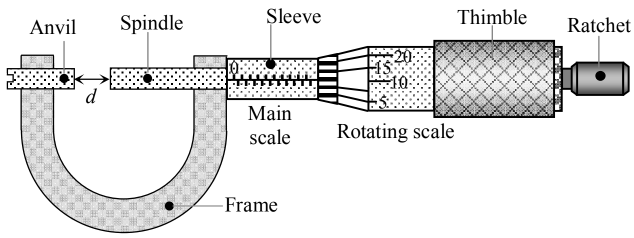


**Figure 1.2**

## MULTIPLE CHOICE QUESTIONS

### Units

1. The magnitude of any physical quantity:
**a.** Depends on the method of measurement
**b.** Does not depend on the method of measurement
**c.** Is more in SI system than in CGS system
**d.** Directly proportional to the fundamental units of mass, length and time

2. Density of wood is 0.5 gm/cc in the CGS system of units. The corresponding value in MKS units is:
**a.** 500 **b.** 5
**c.** 0.5 **d.** 5000

3. Young's modulus of a material has the same units as:
**a.** Pressure **b.** Strain
**c.** Compressibility **d.** Force

4. One nanometre is equal to:
**a.** $10^9$ mm **b.** $10^{-6}$ mm
**c.** $10^{-7}$ cm **d.** $10^{-9}$ mm

5. In $S=a+bt+ct^2$. $S$ is measured in metres and $t$ in seconds. The unit of $c$ is:
**a.** $ms^{-2}$ **b.** $m$
**c.** $ms^{-1}$ **d.** None of these

6. If $x=at+bt^2$, where $x$ is the distance travelled by the body in kilometres while $t$ is the time in seconds, then the units of $b$ are:
**a.** $\mathrm{km/s}$ **b.** $\mathrm{km-s}$
**c.** $\mathrm{km/s^2}$ **d.** $\mathrm{km-s^2}$

7. Which is different from others by units?
**a.** Phase difference **b.** Mechanical equivalent
**c.** Loudness of sound **d.** Poisson's ratio

### Application of Dimensional Analysis

8. If velocity $v$, acceleration $A$ and force $F$ are chosen as fundamental quantities, then the dimensional formula of angular momentum in terms of $v, A$ and $F$ would be
**a.** $FA^{-1}v$ **b.** $Fv^3A^{-2}$
**c.** $Fv^2A^{-1}$ **d.** $F^2v^2A^{-1}$

9. Select the pair whose dimensions are same:
**a.** Pressure and stress **b.** Stress and strain
**c.** Pressure and force **d.** Power and force

10. The dimension of the ratio of angular to linear momentum is:
**a.** $M^0L^1T^0$ **b.** $M^1L^1T^{-1}$
**c.** $M^1L^2T^{-1}$ **d.** $M^{-1}L^{-1}T^{-1}$

11. The unit of absolute permittivity is:
**a.** *Farad - meter* **b.** *Farad / meter*
**c.** $Farad/meter^2$ **d.** *Farad*

12. Unit of Stefan's constant is:
**a.** $Js^{-1}$ **b.** $Jm^{-2}s^{-1}K^{-4}$
**c.** $Jm^{-2}$ **d.** $Js$

13. The unit of surface tension in SI system is:
**a.** $Dyne/cm^2$ **b.** *Newton/m*
**c.** *Dyne/cm* **d.** $Newton/m^2$

14. The SI unit of universal gas constant ($R$) is:
**a.** $Watt\ K^{-1}mol^{-1}$ **b.** $Newton\ K^{-1}mol^{-1}$
**c.** $Joule\ K^{-1}mol^{-1}$ **d.** $Erg\ K^{-1}mol^{-1}$

15. Given that $v$ is speed, $r$ is the radius and $g$ is the acceleration due to gravity. Which of the following is dimensionless?
**a.** $v^2/rg$ **b.** $v^2r/g$
**c.** $v^2g/r$ **d.** $v^2rg$

16. If the time period ($T$) of vibration of a liquid drop depends on surface tension ($S$), radius ($r$) of the drop and density ($\rho$)of the liquid, then the expression of $T$ is:
**a.** $T=k\sqrt{\rho r^3/S}$ **b.** $T=k\sqrt{\rho^{1/2}r^3/S}$
**c.** $T=k\sqrt{\rho r^3/S^{1/2}}$ **d.** None of these

17. $X=3YZ^2$ find dimension of $Y$ in (MKSA) system, if $X$ and $Z$ are the dimension of capacity and magnetic field respectively:
**a.** $M^{-3}L^{-2}T^{-4}A^{-1}$ **b.** $ML^{-2}$
**c.** $M^{-3}L^{-2}T^4A^4$ **d.** $M^{-3}L^{-2}T^8A^4$

18. If $L$, $C$ and $R$ denote the inductance, capacitance and resistance respectively, the dimensional formula for $C^2LR$ is:
**a.** $[ML^{-2}T^{-1}I^0]$ **b.** $[M^0L^0T^3I^0]$
**c.** $[M^{-1}L^{-2}T^6I^2]$ **d.** $[M^0L^0T^2I^0]$

19. A force $F$ is given by $F=at+bt^2$, where $t$ is time. What are the dimensions of $a$ and $b$
**a.** $MLT^{-3}$ and $ML^2T^{-4}$ **b.** $MLT^{-3}$ and $MLT^{-4}$
**c.** $MLT^{-1}$ and $MLT^0$ **d.** $MLT^{-4}$ and $MLT^1$

20. The position of a particle at time $t$ is given by the relation $x(t)=\left(\frac{v_0}{\alpha}\right)(1-c^{-\alpha t})$, where $v_0$ is a constant and $\alpha>0$.
The dimensions of $v_0$ and $\alpha$ are respectively:

**a.** $M^0L^1T^{-1}$ and $T^{-1}$ **b.** $M^0L^1T^0$ and $T^{-1}$
**c.** $M^0L^1T^{-1}$ and $LT^{-2}$ **d.** $M^0L^1T^{-1}$ and $T$

**21.** $E$, $m$, $l$ and $G$ denote energy, mass, angular momentum and gravitational constant respectively, then the dimension of $\frac{El^2}{m^5G^2}$ are:

**a.** Angle **b.** Length
**c.** Mass **d.** Time

**22.** The equation of a wave is given by $Y = A\ \sin\ \omega\left(\frac{x}{v} - k\right)$ where $\omega$ is the angular velocity and $v$ is the linear velocity. The dimension of $k$ is:

**a.** $LT$ **b.** $T$
**c.** $T^{-1}$ **d.** $T^2$

**23.** The potential energy of a particle varies with distance $x$ from a fixed origin as $U = \frac{A\sqrt{x}}{x^2 + B}$, where $A$ and $B$ are dimensional constants then dimensional formula for $AB$ is:

**a.** $ML^{7/2}T^{-2}$ **b.** $ML^{11/2}T^{-2}$
**c.** $M^2L^{9/2}T^{-2}$ **d.** $ML^{13/2}T^{-3}$

**24.** You may not know integration. But using dimensional analysis you can check on some results. In the integral $\int \frac{dx}{(2ax - x^2)^{1/2}} = a^n \sin^{-1}\left(\frac{x}{a} - 1\right)$ the value of $n$ is:

**a.** 1 **b.** – 1 **c.** 0 **d.** $\frac{1}{2}$

**25.** A physical quantity $P = \frac{B^2l^2}{m}$ where $B$ = magnetic induction, $l$ = length and $m$ = mass. The dimension of $P$ is:

**a.** $MLT^{-3}$ **b.** $ML^2T^{-4}I^{-2}$
**c.** $M^2L^2T^{-4}I$ **d.** $MLT^{-2}I^{-2}$

**26.** The equation of the stationary wave is $y = 2a\sin\left(\frac{2\pi ct}{\lambda}\right)\cos\left(\frac{2\pi x}{\lambda}\right)$, which of the following statements is wrong:

**a.** The unit of $ct$ is same as that of $\lambda$
**b.** The unit of $x$ is same as that of $\lambda$
**c.** The unit of $2\pi c/\lambda$ is same as that of $2\pi x/\lambda t$
**d.** The unit of $c/\lambda$ is same as that of $x/\lambda$

**27.** A physical quantity is measured and its value is found to be $nu$ where $n$ = numerical value and $u$ = unit. Then which of the following relations is true:

**a.** $n \propto u^2$ **b.** $n \propto u$
**c.** $n \propto \sqrt{u}$ **d.** $n \propto \frac{1}{u}$

**28.** In C.G.S. system the magnitude of the force is 100 *dynes*. In another system where the fundamental physical quantities are *kilogram*, *metre* and *minute*, the magnitude of the force is:

**a.** 0.036 **b.** 0.36
**c.** 3.6 **d.** 36

**29.** The temperature of a body on Kelvin scale is found to be $X$ K. When it is measured by a Fahrenheit thermometer, it is found to be $X$ F. Then $X$ is:

**a.** 301.25 **b.** 574.25
**c.** 313 **d.** 40

**30.** The dimensions of coefficient of thermal conductivity is:

**a.** $ML^2T^{-2}K^{-1}$ **b.** $MLT^{-3}K^{-1}$
**c.** $MLT^{-2}K^{-1}$ **d.** $MLT^{-3}K$

**31.** The velocity of water waves $v$ may depend upon their wavelength $\lambda$, the density of water $\rho$ and the acceleration due to gravity $g$. The method of dimensions gives the relation between these quantities as:

**a.** $v^2 \propto \lambda g^{-1}\rho^{-1}$ **b.** $v^2 \propto g\lambda\rho$
**c.** $v^2 \propto g\lambda$ **d.** $v^2 \propto g^{-1}\lambda^{-3}$

**32.** From the dimensional consideration, which of the following equation is correct?

**a.** $T = 2\pi\sqrt{\frac{R^3}{GM}}$ **b.** $T = 2\pi\sqrt{\frac{GM}{R^3}}$
**c.** $T = 2\pi\sqrt{\frac{GM}{R^2}}$ **d.** $T = 2\pi\sqrt{\frac{R^2}{GM}}$

**33.** A highly rigid cubical block $A$ of small mass $M$ and side $L$ is fixed rigidly onto another cubical block $B$ of the same dimensions and of low modulus of rigidity $\eta$ such that the lower face of A completely covers the upper face of $B$. The lower face of B is rigidly held on a horizontal surface. A small force $F$ is applied perpendicular to one of the side faces of $A$. After the force is withdrawn block $A$ executes small oscillations. The time period of which is given by:

**a.** $2\pi\sqrt{\frac{M\eta}{L}}$ **b.** $2\pi\sqrt{\frac{L}{M\eta}}$
**c.** $2\pi\sqrt{\frac{ML}{\eta}}$ **d.** $2\pi\sqrt{\frac{M}{\eta L}}$

**34.** If velocity $v$, acceleration $A$ and force $F$ are chosen as fundamental quantities, then the dimensional formula of angular momentum in terms of $v$, $A$ and $F$ would be:

**a.** $FA^{-1}v$ **b.** $Fv^3A^{-2}$

**c.** $Fv^2A^{-1}$ **d.** $F^2v^2A^{-1}$

**35.** The largest mass ($m$) that can be moved by a flowing river depends on velocity ($v$), density ($\rho$), of river water and acceleration due to gravity ($g$). The correct relation is:

**a.** $m \propto \dfrac{\rho^2 v^4}{g^2}$ **b.** $m \propto \dfrac{\rho v^6}{g^2}$

**c.** $m \propto \dfrac{\rho v^4}{g^3}$ **d.** $m \propto \dfrac{\rho v^6}{g^3}$

## Calculation Measures and Errors of Measurement

**36.** A physical quantity is given by $X = M^a L^b T^c$. The percentage error in measurement of $M, L$ and $T$ are $\alpha, \beta$ and $\gamma$ respectively. Then maximum percentage error in the quantity $X$ is:

**a.** $a\alpha + b\beta + c\gamma$ **b.** $a\alpha + b\beta - c\gamma$

**c.** $\dfrac{a}{\alpha} + \dfrac{b}{\beta} + \dfrac{c}{\gamma}$ **d.** None of these

**37.** A physical parameter $a$ can be determined by measuring the parameters b, c, d and e using the relation $a = b^\alpha c^\beta / d^\gamma e^\delta$. If the maximum errors in the measurement of b, c, d and e are $b_1$ %, $c_1$ %, $d_1$ % and $e_1$ %, then the maximum error in the value of $a$ determined by the experiment is:

**a.** $(b_1 + c_1 + d_1 + e_1)\%$ **b.** $(b_1 + c_1 - d_1 - e_1)\%$

**c.** $((\alpha b_1 + \beta c_1 - \gamma d_1 - \delta e_1)\%$ **d.** $(\alpha b_1 + \beta c_1 + \gamma d_1 + \delta e_1)\%$

**38.** The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate. If the maximum error in the measurement of force and length are respectively 4% and 2%, The maximum error in the measurement of pressure is:

**a.** 1% **b.** 2%

**c.** 6% **d.** 8%

**39.** The relative density of material of a body is found by weighing it first in air and then in water. If the weight in air is $(5.00 \pm 0.05)$ *Newton* and weight in water is $(4.00 \pm 0.05)$ *Newton*. Then the relative density along with the maximum permissible percentage error is:

**a.** $5.0 \pm 11\%$ **b.** $5.0 \pm 1\%$

**c.** $5.0 \pm 6\%$ **d.** $1.25 \pm 5\%$

**40.** The resistance $R = \dfrac{V}{i}$ where $V = 100 \pm 5$ volts and $i = 10 \pm 0.2$ *amperes*. What is the total error in $R$?

**a.** 5% **b.** 7%

**c.** 5.2% **d.** 5/2 %

**41.** The period of oscillation of a simple pendulum in the experiment is recorded as 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s respectively. The average absolute error is:

**a.** 0.1 s **b.** 0.11 s

**c.** 0.01 s **d.** 1.0 s

**42.** The length of a cylinder is measured with a meter rod having least count 0.1 *cm*. Its diameter is measured with venier calipers having least count 0.01 *cm*. Given that length is 5.0 *cm*. and radius is 2.0 *cm*. The percentage error in the calculated value of the volume will be:

**a.** 1% **b.** 2%

**c.** 3% **d.** 4%

**43.** A thin copper wire of length *l metre* increases in length by 2% when heated through 10ºC. What is the percentage increase in area when a square copper sheet of length *l metre* is heated through 10º*C*?

**a.** 4% **b.** 8%

**c.** 16% **d.** None of the above

**44.** The period of oscillation of a simple pendulum is given by $T = 2\pi\sqrt{\dfrac{l}{g}}$ where $l$ is about 100 *cm* and is known to have 1*mm* accuracy. The period is about 2*s*. The time of 100 oscillations is measured by a stop watch of least count 0.1 s. The percentage error in $g$ is:

**a.** 0.1% **b.** 1%

**c.** 0.2% **d.** 0.8%

**45.** A body travels uniformly a distance of (13.8 ± 0.2) $m$ in a time (4.0 ± 0.3) s. The velocity of the body within error limits is:

**a.** (3.45 ± 0.2) $ms^{-1}$ **b.** (3.45 ± 0.3) $ms^{-1}$

**c.** (3.45 ± 0.4) $ms^{-1}$ **d.** (3.45 ± 0.5) $ms^{-1}$

**46.** In an experiment, the following observation's were recorded: $L = 2.820$ $m$, $M = 3.00$ $kg$, $l = 0.087$ $cm$, Diameter $D$ = 0.041 *cm* Taking $g$ = 9.81 m/s$^2$ using the formula, $Y = \dfrac{4MgL}{\pi D^2 l}$, the maximum permissible error in $Y$ is:

**a.** 7.96% **b.** 4.56%

**c.** 6.50% **d.** 8.42%

**47.** A physical quantity $A$ is related to four observable $a, b, c$ and $d$ as follows, $A = \frac{a^2 b^3}{c\sqrt{d}}$, the percentage errors of measurement in $a, b, c$ and $d$ are 1%, 3%, 2% and 2% espectively. What is the percentage error in the quantity $A$?

**a.** 12% **b.** 7%

**c.** 5% **d.** 14%

**48.** Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is:

**a.** 1% **b.** 3%

**c.** 5% **d.** 7%

**49.** The resistance $R = \frac{V}{i}$ where $V = 100 \pm 5$ *volts* and $i = 10$ $\pm$ 0.2 amperes. What is the total error in $R$.?

**a.** 5% **b.** 7%

**c.** 5.2% **d.** $\frac{5}{2}$%

**50.** A physical quantity $P$ is given by $P = \frac{A^3 B^{1/2}}{C^{-4} D^{3/2}}$. The quantity which brings in the maximum percentage error in $P$ is:

**a.** $A$ **b.** $B$

**c.** $C$ **d.** $D$

## NCERT EXEMPLAR PROBLEMS

### More than One Answer

**51.** The pairs of physical quantities that have the same dimension are:

**a.** Reynold number and coefficient of fraction

**b.** Curie and frequency of light wave

**c.** latent heat and gravitational potential

**d.** Planck constant and torque

**52.** If dimensions of length are expressed as $G^x c^y h^z$, where $G$, $c$ and $h$ are the universal gravitational constant, speed of light and Planck constant respectively, then:

**a.** $x = \frac{1}{2}, y = \frac{1}{2}$ **b.** $x = \frac{1}{2}, z = \frac{1}{2}$

**c.** $x = -\frac{1}{2}, z = \frac{1}{2}$ **d.** $y = \frac{1}{2}, z = \frac{1}{2}$

**53.** The units of charge are:

**a.** coulomb **b.** frankline

**c.** faraday **d.** ampere $\times$ sec

**54.** Let ($\varepsilon_0$) denote the dimensional formula of the permittivity of the volume and [$\mu_0$] that of the permeability of the vacuum. If $M$ = mass, $L$ = length, $T$ = time and $T$ = time and $I$ = electric current, then:

**a.** $[\varepsilon_0] = [M^{-1}L^{-3}T^{-2}]$ **b.** $[\varepsilon_0] = [M^{-1}L^{-3}T^4 I^2]$

**c.** $[\mu_0] = [M L T^{-2} I^{-2}]$ **d.** $[\mu_0] = [M L^2 T^{-1} I]$

**55.** If $L$, $C$ and $R$ represent the physical quantities inductance, capacitance and resistance respectively, the combinations which have the dimensions of frequency are:

**a.** $(1/RC)$ **b.** $(R/L)$

**c.** $(1/\sqrt{LC})$ **d.** $(C/R)$

**56.** Consider three quantities; $x = \frac{E}{B}$, $y = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ and $z = \frac{l}{CR}$, where $l$ is the length of a wire, $C$ is capacitance and $R$ is resistance and all other symbols have standard meanings then:

**a.** *x, y* have the same dimensions

**b.** *x, z* have the same dimensions

**c.** *y, z* have the same dimensions

**d.** none of the three pairs have the same dimensions

**57.** For a body in a uniformly accelerated motion, the distance of the body form a reference point at time t is given by, $x = at + bt^2 + c$ where *a, b* and *c* are constants of motion. The dimensions of $c$ are the same as those of:

**a.** $x$ **b.** $at$

**c.** $bt^2$ **d.** $b/a$

**58.** When a wave traverses a medium the displacement of a particle located at $x$, at time $t$ is given by, $y = a\sin(bt - cx)$ where *a, b* and *c* are constants of the wave. Which of the following are dimensionless quantities?

**a.** $\frac{y}{a}$ **b.** $bt$ **c.** $cx$ **d.** $\frac{b}{c}$

**59.** In the above question, the dimensions of $b$ are the same as those of:

**a.** wave velocity **b.** angular frequency

**c.** wavelength **d.** wave frequency

**60.** The van der Waals' equation for $n$ moles of a real gas is $\left(P + \frac{a}{V^2}\right)(V - b) = nRT$ where $P$ is the pressure, $V$ is the volume, $T$ is the absolute temperature, $R$ is the molar gas constant and *a, b* are van der Waal's constants. Which of the following have the same dimensions as those of *PV?*

**a.** $nRT$ **b.** $a/V$

**c.** $Pb$ **d.** $ab/V^2$

**61.** The pressure on a square plate is measured by measuring the force on the plate and the length of the sides of the plate by using the formula $P = F/l^2$. If the maximum errors in the measurement of force and length are 4% and 2% respectively, then the maximum error in the measurement of pressure cannot be equal to:

**a.** 1% **b.** 2%
**c.** 8% **d.** 10%

**62.** The focal length of a mirror is given by, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$, where $u$ and $v$ represent objects and image distance respectively. The maximum relative error in $f$ cannot be equal to:

**a.** $\frac{\Delta f}{f} = \frac{\Delta u}{u} + \frac{\Delta v}{v}$ **b.** $\frac{\Delta f}{f} = \frac{1}{\Delta u/u} + \frac{1}{\Delta v/v}$

**c.** $\frac{\Delta f}{f} = \frac{\Delta u}{u} + \frac{\Delta v}{v} - \frac{\Delta(u+v)}{u+v}$

**d.** $\frac{\Delta f}{f} = \frac{\Delta u}{u} + \frac{\Delta v}{v} + \frac{\Delta u}{u+v}\frac{\Delta v}{u+v}$

**63.** Given, $y = a\cos\left(\frac{t}{10} - qx\right)$, where $t$ represents time in second and $x$ represents distance in meter. Which of the following statements are false?

**a.** The unit of $x$ is same as that of $q$
**b.** The unit of $x$ is same as that of $p$
**c.** The unit of $t$ is same as that of $q$
**d.** The unit of $t$ is same as that of $p$

**64.** The length, breadth and thickness of a block are given by $l$ = 12 cm, $b$ = 6 cm and $t$ = 2.45 cm. The volume of the block according to the idea of significant figures should be:

**a.** $1 \times 10^2$ cm$^3$ **b.** $2 \times 10^2$ cm$^3$
**c.** $1.763 \times 10^2$ cm$^3$ **d.** None of these

**65.** Pressure is defined as?

**a.** Momentum per unit area
**b.** Momentum per unit area per unit time
**c.** Momentum per unit volume
**d.** Energy per unit volume

### Assertion and Reason

**Note:** Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:

**a.** If both assertion and reason are true and the reason is the correct explanation of the assertion.
**b.** If both assertion and reason are true but reason is not the correct explanation of the assertion.
**c.** If assertion is true but reason is false.
**d.** If the assertion and reason both are false.
**e.** If assertion is false but reason is true.

**66. Assertion:** Nembert of significant figures in 0.005 is one and that in 0.500 is three.
**Reason:** This is because zeros are not significant.

**67. Assertion:** The quantity $(1/\sqrt{\mu_0 \varepsilon_0})$ is dimensionally equal to velocity and numerically equal to velocity of light.
**Reason:** $\mu_0$ is permeability of free space and $\varepsilon_0$ is the permittivity of free space.

**68. Assertion:** Log $y = A\sin(\omega t - kx)$ dimension less.
**Reason:** Because dimensions of $\omega = [M^0 L^0 T]$.

**69. Assertion:** The time period of a pendulum is given by the formula $T = 2\pi\sqrt{\frac{g}{l}}$.
**Reason:** According to the principle of homogeneity of dimensions only that formula is correct in which the dimensions of LHS is equal to dimensions of RHS.

**70. Assertion:** The graph between $P$ and $Q$ is straight line, when $P/Q$ is constant.
**Reason:**The straight line graph means that P is proportional to $Q$ or $P$ is equal to constant multiplied by $Q$.

**71. Assertion:** $\frac{L}{R}$ and CR both have same dimensions.
**Reason:** $\frac{L}{R}$ and CR both has dimensions of time.

**72. Assertion:** Now a-days, a standard meter is defined in terms of the wavelength of light.
**Reason:** Light has no relation with length.

**73. Assertion:** In the relation $\int = \frac{1}{2l}\sqrt{\frac{T}{m}}$ where symbols have standard meaning, $m$ represents linear mass density.
**Reason:** The frequency has the dimensions of inverse of time

**74. Assertion:** Avogadro number is the number of atoms in one gram mole.
**Reason:** Avogadro number is a dimensionless constant.

**75. Assertion:** The order of accuracy of measurement depends on the least count of the measuring instrement.
**Reason:** The smaller the least count the greater is the number of significant figures in the measured value.

## Comprehension Based

**Paragraph –I**

In simple pendulum experiment a student measures length of string 75.5 cm with meter scale having lest count 0.1 cm. He measures diameter of bob with Vernier calliper having 10 divisions in 1 cm on min scale and 20 divisions of vernier scale coinciding with 18 divisions of man scale. With jaws closed the zero of vernier scale lies on left of zero of main scale and 5th division of vernier scale concides with same main scale division. With bob placed between the jaws the zero of vernier scale crosses 42 divisions of main scale and 7th division concides with any of main scale division. With above observations answer the following question if time measured for 20 vibrations is 40.2 sec with stop watch of least count 0.1 s:

**76.** The diameter of bob measured is recorded as:

**a.** $(4.27 \pm 0.01)$ cm  **b.** $(4.22 \pm 0.01)$ cm

**c.** $(4.32 \pm 0.01)$ cm  **d.** $(4.18 \pm 0.01)$cm

**77.** Which is more accurate measurement and which is more precise measurement?

**a.** Length is more accurate, diameter is more precise

**b.** Length is more precise, diameter is more accurate

**c.** Length is more accurate as well as more precise

**d.** Diameter is more accurate as well as more precise

**78.** Percentage error in measurement of value of $g$ with this pendulum is:

**a.** 0.5 %  **b.** 0.64 %

**c.** 0.56 %  **d.** 0.52 %

**Paragraph –II**

Method of dimensional analysis was devised to derive certain unknown physical relations. But this method has certain limitation due to which it does not give correct information about the relations derived. With knowledge of the limitation answer the following question:

**79.** Distance moved by a particle having uniform acceleration a starting with initial velocity u in nth second is mentioned a $s = u + a(2n-1)$ This relation is:

**a.** dimensionally correct numerically wrong

**b.** both dimensionally and numerically wrong

**c.** both numerically and dimensionally correct

**d.** neither dimensionally nor numerically correct

**80.** Out of the given pair one pair has same dimensional formula:

**a.** gravitational8 potential and torque

**b.** velocity gradient and angular velocity

**c.** tension and surface tension

**d.** force constant and elastic constant

**81.** Out of the given pairs one is not similar to others:

**a.** angular momentum and Planck's constant

**b.** impulse and momentum

**c.** Rydberg constant and wave propagation constant

**d.** gravitational potential energy and surface energy

**Paragraph –III**

Standard gas equation was derived based on kinetic theory of gases which was valid only for ideal gases. However, real gases are no: ideal gases. van der Waals' derived equation which was valid for real gases considering the size of molecules and intermolecular forces between them. He introduced correction in the form of constant $a$ and $b$ and arrived at the following relation $\left(P + \frac{a}{V^2}\right)(V-b) = RT$ where $P, V, T$ are pressure volume and temperature of gas and R is universal gas constant. In this relation:

**82.** The dimensional formula for $ab$ is that of:

**a.** work  **b.** force

**c.** pressure  **d.** momentum

**83.** The dimension of "a" mass, length and time as:

**a.** [1, 2, –2]  **b.** [1, 5, –2]

**c.** [1, –2, 2]  **d.** [1, 3, –2]

**84.** Dimensional formula for R is:

**a.** $[M^1L^2T^{-3}]$  **b.** $[M^1L^2T^{-1}]$

**c.** $[M^1L^2T^{-2}K^{-1}]$  **d.** $[M^1L^3T^{-3}K^{-1}]$

**Paragraph –IV**

A student is given a calorimeter made of copper sheet. He is given a Vernier calliper and screw gauge. The Vernier calliper used by him has 20 division in a centimeter on main scale and 25 divisions of vernier scale coincide with 24 divisions of main scale. Screw gauge also has 20 division in a centimeter on linear scale and 100 division an circular scale. Check the following measurement made by him:

**85.** Least founts of Vernier callipers and screw gauge are:

**a.** 0.01 mm, 0.01 mm  **b.** 0.02 mm, 0.05 mm

**c.** 0.02 mm, 0.005 mm  **d.** 0.02 mm, 0.005 cm

**86.** He measures depth by Vernier callipers as 5.250 cm and diameter as 2.500 cm. The thickness of sheet used is measured by Screw gauge as 250 mm. The area of sheet used to make calorimeter with correct significant figures is:

**a.** 27.500 $cm^2$ **b.** 27.5 $cm^2$

**c.** 27.50 $cm^2$ **d.** 0.275 $cm^2$

**87.** Volume of cylinder with % error is:

**a.** 25.8 ± 0.20% **b.** 25.78 ± 2%

**c.** 25.781 ± 0.2% **d.** 25.8 ± 2.0%

## Match the Column

**88.** Match the statement of Column with those in Column II:

| Column I | Column II |
|---|---|
| **(A)** Fundamental quantity is | **1.** Charge |
| **(B)** Derived quantity is | **2.** $Wm^{-2}$ |
| **(C)** Fundamental unit is | **3.** Current |
| **(D)** Derived unit of intensity of light is | **4.** Candela |

**a.** A → 3, B → 1, C → 4, D → 2
**b.** A → 2, B → 4, C → 3, D → 1
**c.** A → 1, B → 3, C → 2, D → 4
**d.** A → 4, B → 1, C → 3, D → 2

**89.** Match the statement of Column with those in Column II:

| Column I | Column II |
|---|---|
| **(A)** Tension | **1.** $[M^1L^{-1}T^{-2}]$ |
| **(B)** Surface tension | **2.** $[M^0L^1T^{-2}]$ |
| **(C)** Energy density | **3.** $[M^1L^1T^{-2}]$ |
| **(D)** Gravitational field | **4.** $[M^1L^0T^{-2}]$ |

**a.** A → 4, B → 3, C → 2, D → 1
**b.** A → 1, B → 2, C → 3, D → 4
**c.** A → 3, B → 4, C → 1, D → 2
**d.** A → 2, B → 3, C → 4, D → 1

**90.** Match the statement of Column with those in Column II:

| Column I | Column II |
|---|---|
| **(A)** Angular velocity | **1.** Velocity gradient |
| **(B)** Gravitation intensity | **2.** Acceleration |
| **(C)** Stress | **3.** Energy density |
| **(D)** Angle | **4.** Strain |

**a.** A → 4, B → 3, C → 2, D → 1
**b.** A → 3, B → 2, C → 1, D → 4
**c.** A → 2, B → 1, C → 4, D → 3
**d.** A → 1, B → 2, C → 3, D → 4

**91.** Match the statement of Column with those in Column II:

| Column I | Column II |
|---|---|
| **(A)** Magnetic flux | **1.** A $m^2$ |
| **(B)** Magnetic induction | **2.** Nm $A^{-1}$ |
| **(C)** Magnetic dipole moment | **3.** N $A^{-1}$ |
| **(D)** Magnetic permeability | **4.** N $m^{-1}$ $A^{-1}$ |

**a.** A → 1, B → 2, C → 3, D → 4
**b.** A → 4, B → 3, C → 2, D → 1
**c.** A → 3, B → 2, C → 1, D → 4
**d.** A → 2, B → 4, C → 1, D → 3

**92.** Match the statement of Column with those in Column II:

| Column I | Column II |
|---|---|
| **(A)** Velocity gradient | **1.** $[M^{-3}L^2T^4Q^{-4}]$ |
| **(B)** Planck's constant | **2.** $[M^1L^2T^{-1}]$ |
| **(C)** Gravitational field | **3.** $[M^0L^1T^{-2}]$ |
| **(D)** Angular velocity | **4.** $[M^1L^1T^{-1}]$ |

**a.** A → 1, B → 2, C → 3, D → 4
**b.** A → 4, B → 3, C → 2, D → 1
**c.** A → 3, B → 1, C → 4, D → 2
**d.** A → 4, B → 1, C → 2, D → 2

## Integer

**93.** The correct number of significant figures in 0.0005083 is:

**94.** Light from the sun reaches the earth approximately in $x \times 10^2$ sec, where $x$ is:

**95.** If units of measurement of two systems are in the ratio 2 : 1, then the ratio of units of angular momentum in the two systems will be:

**96.** The least count of a watch is 0.2 s. The time for 25 oscillations of a pendulum is measured to be 20 sec. The percentage error in this time measurement is:

**97.** Heat generated in a circuit is given by $H = I^2Rt$. If error in measuring current *I*, resistance *R* and time *t* are 2%, 1% and 3% respectively, then percentage error in calculating heat is:

**98.** A wire has a mass $0.3 \pm 0.003\,g$, radius $0.5 \pm 0.005\,mm$ and length $6 \pm 0.06\,cm$. The maximum percentage error in the measurement of its density is:

**99.** The length of a cylinder is measured with a meter rod having least count 0.1 *cm*. Its diameter is measured with vernier calipers having least count 0.01 *cm*. Given that length is 5.0 *cm*. and radius is 2.0 *cm*. The percentage error in the calculated value of the volume will be:

**100.** The number of significant figures in all the given numbers 25.12, 2009, 4.156 and $1.217 \times 10^{-4}$ is:

## ANSWER

| 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. |
|---|---|---|---|---|---|---|---|---|---|
| b | a | a | c | a | c | d | b | a | a |
| **11.** | **12.** | **13.** | **14.** | **15.** | **16.** | **17.** | **18.** | **19.** | **20.** |
| b | b | b | c | a | a | d | b | b | a |
| **21.** | **22.** | **23.** | **24.** | **25.** | **26.** | **27.** | **28.** | **29.** | **30.** |
| a | b | b | c | b | d | d | c | c | b |
| **31.** | **32.** | **33.** | **34.** | **35.** | **36.** | **37.** | **38.** | **39.** | **40.** |
| c | a | d | b | d | a | d | d | a | b |
| **41.** | **42.** | **43.** | **44.** | **45.** | **46.** | **47.** | **48.** | **49.** | **50.** |
| b | c | a | c | b | c | d | b | b | c |
| **51.** | **52.** | **53.** | **54.** | **55.** | **56.** | **57.** | **58.** | **59.** | **60.** |
| a,b,c | b,c | all | b,c | a,b,c | a,b,c | a,b,c | a,b,c | b,d | all |
| **61.** | **62.** | **63.** | **64.** | **65.** | **66.** | **67.** | **68.** | **69.** | **70.** |
| a,b,c | a,b,c | a,b,c | b | b,c | c | b | c | e | a |
| **71.** | **72.** | **73.** | **74.** | **75.** | **76.** | **77.** | **78.** | **79.** | **80.** |
| a | c | b | c | c | c | a | b | a | b |
| **81.** | **82.** | **83.** | **84.** | **85.** | **86.** | **87.** | **88.** | **89.** | **90.** |
| d | a | b | c | c | c | c | a | c | d |
| **91.** | **92.** | **93.** | **94.** | **95.** | **96.** | **97.** | **98.** | **99.** | **100.** |
| d | a | 4 | 5 | 4 | 1 | 8 | 4 | 3 | 4 |

## SOLUTION

### Multiple Choice Questions

1. **(b)** Because magnitude is absolute

2. **(a)** 1 C.G.S unit of density = 1000 M.K.S. unit of density

$\Rightarrow$ 0.5 gm / cc = 500 kg/m$^3$.

3. **(a)** $Y = \dfrac{\text{Stress}}{\text{strain}} = \dfrac{\text{Force / Area}}{\text{Demensionaless}}$

$\Rightarrow$ $Y \equiv$ Pressure.

4. **(c)** $1\text{ nm} = 10^{-9}\text{m} = 10^{-7}\text{cm}$

5. **(a)** $ct^2$ must have dimensions of $L$

$\Rightarrow$ $c$ must have dimensions of $L/T^2$ *i.e.* $LT^{-2}$.

6. **(c)** $[x] = [bt^2]$

$\Rightarrow$ $[b] = \left[\dfrac{x}{t^2}\right] = \text{km/s}^2$

7. **(d)** Poission ratio is a unitless quantity.

8. **(b)** $L \propto v^x A^y F^z$

$\Rightarrow$ $L = kv^x A^y F^z$

Putting the dimensions in the above relation

$[ML^2T^{-1}] = k[LT^{-1}]^x [LT^{-2}]^y [MLT^{-2}]^z$

$\Rightarrow$ $[ML^2T^{-1}] = k[M^z L^{x+y+z} T^{-x-2y-2z}]$

Comparing the powers of $M, L$ and $T$

$z = 1$ ...(*i*)

$x + y + z = 2$ ...(*ii*)

$-x - 2y - 2z = -1$ ...(*iii*)

On solving (*i*), (*ii*) and (*iii*) $x = 3, y = -2, z = 1$

So, dimension of $L$ in terms of $v, A$ and $f$

$\Rightarrow$ $[L] = [Fv^3A^{-2}]$

9. **(a)** Pressure $= \dfrac{\text{Force}}{\text{Area}} = ML^{-1}T^{-2}$

Stress $= \dfrac{\text{Restoring force}}{\text{Area}} = ML^{-1}T^{-2}$

10. **(a)** $\dfrac{\text{Angular momentum}}{\text{Linear momentum}} = \dfrac{mvr}{mv} = r = [M^0L^1T^0]$

11. **(b)** From the formula $C = 4\pi\varepsilon_0 R$

$\therefore$ $\varepsilon_0 = \dfrac{C}{4\pi R}$

By substituting the unit of capacitance and radius: unit of $\varepsilon_0$ = *Farad/ meter*.

12. **(b)** Stefan's formula $\dfrac{Q}{At} = \sigma T^4$

$\therefore$ $\sigma = \dfrac{Q}{AtT^4}$

$\therefore$ Unit of $\sigma = \dfrac{\text{Joule}}{m^2 \times \sec \times K^4} = Jm^{-2}s^{-1}K^{-4}$

13. **(b)** From the formula of surface tension $T = \dfrac{F}{l}$

By substituting the S.I. units of force and length, we will get the unit of surface tension = *Newton/m*

14. **(c)** Ideal gas equation $PV = nRT$

$\therefore$ $[R] = \dfrac{[P][V]}{[nT]}$

$= \dfrac{[ML^{-1}T^{-2}][L^3]}{[mole]\,[K]} = \dfrac{[ML^2T^{-2}]}{[mole] \times [K]}$

So, the unit will be *Joule* $K^{-1}mol^{-1}$.

15. **(a)** Angle of banking : $\tan\theta = \dfrac{v^2}{rg}$.

*i.e.* $\dfrac{v^2}{rg}$ is dimensionless.

$= \dfrac{\text{amp} \times \text{second} \times \text{Volt}}{\text{Volt} \times \text{amp}} = \text{Second}$

**16.** **(a)** Let $T \propto S^x r^y \rho^z$

by substituting the dimension of $[T] = [T]$

$[S]=[MT^{-2}],[r]=[L],[\rho]=[ML^{-3}]$ and by comparing the power of both the sides $x=-\frac{1}{2}, y=\frac{3}{2}, z=\frac{1}{2}$

So, $T \propto \sqrt{\rho r^3 / S} \Rightarrow T = k\sqrt{\frac{\rho r^3}{S}}$

**17.** **(d)** $X = 3YZ^2$

$\therefore \quad [Y] = \frac{[X]}{[Z^2]}$

$= \frac{[M^{-1}L^{-2}T^4A^2]}{[MT^{-2}A^{-1}]^2} = [M^{-3}L^{-2}T^8A^4]$

**18.** **(b)** $[C^2LR] = \left[C^2L^2\frac{R}{L}\right] = \left[(LC)^2\left(\frac{R}{L}\right)\right]$ and we know that frequency of LC circuits is given by $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$ *i.e.*, the dimension of LC is equal to $[T^2]$ and $\left[\frac{L}{R}\right]$ gives the time constant of $L-R$ circuit so the dimension of $\frac{L}{R}$ is equal to [*T*]. By substituting the above dimensions in the given formula $\left[(LC)^2\left(\frac{R}{L}\right)\right] = [T^2]^2[T^{-1}] = [T^3]$.

**19.** **(b)** From the principle of dimensional homogenity $[F] = [at]$

$\therefore \quad [a] = \left[\frac{F}{t}\right] = \left[\frac{MLT^{-2}}{T}\right] = [MLT^{-3}]$

Similarly $[F] = [bt^2]$

$\therefore \quad [b] = \left[\frac{F}{t^2}\right] = \left[\frac{MLT^{-2}}{T^2}\right] = [MLT^{-4}]$.

**20.** **(a)** From the principle of dimensional homogeneity $[\alpha\, t]$= dimensionless

$\therefore \quad [\alpha] = \left[\frac{1}{t}\right] = [T^{-1}]$

Similarly $[x] = \frac{[v_0]}{[\alpha]}$

$\therefore \quad [v_0] = [x][\alpha] = [L][T^{-1}] = [LT^{-1}]$.

**21.** **(a)** $[E]$ = energy = $[ML^2T^{-2}]$,

$[m]$ = mass = $[M]$,

$[l]$ = Angular momentum = $[ML^2T^{-1}]$

$[G]$ = Gravitational constant = $[M^{-1}L^3T^{-2}]$

Substituting dimensions of above quantities in $\frac{El^2}{m^5G^2}$

$= \frac{[ML^2T^{-2}]\times[ML^2T^{-1}]^2}{[M^5]\times[M^{-1}L^3T^{-2}]^2} = [M^0L^0T^0]$

*i.e.*, the quantity should be angle.

**22.** **(b)** According to principle of dimensional homogeneity $[k] = \left[\frac{x}{v}\right] = \left[\frac{L}{LT^{-1}}\right] = [T]$.

**23.** **(b)** From the dimensional homogeneity $[x^2] = [B]$

$\therefore \quad [B] = [L^2]$

As well as $[U] = \frac{[A][x^{1/2}]}{[x^2]+[B]}$

$\Rightarrow \quad [ML^2T^{-2}] = \frac{[A][L^{1/2}]}{[L^2]}$

$\therefore \quad [A] = [ML^{7/2}T^{-2}]$

Now $[AB] = [ML^{7/2}T^{-2}]\times[L^2] = [ML^{11/2}T^{-2}]$

**24.** **(c)** Let $x$ = length

$\therefore \quad [X]=[L]$ and $[dx]=[L]$

By principle of dimensional homogeneity $\left[\frac{x}{a}\right]$= dimensionless

$\therefore \quad [a] = [x] = [L]$

By substituting dimension of each quantity in both sides:

$\frac{[L]}{[L^2 - L^2]^{1/2}} = [L^n]$

$\therefore \quad n = 0$

**25.** **(b)** $F = BIL$

$\therefore \quad$ Dimension of $[B] = \frac{[F]}{[I][L]} = \frac{[MLT^{-2}]}{[I][L]}$

$= [MT^{-2}I^{-1}]$

Now dimension of $[P] = \frac{B^2l^2}{m}$

$= \frac{[MT^{-2}I^{-1}]^2\times[L^2]}{[M]}$

$= [ML^2T^{-4}I^{-2}]$

26. **(d)** Here, $\frac{2\pi ct}{\lambda}$ as well as $\frac{2\pi x}{\lambda}$ are dimensionless (angle)

*i.e.* $\left[\frac{2\pi ct}{\lambda}\right]=\left[\frac{2\pi x}{\lambda}\right]=M^0L^0T^0$

So, (i) unit of $c\,t$ is same as that of $\lambda$

(ii) unit of $x$ is same as that of $\lambda$

(iii) $\left[\frac{2\pi c}{\lambda}\right]=\left[\frac{2\pi x}{\lambda\, t}\right]$ and

(iv) $\frac{x}{\lambda}$ is unit less. It is not the case with $\frac{c}{\lambda}$.

27. **(d)** We know $P=nu=\text{constant}$

$\therefore\quad n_1u_1=n_2u_2$

or $\quad n\propto\frac{1}{u}$.

28. **(c)** $n_1=100$

$M_1=g,\ L_1=cm,\ T_1=\text{sec}$ and

$M_2=kg,\ L_2=meter,\ T_2=\text{minute},$

$x=1,\ y=1,\ z=-2$

By substituting these values in the following conversion formula $n_2=n_1\left[\frac{M_1}{M_2}\right]^x\left[\frac{L_1}{L_2}\right]^y\left[\frac{T_1}{T_2}\right]^2$

$$n_2=100\left[\frac{gm}{kg}\right]^1\left[\frac{cm}{meter}\right]^1\left[\frac{\text{sec}}{\text{minute}}\right]^{-2}$$

$$n_2=100\left[\frac{gm}{10^3\,gm}\right]^1\left[\frac{cm}{10^2\,cm}\right]^1\left[\frac{\text{sec}}{60\,\text{sec}}\right]^{-2}=3.6$$

29. **(c)** Relation between centigrade and Fahrenheit

$$\frac{K-273}{5}=\frac{F-32}{9}$$

According to Illustration

$$\frac{X-273}{5}=\frac{X-32}{9}$$

$\therefore\quad X=313.$

30. **(b)** $\frac{dQ}{dt}=-KA\left(\frac{d\theta}{dx}\right)$

$\Rightarrow\quad [K]=\frac{[ML^2T^{-2}]}{[T]}\times\frac{[L]}{[L^2][K]}=MLT^{-3}K^{-1}$

31. **(c)** Let $v^x=kg^y\lambda^z\rho^\delta$.

Now by substituting the dimensions of each quantities and equating the powers of $M$, $L$ and $T$ we get $\delta=0$ and $x=2,y=1,z=1$.

32. **(a)** $T=2\pi\sqrt{\frac{R^3}{GM}}=2\pi\sqrt{\frac{R^3}{gR^2}}=2\pi\sqrt{\frac{R}{g}}$

[As $GM=gR^2$]

Now by substituting the dimension of each quantity in both sides.

$$[T]=\left[\frac{L}{LT^{-2}}\right]^{1/2}=[T]$$

L.H.S. = R.H.S.

*i.e.,* the above formula is Correct.

33. **(d)** Given

$m=\text{mass}=[M]$

$\eta=$ coefficient of rigidity

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

$L=\text{length}=[L]$

By substituting the dimension of these quantity we can check the accuracy of the given formulae

$$[T]=2\pi\left(\frac{[M]}{[\eta][L]}\right)^{1/2}=\left[\frac{M}{ML^{-1}T^{-2}L}\right]^{1/2}=[T].$$

L.H.S. = R.H.S.

*i.e.,* the above formula is Correct.

34. **(b)** Given, $v=$ velocity $=[LT^{-1}]$

$A=$ Acceleration $=[LT^{-2}]$

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

By substituting, the dimension of each quantity we can check the accuracy of the formula

[Angular momentum] $=Fv^3A^{-2}$

$$[ML^2T^{-1}]=[MLT^{-2}]\,[LT^{-1}]^3[LT^{-2}]^{-2}=[ML^2T^{-1}]$$

L.H.S. = R.H.S.

*i.e.,* the above formula is Correct.

35. **(d)** Given, $m=\text{mass}=[M]$

$v=\text{velocity}=[LT^{-1}]$

$\rho=\text{density}=[ML^{-3}]$

$g=$ acceleration due to gravity $=[LT^{-2}]$

By substituting, the dimension of each quantity we can check the accuracy of the formula $m=K\frac{\rho v^6}{g^3}$

$$\Rightarrow\quad [M]=\frac{[ML^{-3}][LT^{-1}]^6}{[LT^{-2}]^3}=[M]$$

L.H.S. = R.H.S.

*i.e.,* the above formula is Correct.

**36.** **(a)** Percentage error in $X = a\alpha + b\beta + c\gamma$.

**37.** **(d)** $a = \frac{b^\alpha c^\beta}{d^\gamma e^\delta}$

So, maximum error in $a$ is given by $\left(\frac{\Delta a}{a}\times 100\right)_{\max}$

$= \alpha\cdot\frac{\Delta b}{b}\times 100 + \beta\cdot\frac{\Delta c}{c}\times 100 + \gamma\cdot\frac{\Delta d}{d}\times 100 + \delta\cdot\frac{\Delta e}{e}\times 100$

$= (\alpha b_1 + \beta c_1 + \gamma d_1 + \delta e_1)\%$

**38.** **(d)** $P = \frac{F}{A} = \frac{F}{l^2}$

So, maximum error in pressure ($P$)

$\left(\frac{\Delta P}{P}\times 100\right)_{\max} = \frac{\Delta F}{F}\times 100 + 2\frac{\Delta l}{l}\times 100$

$= 4\% + 2 \times 2\% = 8\%$

**39.** **(a)** Weight in air $= (5.00 \pm 0.05)\,N$

Weight in water $= (4.00 \pm 0.05)\,N$

Loss of weight in water $= (1.00 \pm 0.1)\,N$

Now relative density $= \frac{\text{weight in air}}{\text{weight loss in water}}$

*i.e.* $R.D = \frac{5.00 \pm 0.05}{1.00 \pm 0.1}$

Now relative density with max permissible error

$= \frac{5.00}{1.00} \pm \left(\frac{0.05}{5.00} + \frac{0.1}{1.00}\right)\times 100$

$= 5.0 \pm (1+10)\% = 5.0 \pm 11\%$

**40.** **(b)** $R = \frac{V}{I}$

$\therefore \left(\frac{\Delta R}{R}\times 100\right)_{\max} = \frac{\Delta V}{V}\times 100 + \frac{\Delta I}{I}\times 100$

$= \frac{5}{100}\times 100 + \frac{0.2}{10}\times 100$

$= (5+2)\% = 7\%$

**41.** **(b)** Average value

$= \frac{2.63 + 2.56 + 2.42 + 2.71 + 2.80}{5} = 2.62\ \text{sec}$

Now $|\Delta T_1| = 2.63 - 2.62 = 0.01$

$|\Delta T_2| = 2.62 - 2.56 = 0.06$

$|\Delta T_3| = 2.62 - 2.42 = 0.20$

$|\Delta T_4| = 2.71 - 2.62 = 0.09$

$|\Delta T_5| = 2.80 - 2.62 = 0.18$

Mean absolute error

$\Delta T = \frac{|\Delta T_1| + |\Delta T_2| + |\Delta T_3| + |\Delta T_4| + |\Delta T_5|}{5}$

$= \frac{0.54}{5} = 0.108 = 0.11\,sec$

**42.** **(c)** Volume of cylinder $V = \pi r^2 l$

Percentage error in volume

$\frac{\Delta V}{V}\times 100 = \frac{2\Delta r}{r}\times 100 + \frac{\Delta l}{l}\times 100$

$= \left(2\times\frac{0.01}{2.0}\times 100 + \frac{0.1}{5.0}\times 100\right) = (1+2)\% = 3\%$

**43.** **(a)** Since percentage increase in length = 2%

Hence, percentage increase in area of square sheet

$= 2 \times 2 = 4\%$

**44.** **(c)** $T = 2\pi\sqrt{\frac{l}{g}}$

$\Rightarrow T^2 = \frac{4\pi^2 l}{g}$

$\Rightarrow g = \frac{4\pi^2 l}{T^2}$

Here % error in $l = \frac{1mm}{100cm}\times 100 = \frac{0.1}{100}\times 100 = 0.1\%$

% error in $T = \frac{0.1}{2\times 100}\times 100 = 0.05\%$

$\therefore$ % error in $g$ = % error in $l$ + 2(% error in $T$)

$= 0.1 + 2\times 0.05 = 0.2\%$

**45.** **(b)** Here

$S = (13.8 \pm 0.2)\,m$

$t = (4.0 \pm 0.3)\ sec$

Expressing it in percentage error, we have,

$S = 13.8 \pm \frac{0.2}{13.8}\times 100\% = 13.8 \pm 1.4\%$

$t = 4.0 \pm \frac{0.3}{4}\times 100\% = 4 \pm 7.5\%$

$\because V = \frac{s}{t} = \frac{13.8 \pm 1.4}{4 \pm 7.5} = (3.45 \pm 0.3)\,m/s$

**46.** **(c)** $Y = \frac{4MgL}{\pi D^2 l}$

So maximum permissible error in $Y = \frac{\Delta Y}{Y}\times 100$

$= \left(\frac{\Delta M}{M} + \frac{\Delta g}{g} + \frac{\Delta L}{L} + \frac{2\Delta D}{D} + \frac{\Delta l}{l}\right)\times 100$

$$=\left(\frac{1}{300}+\frac{1}{981}+\frac{1}{2820}+2\times\frac{1}{41}+\frac{1}{87}\right)\times 100$$

$$=\left(\frac{1}{300}+\frac{1}{981}+\frac{1}{2820}+2\times\frac{1}{41}+\frac{1}{87}\right)\times 100$$

$= 0.065\times 100 = 6.5\%$

**47.** **(d)** Percentage error in $A=\left(2\times1+3\times3+1\times2+\frac{1}{2}\times2\right)\%$

$=14\%$

**48.** **(b)** $V=\frac{4}{3}\pi r^3$

$\therefore$ % error is volume = 3 × % error in radius = 3 × 1 = 3%

**49.** **(b)** $\left(\frac{\Delta R}{R}\times 100\right)_{\max}=\frac{\Delta V}{V}\times 100+\frac{\Delta I}{I}\times 100$

$$=\frac{5}{100}\times 100+\frac{0.2}{10}\times 100$$

$=(5+2)\%=7\%$

**50.** **(c)** Quantity $C$ has maximum power. So it brings maximum error in $P$.

## NCERT Exemplar Problems

### More than One Answer

**51.** **(a, b, c)** Reynold number is simply a number while coefficient of friction is the ratio of two forces; hence both quantities are dimensionless. Curie is the unit for expressing rate of disintegration, hence, possesses dimensions $[T^{-1}]$ same as that of frequency.

Latent Heat $[L]=\frac{[Q]}{[m]}=\frac{[ML^2T^{-2}]}{[M]}=[L^2T^{-2}]$

Gravitational potential

$$[V]=\frac{[GM]}{[r]}=\frac{[M^{-1}L^3T^{-2}M]}{[L]}=[L^2T^{-2}]$$

Further, Planck constant has got the dimensions of angular momentum $L$ while torque τ possesses the dimensions of $[dL/dt]$.

**52.** **(b, c)** $[L]=[G]^x[c]^y[h]^z$

Or $[L^{-1}M^0T^0]=[M^{-1}L^3T^{-2}]^x[ML^2T^{-1}]^z$

$=[M]^{-x+z}[L]^{3x+y+2z}[T]^{-2x-y-z}$

Hence $-x+z=0$ . . .(*i*)

$3x+y+2z=0$ . . .(*ii*)

$-2x-y-z=0$ . . .(*iii*)

Solving, we get: $x=\frac{1}{2}, y=-\frac{3}{2}, z=\frac{1}{2}$

**53.** **(a, b, c, d)** SI unit of charge is coulomb.

Further1 Frankline = 1 esu of charge 1 faraday = 96,500 coulomb and 1 amp × sec = 1 coulomb

**54.** **(b, c)** $F=\frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$

So, $[\varepsilon_0]=\frac{[q]^2}{[F][r]^2}=\frac{[A^2T^2]}{[MLT^{-2}][L^2]}$

$=[M^{-1}L^{-3}T^4A^2]=[M^{-1}L^{-3}T^4I^2]$

Now $\frac{dF}{dL}=\frac{\mu_0}{4\pi}=\frac{I_1I_2}{r}$

$\therefore$ $[\mu_0]=\frac{[F]}{[I^2]}=[MLT^{-2}I^{-2}]$

**55.** **(a, b, c )** $\frac{\text{R}}{\text{L}}=\frac{\text{ohm}}{\text{henry}}=\frac{\text{ohm}}{\text{ohm}\times\text{sec}}=\text{sec}^{-1}$

$$\frac{1}{\text{CR}}=\frac{1}{\text{farad}\times\text{ohm}}=\frac{\text{volt}}{\text{coul}}\times\frac{\text{amp}}{\text{volt}}=\text{sec}^{-1}$$

$$\frac{1}{\sqrt{LC}}=\frac{1}{\sqrt{\text{henery}\times\text{farad}}}=\frac{1}{\sqrt{\text{ohm}\times sex\times\frac{\text{coul}}{\text{volt}}}}$$

$$=\frac{1}{\sqrt{\frac{\text{volt}}{\text{amp}}\times\text{sec}\times\frac{\text{coul}}{\text{volt}}}}=\frac{1}{\sqrt{\frac{\text{sec}\times\text{amp}\times\text{sec}}{\text{amp}}}}=\text{sec}^{-1}$$

**56.** **(a, b, c)** Unit of $\text{x}=\frac{\text{unit of E}}{\text{unit of B}}=\frac{\frac{\text{volt}}{\text{metre}}}{\frac{\text{volt}}{\text{metre}^2/\text{sec}}}$

$$=\frac{\text{metre}}{\text{sec}}=\text{unit of velocity}$$

$$\text{y}=\frac{1}{\sqrt{\mu_0\varepsilon_0}}=\text{c}=\text{velocity of light}$$

and unit of $\frac{1}{\text{CR}}=\frac{\text{metre}}{\text{farad}\times\text{ohm}}$

$$=\frac{\text{metre}}{\frac{\text{coul}}{\text{volt}}\times\frac{\text{volt}}{\text{amp}}}=\frac{\text{metre}}{\frac{\text{amp}\times\text{sec}}{\text{amp}}}$$

$$=\frac{\text{metre}}{\text{sec}}=\text{unit of velocity}$$

**57.** **(a, b, c)** From the principle of homogeneity, the dimension of $x$ must be the same as those at, $\text{bt}^2$ and $c$.

**58. (a, b, c)** Since, the sine function is dimensionless, $\sin(bt - cx)$ is also dimensionless. Therefore, $y$ and $a$ must have the same dimensions, *i.e., y/a* is dimensionless. Since, the arguments of a sine function (or any trigonometric function) must be dimensionless, $bt$ and $cx$ are also dimensionless.

**59. (b, d)** Since bt is dimensionless, the dimensions of b = dimensions of $(1/t) = [T^{-1}]$, which are the dimensions of angular frequency as well as wave frequency.

**60. (a, b, c, d)** Expanding van der Waals' equation, we get: $PV - Pb + \frac{a}{V} - \frac{ab}{V^2} = nRT.$ From the principle of homogeneity if follows that all the four choices area correct.

**64. (b)** Volume $V = l \times b \times t$

$= 12 \times 6 \times 2.45$

$= 176.4\ cm^3$

$V = 1.764 \times 10^2\ cm^3$

Since, the minimum number of significant figure is one in breadth, hence volume will also contain only one significant figure.

Hence, $V = 2 \times 10^2\ cm^3$.

**Assertion and Reason**

**67. (b)** Both assertion and reason are true but reason is not the correct explanation of assertion:

$[\varepsilon_0] = [M^{-1}L^{-3}T^4I^2]$

$[\mu_0] = [MLT^{-2}I^{-2}]$

$$\therefore \quad \frac{1}{\sqrt{\frac{\mu_0}{4\pi} \times 4\pi\varepsilon_0}} = \sqrt{\frac{9 \times 10^9}{10^{-7}}}$$

$= \sqrt{9 \times 10^{16}} = 3 \times 10^8$ m/s

Also $\left[\frac{1}{\sqrt{\mu_0\varepsilon_0}}\right] = \left[\frac{1}{\sqrt{L^{-2}T^2}}\right] = \left[\sqrt{\frac{L^2}{T^2}}\right] = [v]$

There fore $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$ has dimensions of velocity and numerically equal to velocity of light.

**68. (c)** As ω (angular velocity) has the dimensions of $[T^{-1}]$ not [T].

**69. (e)** Let us write the dimensions of various quantities on two sides of the given equation LHS = T = [T]

RHS $= 2\pi\sqrt{\frac{g}{l}} = \sqrt{\frac{LT^{-2}}{L}} = [T^{-1}]$ ($\because$ 2π has no dimensions)

As dimensions of LHS not equal to dimensions of RHS, therefore according to principle of homogeneity the relation $T = 2\pi/\sqrt{g/l}$ is not valid

**70. (a)** According to statement of reason, as the graph is a straight line, $P \propto Q$ or $P$ = constant × $Q$

*i.e.,* $\frac{P}{Q}$ = constant

**71. (a)** Unit of quantum ($L/R$) is henry/ohm.

As henry = ohm × sec, hence unit of $\frac{L}{R}$ is sec,

*i.e.,* $\left[\frac{L}{R}\right] = [T]$

Similarly, unit of product CR is farad × ohm

or $\frac{\text{coulomb}}{\text{volt}} \times \frac{\text{volt}}{\text{amp}}$

or $\frac{\text{sec} \times \text{amp}}{\text{amp}}$ or sec.

*i.e.,* $[CR] = [T]$

Therefore $\left[\frac{L}{R}\right]$ and $[CR]$ both have same dimensions.

**72. (c)** Because representation of standard metre in terms of wavelength of light is most accurate.

**73. (b)** For $f = \frac{1}{2l}\sqrt{\frac{T}{m}}$,

$f^2 = \frac{T}{4l^2m}$

Or $m = \frac{T}{4l^2f^2} = \frac{[MLT^{-2}]}{[L^2\ T^{-2}]} = \frac{[M]}{[L]}$

$= \frac{\text{mass}}{\text{length}}$ = linear mass density.

**74. (c)** Avogadro number ($N$) represents the number of atoms in 1 gram mole of an element, *i.e.,* it has the dimensions of $\text{mole}^{-1}$.

**Comprehension Based**

**76. (c)** LC of vernier callipers $= \frac{1\,\text{MSD}}{10} = \frac{1\,\text{mm}}{10} = 0.1\,\text{mm}$

$\because$ Here 10 division of vermier scale coincide with a division of main scale

Zero error $= -0.1 \times 5 = -0.5$ mm

Zero correction $= +0.5$ mm

Observed value of diameter = Main scale reading + coinciding × $VC = 42.+0.1\times 7 = 42.7$ mm

Corrected value of diameter $= 42.7+0.5 = 43.2$

Correct value $= (43.2 \pm 0.1)$ mm $= (4.32 \pm 0.01)$ mm

**77.** **(a)** Lesser is relative or percentage error more accurate is the measurement $\frac{\Delta l}{l} = \frac{0.1}{75.5}\times 100 = 0.14\%$

$\frac{\Delta D}{D} = \frac{0.1}{43.2}\times 100 = 0.24\%$

$\therefore$ Length is more accurate measurement.

Smaller is least count, more precise is measurement

LC of meter scale for length measurement is 0.1 cm.

LC of Vernier callipers of diameter measurement is 0.01 cm

$\therefore$ Diameter measurement is more precise

**78.** **(b)** Measured length will be $= L = l + D/2 = 75.5 + \frac{4.32}{2}$

$= 75.5 + 2.16 = 77.66 = 77.7$ cm

With due regard to S.F.'s

$\Delta L = 0.1 + 0.01 = 0.11$ cm $= 0.1$ cm

Measured value of time $= t = (40.2 \pm 0.1)$ s

Time period of simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$

or $g = 4\pi^2 \frac{L}{T^2}$

$\therefore \frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T} = \frac{\Delta L}{L} + 2\frac{\Delta t}{t}$

$= \frac{0.1}{77.7} + 2\frac{0.1}{10.2}$ % Error is $g = \frac{\Delta g}{g}\times 100$

$= \left[\frac{0.1}{77.7} + \frac{0.2}{40.2}\right]\times 100 = 0.14 + 0.5 \simeq 0.64\%$

**79.** **(a)** Using homogeneity principles $s = u + a(2n-1)$

Distance in nth sec $= \frac{\text{Distance}}{\text{Time}} = [LT^{-1}]$

$u$ = initial velocity $= \frac{\text{Distance}}{\text{Time}} = [LT^{-1}]$

$a(2n-1) = \text{Acceleration} \times \text{Time} = [LT^{-1}]$

But numerically correct relation is

$s_n - s_{n-1} = \left(u\times n + \frac{1}{2}an^2\right) - u(n-1) + \frac{a}{2}(n-1)^2$

$= u + \frac{a}{2}(2n-1)$

**80.** **(b)** Velocity gradient

$= \frac{dv}{dx} = \frac{L}{T}\times\frac{1}{L} = [M^0L^0T^{-1}]$

Angular velocity

$= \omega = \frac{2\pi}{T} = [M^0L^0T^{-1}]$

**81.** **(d)** This pair does not have same dimensional formula

Gravitational potential energy is $= [M^1L^2T^{-2}]$

Surface energy $= \frac{\text{Energy}}{\text{Area}} = [M^1L^0T^{-2}]$

All other options a, b and c have identical dimensional formula for pair mentioned.

(a) Angular momentum $\vec{r}\times\vec{p} = mvr = [M^1L^2T^{-1}]$

Planck's constant

$= \frac{\text{Energy}}{\text{Frequency}} = [M^1L^2T^{-1}]$

(b) Impulse = Force × Time

= Mass × Acceleration × time

= Mass × Vel

$[M^1L^1T^{-1}]$ = Momentum $= [M^1L^1T^{-1}]$

(c) Reydberg constant $= \frac{1}{\lambda}$

Wave propagation constant $= \frac{2\pi}{\lambda}$

Both have dimensions of length

**82.** **(a)** Using homogeneity principle, $P = \frac{a}{V^2}$

or $a = PV^2, V = b$

or $\frac{a}{b} = \frac{PV^2}{V}$ = Pressure × Volume

$= \frac{\text{Force}}{\text{Area}} =$ Volume = Force × Distance = Work

**83.** **(b)** $P = \frac{a}{V^2}$

or $a = PV^2 = \frac{\text{Force}}{\text{Area}} \times (\text{volume})^2$

$= \frac{[\mathrm{M^1L^1T^{-2}}]}{[\mathrm{L^{-2}}]}\times[\mathrm{L^6}] = [\mathrm{M^1L^5T^{-2}}]$

**84.** **(c)** Using homogeneity principle $RT = PV$

or $R = \frac{PV}{T} = \frac{\text{Pressure } \times \text{Volume}}{\text{Temperatuer}}$

$= \frac{\text{Force}}{\text{Area}}\times\frac{\text{Volume}}{\text{Temperature}} = [\mathrm{M^1L^2T^{-2}K^{-1}}]$

**85.** **(c)** For Vernier callipers:

Least Count $= \dfrac{1\,\text{MSD}}{\text{No. of divisions on vernier scale}}$

$= \dfrac{1}{20} \times \dfrac{1}{25} = \dfrac{1}{500}$ cm = 0.002 cm

For Screw gauge,

Lest Count $= \dfrac{\text{Pitch}}{\text{No. of divisions on C.S.}}$

$= \dfrac{1}{20} \times \dfrac{1}{100} = \dfrac{1}{2000}$ cm

= 0.0005 cm = 0.005 mm

**86.** **(c)** Area of sheet used

= Curved area + Cross section of bottom

$= 2\pi rl + \pi r^2 = \pi r(2l + r)$

Rounded off to 4 significant figures

$= \dfrac{22}{7} \times \dfrac{2.5}{2}(5.25 + 2.5/2)$

$= 27.500\,\text{cm}^2 \simeq 27.50\,\text{cm}^2$

**87.** **(c)** Volume of calorimeter $= \pi r^2 \times l = \pi \dfrac{D^2}{4} \times l$

$= 3.14 \times \dfrac{(2.5)^2}{4} \times 5.25\ \text{cm}^2 = 27.781$ cc

% Error $= 100 \times \dfrac{\Delta V}{V} = \left(\dfrac{2\Delta D}{D} + \dfrac{\Delta l}{l}\right) \times 100$

$= \dfrac{2 \times 0.002}{2.500} \times 100 + \dfrac{2 \times 0.002}{5.250} \times 100$

$= 0.16\% + 0.04\% = 0.20\%$

**Match the Column**

**88.** **(a)** A $\to$ 3, B $\to$ 1, C $\to$ 4, D $\to$ 2

Current one of 7 fundamental quantities

Charge = Current × Time is derived quantity

Candeal is fundamental unit of luminous intensity

Intensity of light is energy falling on unit area/sec

$I = \dfrac{\text{Energy}}{\text{Area} \times \text{sec}} = \text{W m}^{-2}$

**89.** **(c)** A $\to$ 3, B $\to$ 4, C $\to$ 1, D $\to$ 2

Tension is force $= [M^1L^1T^{-2}]$

Surface tension $= \dfrac{\text{Force}}{\text{Lenght}} = [M^1L^0T^{-2}]$

Energy density $= \dfrac{\text{Force}}{\text{Volume}} = [M^1L^{-1}T^{-2}]$

Gravitational field $= \dfrac{\text{Gravitational force}}{\text{Mass}} = [M^0L^1T^{-2}]$

**90.** **(d)** A $\to$ 1, B $\to$ 2, C $\to$ 3, D $\to$ 4

Angular velocity $= \dfrac{\text{Angle}}{\text{Time}} = [M^0L^0T^{-1}]$

Velocity gradient $= \dfrac{\text{Velocity}}{\text{Distance}} = [M^0L^0T^{-1}]$

Gravitational intensity $= \dfrac{\text{Gravitational force}}{\text{Mass}} = [M^0L^1T^{-2}]$

Acceleration $= \dfrac{\text{Force}}{\text{Mass}} = [M^0L^1T^{-2}]$

Stress $= \dfrac{\text{Force}}{\text{Area}} = [M^1L^{-1}T^{-2}]$

Energy density $= \dfrac{\text{Energy}}{\text{Volume}} = [M^1L^{-1}T^{-2}]$

Angle $= \dfrac{\text{Arc}}{\text{Radius}} = [M^0L^0T^0]$

Strain $= \dfrac{\text{Increase in lenght}}{\text{Original lenght}} = [M^0L^0T^0]$

**91.** **(d)** A $\to$ 2, B $\to$ 4, C $\to$ 1, D $\to$ 3

To find units and dimensions of physical quantities try to correlate the given quantities with force or energy. Thus force on conductor carrying current $F = BIl$.

Magnetic flux $= \vec{B} \cdot \overrightarrow{dS}$

= Magnetic induction × Area = $\text{NmA}^{-1}$

Magnetic induction of $= B = \dfrac{F}{Il}$

$B = \text{Nm}^{-1}\ \text{A}^{-1}$

Magnetic dipole moment: Torque on magnet in magnetic field $\tau = MB\sin\theta$

$\therefore$ Magnetic dipole moment

$= \dfrac{\text{Torque}}{\text{Magnetic induction}}$

$M = \dfrac{\text{Nm}}{\text{Nm}^{-1}\text{A}^{-1}} = \text{Am}^{-2}$

Magnetic permeability: $B = \dfrac{\mu_0 I}{2r} = \dfrac{F}{Il}$

Or $\mu_0 = \dfrac{N}{A^2} = \text{NA}^{-2}$

**92.** **(a)** A $\to$ 1, B $\to$ 2, C $\to$ 3, D $\to$ 4

Velocity gradient $= \dfrac{dV}{dx} = \dfrac{L}{T} \times \dfrac{1}{L} = [M^0L^0T^{-1}]$

Planck's constant $= \dfrac{\text{Energy}}{\text{Frequency}} = [M^1L^2T^{-1}]$

Gravitational field $= \dfrac{\text{Force}}{\text{Mass}} = [M^0L^1T^{-2}]$

Angular velocity $= \dfrac{2\pi}{T} = [M^0L^0T^{-1}]$

**Integer**

**93.** **(4)** In 0.0005083, there are four significant figures viz. 5, 0, 8 and 3, as per rules.

**94.** **(5)** $t = \frac{s}{c} = \frac{1.5\times10^{11}(m)}{3\times10^{8}(m/s)}$

$= 0.5\times10^{3}s = 5\times10^{2}s.$

$\therefore$ $x = 5.$

**95.** **(4)** Here, $\frac{M_1}{M_2} = \frac{L_1}{L_2} = \frac{T_1}{T_2} = \frac{2}{1}$

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

$\therefore$ $\frac{M_1L_1^2T_1^{-1}}{M_2L_2^2T_2^{-1}} = \left(\frac{M_1}{M_2}\right)\times\left(\frac{L_1}{L_2}\right)^2\left(\frac{T_2}{T_1}\right)$

$= \frac{2}{1}\left(\frac{2}{1}\right)^2\times\frac{1}{2} = 4.$

**96.** **(1)** Error in measuring time of 20 s = 0.2 s

% age error $= \frac{0.2}{20}\times100 = 1\%.$

**97.** **(8)** As $H = I^2Rt$

$\therefore$ $\frac{\Delta H}{H} = 2\left(\frac{\Delta I}{I}\right) + \frac{\Delta R}{R} + \frac{\Delta t}{t}$

$= 2\times2\% + 1\% + 3\% = 8\%$

**98.** **(4)** Density, $\rho = \frac{M}{V} = \frac{M}{\pi r^2 L}$

$\Rightarrow \frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + 2\frac{\Delta r}{r} + \frac{\Delta L}{L}$

$= \frac{0.003}{0.3} + 2\times\frac{0.005}{0.5} + \frac{0.06}{6}$

$= 0.01 + 0.02 + 0.01 = 0.04$

$\therefore$ Percentage error $= \frac{\Delta\rho}{\rho}\times100 = 0.04\times100 = 4\%$

**99.** **(3)** Volume of cylinder $V = \pi r^2 l$

Percentage error in volume

$\frac{\Delta V}{V}\times100 = \frac{2\Delta r}{r}\times100 + \frac{\Delta l}{l}\times100$

$= \left(2\times\frac{0.01}{2.0}\times100 + \frac{0.1}{5.0}\times100\right)$

$= (1+2)\% = 3\%$

**100.** **(4)** The number of significant figures in all of the given number is 4.

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