##  <br> Units and Measurements

## Topic-1: Unit of Physical Quantities

## 1 MCQs with One Correct Answer

1. The $S I$ unit of inductance, the henry can be written as
[1998-2 Marks]
(a) weber/ampere
(b) volt-sec/amp
(c) Joule/(ampere) ${ }^{2}$
(d) ohm-second

## 7 Match the Following

2. 

## Column I

## Column II

(A) $G M_{e} M_{s}, G-$
universal gravitational constant,
$M_{e}$ - mass of the earth,
$M_{s}$ - mass of the Sun
(B) $\frac{3 R T}{M}, R$ - universal gas constant,
(q) (kilogram) (metre) ${ }^{3}$
$T$ - absolute temperature,
$M$ - molar mass
(C) $\frac{F^{2}}{q^{2} B^{2}}, F$-Force,
$q$ - charge,
$B$ - magnetic field
(D) $\frac{G M_{e}}{\mathrm{R}_{\mathrm{e}}}, G$-universal
$M_{e}$ - mass of the earth,
$R_{e}$ - radius of the earth

## Column I

(A) Capacitance
(B) Inductance
(C) Magnetic Induction
(s) $($ farad $)(\text { volt })^{2}(\mathrm{~kg})^{-1}$
(r) $(\text { metre })^{2}(\text { second })^{-2}$
[2007]

## Column II

(i) ohm-second
(ii) coulomb $^{2}$ - joule $^{-1}$
(iii) coulomb (volt) $)^{-1}$
(iv) newton (amp-metre) ${ }^{-1}$
(v) volt-second (ampere) ${ }^{-1}$
[1990-3 Marks]

## 10 Subjective Problems

4. Give the MKS units for each of the following quantities.
(A) Young's modulus
[1980]
(B) Magnetic Induction
(C) Power of a lens

Topic-2: Dimensions of Physical Quantities

## 1 MCQs with One Correct Answer

1. Young's modulus of elasticity Y is expressed in terms of three derived quantities, namely, the gravitational constant G, Planck's constant $h$ and the speed of light $c$, as $\mathrm{Y}=\mathrm{c}^{\alpha} \mathrm{h}^{\beta} \mathrm{G}^{\gamma}$. Which of the following is the correct option?
[Adv. 2023]
(a) $\alpha=7, \beta=-1, \gamma=-2$
(b) $\alpha=-7, \beta=-1, \gamma=-2$
(c) $\alpha=7, \beta=-1, \gamma=2$
(d) $\alpha=-7, \beta=1, \gamma=-2$
2. Area of the cross-section of a wire is measured using a screw gauge. The pitch of the main scale is 0.5 mm . The circular scale has 100 divisions and for one full rotation of the circular scale, the main scale shifts by two divisions. The measured readings are listed below.
[Adv. 2022]

| Meas urement <br> condition | Main scale <br> reading | Circular scale <br> reading |
| :--- | :---: | :---: |
| Two arms of gauge <br> touching each other <br> without wire | 0 division | 4 divisions |
| Attempt-1: With wire | 4 divisions | 20 divisions |
| Attempt-2: With wire | 4 divisions | 16 divisions |

What are the diameter and cross-sectional area of the wire measured using the screw gauge?
(a) $2.22 \pm 0.02 \mathrm{~mm}, \pi(1.23 \pm 0.02) \mathrm{mm}^{2}$
(b) $2.22 \pm 0.01 \mathrm{~mm}, \pi(1.23 \pm 0.01) \mathrm{mm}^{2}$
(c) $2.14 \pm 0.02 \mathrm{~mm}, \pi(1.14 \pm 0.02) \mathrm{mm}^{2}$
(d) $2.14 \pm 0.01 \mathrm{~mm}, \pi(1.14 \pm 0.01) \mathrm{mm}^{2}$
3. Let $\left[\epsilon_{0}\right]$ denote the dimensional formula of the permittivity of vacuum. If $\mathrm{M}=$ mass, $\mathrm{L}=$ length, $\mathrm{T}=$ time and $\mathrm{A}=$ electric current, then:
[2012]
(a) $\epsilon_{0}=\left[\mathrm{M}^{-1} \mathrm{~L}^{-3} \mathrm{~T}^{2} \mathrm{~A}\right]$
(b) $\epsilon_{0}=\left[\mathrm{M}^{-1} \mathrm{~L}^{-3} \mathrm{~T}^{4} \mathrm{~A}^{2}\right]$
(c) $\epsilon_{0}=\left[\mathrm{M}^{1} \mathrm{~L}^{2} \mathrm{~T}^{1} \mathrm{~A}^{2}\right]$
(d) $\epsilon_{0}=\left[\mathrm{M}^{1} \mathrm{~L}^{2} \mathrm{~T}^{1} \mathrm{~A}\right]$
4. Which of the following set have different dimensions?
(a) Pressure, Young's modulus, Stress
[2005S]
(b) EMF, Potential difference, Electric potential
(c) Heat, Work done, Energy
(d) Dipole moment, Electric flux, Electric field
5. Pressure depends on distance as, $P=\frac{\alpha}{\beta} \exp \left(-\frac{\alpha z}{k \theta}\right)$, where $\alpha, \beta$ are constants, $z$ is distance, $k$ is Boltzman's constant and $\theta$ is temperature. The dimension of $\beta$ are
(a) $M^{0} L^{0} T^{0}$
(b) $M^{-1} L^{-1} T^{-1}$
(c) $M^{0} L^{2} T^{0}$
(d) $M^{-1} L^{1} T^{2}$
[2004S]
6. A quantity $X$ is given by $\varepsilon_{0} L \frac{\Delta V}{\Delta t}$ where $\epsilon_{0}$ is the permittivity of the free space, $L$ is a length, $\Delta V$ is a potential difference and $\Delta t$ is a time interval. The dimensional formula for $X$ is the same as that of
[2001S]
(a) resistance
(b) charge
(c) voltage
(d) current
7. The dimension of $\left(\frac{1}{2}\right) \varepsilon_{0} E^{2}\left(\varepsilon_{0}\right.$ : permittivity of free space, $E$ electric field)
[2000S]
(a) $M L T^{-1}$
(b) $M L^{2} T^{-2}$
(c) $M L^{-1} T^{-2}$
(d) $M L^{2} T$

## 2 Integer Value Answer

8. In a particular system of units, a physical quantity can be expressed in terms of the electric charge $e$, electron mass $m_{e}$, Planck's constant $h$, and Coulomb's constant $k=\frac{1}{4 \pi \epsilon_{0}}$, where $\epsilon_{0}$ is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B]=[e]^{\alpha}\left[m_{e}\right]^{\beta}[h]^{\gamma}[k]^{\delta}$. The value of $\alpha+$ $\beta+\gamma+\delta$ is $\qquad$ .
[Adv. 2022]
9. To find the distance $d$ over which a signal can be seen clearly in foggy conditions, a railways-engineer uses dimensions and assumes that the distance depends on the mass density $\rho$ of the fog, intensity (power/area) $S$ of the light from the signal and its frequency $f$. The engineer finds that $d$ is proportional to $S^{1 / n}$. The value of $n$ is
[Adv. 2014]

## 4 Fill in the Blanks

10. The dimension of electrical conductivity is
[1997-1 Mark]
11. The equation of state for real gas is given by $\left(P+\frac{a}{V^{2}}\right)(V-b)=R T$. The dimensions of the constant $a$ is $\qquad$ .
[1997-2 Marks]
12. In the formula $X=3 Y Z^{2}, X$ and $Z$ have dimensions of capacitance and magnetic induction respectively. The
dimensions of $Y$ in $M K S Q$ sytem are
[1988-2 Marks]
13. Planck's constant has dimension
[1985-2 Marks]

## $6 \quad \mathrm{MCQ}$ s with One or More than One Correct Answer

14. A physical quantity $\vec{S}$ is defined as $\vec{S}=(\vec{E} \times \vec{B}) / \mu_{0}$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and $\mu_{0}$ is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantities?
[Adv. 2021]
(a) $\frac{\text { Energy }}{\text { Charge } \times \text { Current }}$
(b) $\frac{\text { Force }}{\text { Length } \times \text { Time }}$
(c) $\frac{\text { Energy }}{\text { Volume }}$
(d) $\frac{\text { Power }}{\text { Area }}$
15. Sometimes it is convenient to construct a system of units so that all quantities can be expressed in terms of only one physical quantity. In one such system, dimensions of different quantities are given in terms of a quantity $X$ as follows:
[position $]=\left[X^{\alpha}\right] ;$ speed $]=\left[X^{\beta}\right] ;$ [acceleration $]=\left[X^{p}\right]$; [linear momentum $]=\left[X^{q}\right] ;[$ force $]=\left[X^{r}\right]$. Then [Adv. 2020]
(a) $\alpha+p=2 \beta$
(b) $p+q-r=\beta$
(c) $p-q+r=\alpha$
(d) $p+q+r=\beta$
16. Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimensions of L , which of the following statement( s ) is/ are correct?
[Adv. 2019]
(a) The dimension of force is $L^{-2}$
(b) The dimension of linear momentum is $L^{-1}$
(c) The dimension of energy is $L^{-2}$
(d) The dimension of power is $L^{-5}$
17. A length-scale $(l)$ depends on the permittivity $(\varepsilon)$ of a dielectric material. Boltzmann constant $\left(\mathrm{k}_{\mathrm{B}}\right)$, the absolute temperature ( T ), the number per unit volume ( n ) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for $I$ is(are) dimensionally correct?
[Adv. 2016]
(a) $l=\sqrt{\left(\frac{\mathrm{nq}^{2}}{\varepsilon \mathrm{k}_{\mathrm{B}} \mathrm{T}}\right)}$
(b) $l=\sqrt{\left(\frac{\varepsilon \mathrm{k}_{\mathrm{B}} \mathrm{T}}{\mathrm{nq}^{2}}\right)}$
(c) $l=\sqrt{\left(\frac{\mathrm{q}^{2}}{\varepsilon \mathrm{n}^{2 / 3} \mathrm{k}_{\mathrm{B}} \mathrm{T}}\right)}$
(d) $l=\sqrt{\left(\frac{\mathrm{q}^{2}}{\varepsilon \mathrm{n}^{1 / 3} \mathrm{k}_{\mathrm{B}} \mathrm{T}}\right)}$
18. In terms of potential difference $V$, electric current $I$, permittivity $\varepsilon_{0}$, permeability $\mu_{0}$ and speed of light $c$, the dimensionally correct equation(s) is(are)
[Adv. 2015]
(a) $\mu_{0} \mathrm{I}^{2}=\varepsilon_{0} \mathrm{~V}^{2}$
(b) $\varepsilon_{0} \mathrm{I}=\mu_{0} \mathrm{~V}$
(c) $\mathrm{I}=\varepsilon_{0} \mathrm{cV}$
(d) $\mu_{0} \mathrm{cI}=\varepsilon_{0} \mathrm{~V}$
19. Planck's constant $h$, speed of light $c$ and gravitational constant $G$ are used to form a unit of length $L$ and a unit of mass $M$. Then the correct option(s) is(are) [Adv. 2015]
(a) $M \propto \sqrt{c}$
(b) $M \propto \sqrt{G}$
(c) $L \propto \sqrt{h}$
(d) $L \propto \sqrt{G}$
20. Let $\left[\varepsilon_{0}\right]$ denote the dimensional formula of the permittivity of the vacuum, and $\left[\mu_{0}\right.$ ] that of the permeability of the vacuum. If $M=$ mass, $L=$ length, $T=$ time and $I=$ electric current,
[1998-2 Marks]
(a) $\left[\varepsilon_{0}\right]=M^{-1} L^{-3} T^{2} I$
(b) $\left[\varepsilon_{0}\right]=M^{-1} L^{-3} T^{4} I^{2}$
(c) $\left[\mu_{0}\right]=M L T^{-2} I^{-2}$
(d) $\left[\mu_{0}\right]=M L^{2} T^{-1} I$
21. The pairs of physical quantities that have the same dimensions is (are) :
[1995S]
(a) Reynolds number and coefficient of friction
(b) Curie and frequency of a light wave
(c) Latent heat and gravitational potential
(d) Planck's constant and torque
22. The dimensions of the quantities in one (or more) of the following pairs are the same. Identify the pair (s)
(a) Torque and Work
[1986-2 Marks]
(b) Angular momentum and Work
(c) Energy and Young's modulus
(d) Light year and Wavelength

## 7 Match the Following

23. Match List I with List II and select the correct answer using the codes given below the lists:
[Adv. 2013]

## List I

P. Boltzmann constant

## List II

1. $\left[\mathrm{ML}^{2} \mathrm{~T}^{-1}\right]$
Q. Coefficient of viscosity
2. $\left[\mathrm{ML}^{-1} \mathrm{~T}^{-1}\right]$
R. Planck constant
3. $\left[\mathrm{MLT}^{-3} \mathrm{~K}^{-1}\right]$
S. Thermal conductivity
4. $\left[\mathrm{ML}^{2} \mathrm{~T}^{-2} \mathrm{~K}^{-1}\right]$

## Codes:


24. Match the physical quantities given in column I with dimensions expressed in terms of mass ( $M$ ), length ( $L$ ), time $(T)$, and charge $(Q)$ given in column II and write the correct answer against the matched quantity in a tabular form in your answer book.
[1983-6 Marks]

## Column I

Angular momentum
Latent heat
Torque
Capacitance
Inductance
Resistivity

## Column II

$M L^{2} T^{-2}$
$M L^{2} Q^{-2}$
$M L^{2} T^{-1}$
$M L^{3} T^{-1} Q^{-2}$
$M^{-1} L^{-2} T^{2} Q^{2}$
$L^{2} T^{-2}$

## 8 Comprehension/Passage Based Questions

## Passage

In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, $[E]$ and $[B]$ stand for dimensions of electric and magnetic fields respectively, while $\left[\varepsilon_{0}\right]$ and $\left[\mu_{0}\right]$ stand for dimensions of the permittivity and permeability of free space respectively. $[L]$ and $[T]$ are dimensions of length and time respectively. All the quantities are given in SI units. [Adv. 2018]
25. The relation between $[E]$ and $[B]$ is
(a) $[E]=[B][L][T]$
(b) $[E]=[B][L]^{-1}[T]$
(c) $[E]=[B][L][T]^{-1}$
(d) $[E]=[B][L]^{-1}[T]^{-1}$
26. The relation between $\left[\varepsilon_{0}\right]$ and $\left[\mu_{0}\right]$ is
(a) $\left[\mu_{0}\right]=\left[\varepsilon_{0}\right][L]^{2}[T]^{-2}$
(b) $\left[\mu_{0}\right]=\left[\varepsilon_{0}\right][L]^{-2}[T]^{2}$
(c) $\left[\mu_{0}\right]=\left[\varepsilon_{0}\right]^{-1}[L]^{2}[T]^{-2}$
(d) $\left[\mu_{0}\right]=\left[\varepsilon_{0}\right]^{-1}[L]^{-2}[T]^{2}$

10 Subjective Problems
27. Write the dimensions of the following in terms of mass, time, length and charge
[1982-2 Marks]
(i) magnetic flux
(ii) rigidity modulus
28. A gas bubble, from an explosion under water, oscillates with a period $T$ proportional to $p^{a} d^{b} E^{c}$. Where ' $P$ ' is the static pressure, ' $d$ ' is the density of water and ' $E$ ' is the total energy of the explosion. Find the values of $a, b$ and $c$.
[1981-3 Marks]

## Topic-3: Errors in Measurements \& Experimental Physics

## 1 MCQs with One Correct Answer

1. The smallest division on the main scale of a Vernier calipers is 0.1 cm . Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this calipers with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is
[Adv. 2021]

(a) 3.07 cm
(b) 3.11 cm
(c) 3.15 cm
(d) 3.17 cm
2. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta \mathrm{T}=0.01$ seconds and he measures the depth of the well to be $L=20$ meters. Take the acceleration due to gravity $g=10 \mathrm{~ms}^{-2}$ and the velocity of sound is $300 \mathrm{~ms}^{-1}$. Then the fractional error in the measurement, $\delta \mathrm{L} / \mathrm{L}$, is closest to
[Adv. 2017]
(a) $0.2 \%$
(b) $1 \%$
(c) $3 \%$
(d) $5 \%$
3. There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers $\left(\mathrm{C}_{1}\right)$ has 10 equal divisions that correspond to 9 main scale divisions. The

Vernier scale of the other caliper $\left(\mathrm{C}_{2}\right)$ has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm ) by calipers $\mathrm{C}_{1}$ and $\mathrm{C}_{2}$, respectively, are

(a) 2.85 and 2.82
(b) 2.87 and 2.83
(c) 2.87 and 2.86
(d) 2.87 and 2.87
4. The diameter of a cylinder is measured using a Vernier callipers with no zero error. It is found that the zero of the Vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The Vernier scale has 50 divisions equivalent to 2.45 cm . The $24^{\text {th }}$ division of the Vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is
[Adv. 2013]
(a) 5.112 cm
(b) 5.124 cm
(c) 5.136 cm
(d) 5.148 cm
5. In the determination of Young's modulus $\left(Y=\frac{4 M L g}{\pi l d^{2}}\right)$ by using Searle's method, a wire of length $L=2 \mathrm{~m}$ and diameter $d=0.5 \mathrm{~mm}$ is used. For a load $M=2.5 \mathrm{~kg}$, an extension $l=0.25 \mathrm{~mm}$ in the length of the wire is observed. Quantities $d$ and $l$ are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm . The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the $Y$ measurement
[2012]
(a) due to the errors in the measurements of $d$ and $l$ are the same.
(b) due to the error in the measurement of $d$ is twice that due to the error in the measurement of $l$.
(c) due to the error in the measurement of $l$ is twice that due to the error in the measurement of $d$.
(d) due to the error in the measurement of $d$ is four times that due to the error in the measurement of $l$.
6. The density of a solid ball is to be determined in an experiment. The diameter of the ball is measured with a screw gauge, whose pitch is 0.5 mm and there are 50 divisions on the circular scale. The reading on the main scale is 2.5 mm and that on the circular scale is 20 divisions. If the measured mass of the ball has a relative error of $2 \%$, the relative percentage error in the density is [2011]
(a) $0.9 \%$
(b) $2.4 \%$
(c) $3.1 \%$
(d) $4.2 \%$
7. A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the Vernier scale which match with 16 main scale divisions. For this Vernier calipers, the least count is
[2010]
(a) 0.02 mm
(b) 0.05 mm
(c) 0.1 mm
(d) 0.2 mm
8. A student performs an experiment to determine the Young's modulus of a wire, exactly 2 m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of $\pm 0.05 \mathrm{~mm}$ at a load of exactly 1.0 kg . The student also
measures the diameter of the wire to be 0.4 mm with an uncertainty of $\pm 0.01 \mathrm{~mm}$. Take $g=9.8 \mathrm{~m} / \mathrm{s}^{2}$ (exact). The Young's modulus obtained from the reading is [2007]
(a) $(2.0 \pm 0.3) \times 10^{11} \mathrm{~N} / \mathrm{m}^{2}$
(b) $(2.0 \pm 0.2) \times 10^{11} \mathrm{~N} / \mathrm{m}^{2}$
(c) $(2.0 \pm 0.1) \times 10^{11} \mathrm{~N} / \mathrm{m}^{2}$
(d) $(2.0 \pm 0.05) \times 10^{11} \mathrm{~N} / \mathrm{m}^{2}$
9. A student performs an experiment for determination of $g\left(=\frac{4 \pi^{2} \ell}{T^{2}}\right)$. The error in length $\ell$ is $\Delta \ell$ and in time $T$ is $\Delta T$ and $n$ is number of times the reading is taken. The measurement of $g$ is most accurate for [2006-3M,-1]

|  | $\boldsymbol{\Delta} \boldsymbol{\ell}$ | $\boldsymbol{\Delta} \boldsymbol{T}$ |
| :---: | :---: | :---: |
| (a) | 5 mm | 0.2 sec |
| (b) | 5 mm | 0.2 sec |
| (c) | 5 mm | 0.10 |
| (d) 1 mm | 0.1 sec | 20 |
| (dec | 50 |  |

10. In a screw gauge, the zero of mainscale coincides with fifth division of circular scale in figure (i). The circular division of screw gauge are 50 . It moves 0.5 mm on main scale in one rotation. The diameter of the ball in figure (ii) is
[2006-3M,-1]

(a) 2.25 mm
(b) 2.20 mm
(c) 1.20 mm
(d) 1.25 mm
11. A wire of length $\ell=6 \pm 0.06 \mathrm{~cm}$ and radius $r=0.5 \pm 0.005 \mathrm{~cm}$ and mass $m=0.3 \pm 0.003 \mathrm{gm}$. Maximum percentage error in density is
[2004S]
(a) 4
(b) 2
(c) 1
(d) 6.8
12. A cube has a side of length $1.2 \times 10^{-2} \mathrm{~m}$. Calculate its volume.
(a) $1.7 \times 10^{-6} \mathrm{~m}^{3}$
(b) $1.73 \times 10^{-6} \mathrm{~m}^{3}$
(c) $1.70 \times 10^{-6} \mathrm{~m}^{3}$
(d) $1.732 \times 10^{-6} \mathrm{~m}^{3}$
[2003S]

## 2 Integer Value Answer

13. In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is $10 \pm 0.1 \mathrm{~cm}$ and the distance of its real image from the lens is $20 \pm 0.2 \mathrm{~cm}$. The error in the determination of focal length of the lens is $n \%$. The value of $n$ is $\qquad$ .
[Adv. 2023]
14. The energy of a system as a function of time $t$ is given as $E(t)=A^{2} \exp (-\alpha \mathrm{t}$,$) where \alpha=0.2 \mathrm{~s}^{-1}$. The measurement of $A$ has an error of $1.25 \%$. If the error in the measurement of time is $1.50 \%$, the percentage error in the value of $E(t)$ at $t=5 \mathrm{~s}$ is
[Adv. 2015]
15. During Searle's experiment, zero of the Vernier scale lies between $3.20 \times 10^{-2} \mathrm{~m}$ and $3.25 \times 10^{-2} \mathrm{~m}$ of the main scale. The $20^{\text {th }}$ division of the Vernier scale exactly coincides
with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between $3.20 \times 10^{-2} \mathrm{~m}$ and $3.25 \times 10^{-2} \mathrm{~m}$ of the main scale but now the $45^{\text {th }}$ division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is $8 \times 10^{-7} \mathrm{~m}^{2}$. The least count of the Vernier scale is $1.0 \times$ $10^{-5} \mathrm{~m}$. The maximum percentage error in the Young's modulus of the wire is
[Adv. 2014]

## 3 Numeric / New Stem Based Questions

16. An optical bench has 1.5 m long scale having four equal divisions in each cm . While measuring the focal length of a convex lens, the lens is kept at 75 cm mark of the scale and the object pin is kept at 45 cm mark. The image of the object pin on the other side of the lens overlaps with image pin that is kept at 135 cm mark. In this experiment, the percentage error in the measurement of the focal length of the lens is
[Adv. 2019]
17. A steel wire of diameter 0.5 mm and Young's modulus $2 \times 10^{11} \mathrm{Nm}^{-2}$ carries a load of mass $M$. The length of the wire with the load is 1.0 m . A vernier scale with 10 divisions is attached to the end of this wire. Next to the steel wire is a reference wire to which a main scale, of least count 1.0 mm , is attached. The 10 divisions of the vernier scale correspond to 9 divisions of the main scale. Initially, the zero of vernier scale coincides with the zero of main scale. If the load on the steel wire is increased by 1.2 kg , the vernier scale division which coincides with a main scale division is $\qquad$ Take $\mathrm{g}=10 \mathrm{~m} \mathrm{~s}^{-2}$ and $\pi=3.2$.
[Adv. 2018]
18. The side of a cube is measured by vernier callipers ( 10 divisions of a vernier scale coincide with 9 divisions of main scale, where 1 division of main scale is 1 mm ). The main scale reads 10 mm and first division of vernier scale coincides with the main scale. Mass of the cube is 2.736 g . Find the density of the cube in appropriate significant figures.
[2005-2 Marks]
19. In Searle's experiment, which is used to find Young's Modulus of elasticity, the diameter of experimental wire is $D=0.05 \mathrm{~cm}$ (measured by a scale of least count 0.001 cm ) and length is $L=110 \mathrm{~cm}$ (measured by a scale of least count 0.1 cm ). A weight of 50 N causes an extension of $X$ $=0.125 \mathrm{~cm}$ (measured by a micrometer of least count 0.001 cm ). Find maximum possible error in the values of Young's modulus. Screw gauge and meter scale are free from error.
[2004-2 Marks]
20. A screw gauge having 100 equal divisions and a pitch of length 1 mm is used to measure the diameter of a wire of length 5.6 cm . The main scale reading is 1 mm and $47^{\text {th }}$ circular division coincides with the main scale. Find the curved surface area of wire in $\mathrm{cm}^{2}$ to appropriate significant figure.
(use $\pi=\frac{22}{7}$ ).
[2004-2 Marks]

## 6 MCQs with One or More than One Correct Answer

21. In an experiment to determine the acceleration due to gravity g , the formula used for the time period of a periodic
motion is $T=2 \pi \sqrt{\frac{7(R-r)}{5 g}}$. The values of $R$ and $r$ are measured to be $(60 \pm 1) \mathrm{mm}$ and $(10 \pm 1) \mathrm{mm}$, respectively. In five successive measurements, the time period is found to be $0.52 \mathrm{~s}, 0.56 \mathrm{~s}, 0.57 \mathrm{~s}, 0.54 \mathrm{~s}$ and 0.59 s . The least count of the watch used for the measurement of time period is 0.01 s . Which of the following statement(s) is (are) true?
[Adv. 2016]
(a) The error in the measurement of r is $10 \%$
(b) The error in the measurement of T is $3.75 \%$
(c) The error in the measurement of T is $2 \%$
(d) The error in the determined value of $g$ is $11 \%$
22. Consider a Vernier callipers in which each 1 cm on the main scale is divided into 8 equal divisions and a screw gauge with 100 divisions on its circular scale. In the Vernier callipers, 5 divisions of the Vernier scale coincide with 4 divisions on the main scale and in the screw gauge, one complete rotation of the circular scale moves it by two divisions on the linear scale. Then :
[Adv. 2015]
(a) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(b) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm
(c) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(d) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm
23. Using the expression $2 \mathrm{~d} \sin \theta=\lambda$, one calculates the values of $d$ by measuring the corresponding angles $\theta$ in the range 0 to $90^{\circ}$. The wavelength $\lambda$ is exactly known and the error in $\theta$ is constant for all values of $\theta$. As $\theta$ increases from $0^{\circ}$
[Adv. 2013]
(a) The absolute error in $d$ remains constant
(b) The absolute error in $d$ increases
(c) The fractional error in $d$ remains constant
(d) The fractional error in $d$ decreases
24. A student uses a simple pendulum of exactly 1 m length to determine $g$, the acceleration due to gravity. He uses a stop watch with the least count of 1 sec for this and records 40 seconds for 20 oscillations. For this observation, which of the following statement(s) is (are) true?
[2010]
(a) Error $\Delta T$ in measuring $T$, the time period, is 0.05 seconds
(b) Error $\Delta T$ in measuring $T$, the time period, is 1 second
(c) Percentage error in the determination of $g$ is $5 \%$
(d) Percentage error in the determination of $g$ is $2.5 \%$

## 8 Comprehension/Passage Based Questions

## Passage

If the measurement errors in all the independent quantities are known, then it is possible to determine the error in any dependent quantity. This is done by the use of series expansion and truncating the expansion at the first power of the error. For example, consider the relation $z=x / y$. If the errors in $x, y$ and $z$ are $\Delta x, \Delta y$ and $\Delta z$, respectively, then

$$
z \pm \Delta z=\frac{x \pm \Delta x}{y \pm \Delta y}=\frac{x}{y}\left(1 \pm \frac{\Delta x}{x}\right)\left(1 \pm \frac{\Delta y}{y}\right)^{-1} .
$$

The series expansion for $\left(1 \pm \frac{\Delta y}{y}\right)^{-1}$, to first power in $\Delta y / y$, is $1 \mp(\Delta y / y)$. The relative errors in independent variables are always added. So the error in $z$ will be

$$
\Delta z=z\left(\frac{\Delta x}{x}+\frac{\Delta y}{y}\right)
$$

The above derivation makes the assumption that $\Delta x / x \ll 1$, $\Delta y / y \ll 1$. Therefore, the higher powers of these quantities are neglected.
[Adv. 2018]
25. Consider the ratio $r=\frac{(1-a)}{(1+a)}$ to be determined by measuring a dimensionless quantity $a$. If the error in the
measurement of $a$ is $\Delta a(\Delta a / a \ll 1$, then what is the error $\Delta r$ in determining $r$ ?
(a) $\frac{\Delta a}{(1+a)^{2}}$
(b) $\frac{2 \Delta a}{(1+a)^{2}}$
(c) $\frac{2 \Delta a}{\left(1-a^{2}\right)}$
(d) $\frac{2 a \Delta a}{\left(1-a^{2}\right)}$
26. In an experiment the initial number of radioactive nuclei is 3000 . It is found that $1000 \pm 40$ nuclei decayed in the first 1.0 s . For $|x| \ll 1, \ln (1+x)=x$ up to first power in $x$. The error $\Delta \lambda$, in the determination of the decay constant $\lambda$, in $s^{-1}$, is
(a) 0.04
(b) 0.03
(c) 0.02
(d) 0.01

## 10 Subjective Problems

27. If $n^{\text {th }}$ division of main scale coincides with $(n+1)^{\text {th }}$ divisions of vernier scale. Given one main scale division is equal to ' $a$ ' units. Find the least count of the vernier.
[2003-2 Marks]

## Topic-4: Miscellaneous (Mixed Concepts) Problems

## 8 Comprehension/Passage Based Questions

## Passage

A dense collection of equal number of electrons and positive ions is called neutral plasma. Certain solids containing fixed positive ions surrounded by free electrons can be treated as neutral plasma. Let ' $N$ ' be the number density of free electrons, each of mass ' $m$ '. When the electrons are subjected to an electric field, they are displaced relatively away from the heavy positive ions. If the electric field becomes zero, the electrons begin to oscillate about the positive ions with a natural angular frequency ' $\omega_{\mathrm{p}}$ ' which is called the plasma frequency. To sustain the oscillations, a time varying electric field needs to be applied that has an angular frequency $\omega$, where a part of the energy is absorbed and a part of it is reflected. As $\omega$ approaches $\omega_{p}$ all the
free electrons are set to resonance together and all the energy is reflected. This is the explanation of high reflectivity of metals.
[2011]

1. Taking the electronic charge as ' $e$ ' and the permittivity as ' $\varepsilon_{0}$ '. Use dimensional analysis to determine the correct expression for $\omega_{\mathrm{p}}$.
(a) $\sqrt{\frac{N e}{m \varepsilon_{0}}}$
(b) $\sqrt{\frac{m \varepsilon_{0}}{N e}}$
(c) $\sqrt{\frac{N e^{2}}{m \varepsilon_{0}}}$
(d) $\sqrt{\frac{N e^{2}}{m \varepsilon_{0}}}$
2. Estimate the wavelength at which plasma reflection will occur for a metal having the density of electrons $\mathrm{N} \approx 4 \times 10^{27} \mathrm{~m}^{-3}$. Taking $\varepsilon_{0}=10^{-11}$ and mass $\mathrm{m} \approx 10^{-30}$, where these quantities are in proper SI units.
(a) 800 nm
(b) 600 nm
(c) 300 nm
(d) 200 nm

## Answer Key

## Topic-1 : Unit of Physical Quantities

1. $(a, b, c, d)$
2. $\mathrm{A} \rightarrow \mathrm{p}, \mathrm{q} ; \mathrm{B} \rightarrow \mathrm{r}, \mathrm{s} ; \mathrm{C} \rightarrow \mathrm{r}, \mathrm{s} ; \mathrm{D} \rightarrow \mathrm{r}, \mathrm{s}$

Topic-2 : Dimensions of Physical Quantities

1. (a)
2. (c)
3. (b)
4. (d)
5. (c)
6. (d)
7. (c)
8. (4)
9. (3)
10. (b, d)
11. $(\mathrm{a}, \mathrm{b})$
12. $(a, b, c)$
13. (b, d)
14. $(a, c)$
15. $(a, c, d)$
16. (b, c)
17. $(a, b, c) 2$
18. $(a, d)$
19. (c)
20. (c)
21. (d)
22. (c)
23. (b)
24. (b)
25. (b)
26. (a)
27. (c)
28. (d)
29. (b)
30. (d)
31. (c)
32. (a)
33. (a)
34. (1)
35. (4)
36. (4)
37. (1.39)
38. (3.00)
39. $\left(2.66 \mathrm{~g} \mathrm{~cm}^{-3}\right)$
40. $\left(2.6 \mathrm{~cm}^{2}\right)$
41. $(\mathrm{a}, \mathrm{b}$,
d)22. (b, c)
42. (d)
43. $(a, c)$
44. (b)
45. (c)

Topic-4 : Miscellaneous (Mixed Concepts) Problems

1. (c) 2. (b)
