



JEEEnius AI

PREVIOUS YEAR QUESTIONS · 2007–2025

JEE Advanced

Chapter-wise PYQs

Physics

2007–2025 Questions from 19 years

Chapter-wise previous year questions with full solutions · Papers 1 & 2

648

QUESTIONS

298

FIGURES

20

CHAPTERS



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JEE Advanced Chapter-wise PYQs · Physics

Chapter-wise previous year questions with full solutions · Papers 1 & 2

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- **Chapter-wise, newest first.** Every chapter opens with its questions, latest year first, followed by an answer key and then full solutions. Attempt the questions before turning to the key.
- **Source line.** Each question shows where it was asked — year, paper and marking scheme, and its type when it is not a single-correct MCQ.
- **Weightage table.** Physics opens with a table of how often every chapter was asked, overall and in the last five years. Use it to plan revision.
- **More than an answer.** Solutions carry a difficulty rating, a suggested time and the topic; many add a quick approach, the common traps students fall into, and what to revise.
- **Ref numbers.** Each solution carries a Ref number. Quote it to report an error.

Questions by year

2007 29	2008 38	2009 36	2010 43	2011 40	2012 39	2013 39	2014 30	2015 40	2016 27	2017 27	2018 36	2019 36
2020 32	2021 34	2022 26	2023 33	2024 34	2025 29							



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Contents

JEE Advanced 2007–2025	5		
Physics	6		
Units and Measurements	34	7	
Kinematics	14	37	
Laws of Motion	26	52	
Work, Energy and Power	26	75	
Rotational Motion	50	100	
Gravitation	22	152	
Properties of Solids and Liquids	30	175	
Thermodynamics	60	200	
			Kinetic Theory of Gases 9 265
			Oscillations and Waves 54 273
			Electrostatics 73 322
			Current Electricity 31 395
			Magnetism and Magnetic Effects of Current 31 428
			Electromagnetic Induction and Alternating Currents 39 462
			Electromagnetic Waves 4 506
			Optics 77 510
			Dual Nature of Matter and Radiation 3 587
			Atoms and Nuclei 58 591
			Electronic Devices 6 639
			Other Physics questions 1 645

JEE Advanced 2007–2025

648 questions

Physics

Chapter	All years	Last 5 years
Units and Measurements	34	9
Kinematics	14	5
Laws of Motion	26	3
Work, Energy and Power	26	5
Rotational Motion	50	14
Gravitation	22	6
Properties of Solids and Liquids	30	5
Thermodynamics	60	20
Kinetic Theory of Gases	9	1
Oscillations and Waves	54	13
Electrostatics	73	20
Current Electricity	31	6
Magnetism and Magnetic Effects of Current	31	4
Electromagnetic Induction and Alternating Currents	39	12
Electromagnetic Waves	4	2
Optics	77	18
Dual Nature of Matter and Radiation	3	0
Atoms and Nuclei	58	13
Electronic Devices	6	0
Other Physics questions	1	0

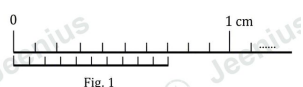
PHYSICS · CHAPTER 1

Units and Measurements

34 questions · 2025 3 · 2024 2 · 2023 1 · 2022 1 · 2021 2 · 2020 1 · 2019 1 · 2018 4 · 2017 1 · 2016 4 · 2015 4 · 2014 2
2013 3 · 2012 1 · 2011 1 · 2010 2 · 2008 1

1 JEE ADV 2025 · PAPER 1 · +3, -1

Figure 1 shows the configuration of main scale and Vernier scale before measurement. Figure 2 shows the configuration corresponding to the measurement of diameter D of a tube. The Vernier scale has 10 divisions equal to 7 mm. In the measurement shown, the main scale reading is 1 mm and the 1st Vernier scale marking coincides with a main scale division. The measured value of D is:



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- (A) 0.12 cm (B) 0.11 cm
(C) 0.13 cm (D) 0.14 cm

2 JEE ADV 2025 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

Length, breadth and thickness of a strip having a uniform cross section are measured to be 10.5 cm, 0.05 mm, and $6.0 \mu\text{m}$, respectively. Which of the following option(s) give(s) the volume of the strip in cm^3 with correct significant figures?

- (A) 3.2×10^{-5} (B) 32.0×10^{-6}
(C) 3.0×10^{-5} (D) 3×10^{-5}

3 JEE ADV 2025 · PAPER 2 · +3, -1

A temperature difference can generate e.m.f. in some materials. Let S be the e.m.f. produced per unit temperature difference between the ends of a wire, σ the electrical conductivity and κ the thermal conductivity of the material of the wire. Taking M , L , T , I and K as dimensions of mass, length, time, current and temperature, respectively, the dimensional formula of the quantity

$$Z = \frac{S^2 \sigma}{\kappa}$$

is

- (A) $[M^0 L^0 T^0 I^0 K^0]$ (B) $[M^0 L^0 T^0 I^0 K^{-1}]$
(C) $[M^1 L^2 T^{-2} I^{-1} K^{-1}]$ (D) $[M^1 L^2 T^{-4} I^{-1} K^{-1}]$

4 JEE ADV 2024 · PAPER 1 · +3, -1

A dimensionless quantity is constructed in terms of electronic charge e , permittivity of free space ϵ_0 , Planck's constant h , and speed of light c . If the dimensionless quantity is written as $e^\alpha \epsilon_0^\beta h^\gamma c^\delta$ and n is a non-zero integer, then $(\alpha, \beta, \gamma, \delta)$ is given by

- (A) $(2n, -n, -n, -n)$ (B) $(n, -n, -2n, -n)$
(C) $(n, -n, -n, -2n)$ (D) $(2n, -n, -2n, -2n)$

5 JEE ADV 2024 · PAPER 2 · NUMERICAL · +4, 0

The dimensions of a cone are measured using a scale with a least count of 2 mm. The diameter of the base and the height are both measured to be 20.0 cm. The maximum percentage error in the determination of the volume is _____.

6 JEE ADV 2023 · PAPER 2 · +3, -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

$$Y = c^\alpha h^\beta G^\gamma$$

Which of the following is the correct option?

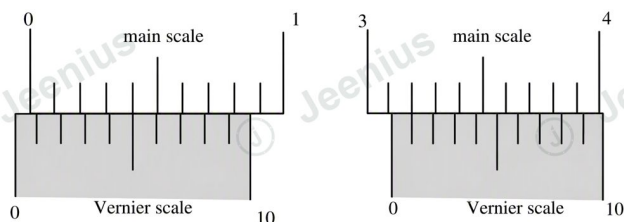
- (A) $\alpha = 7, \beta = -1, \gamma = -2$
(B) $\alpha = -7, \beta = -1, \gamma = -2$
(C) $\alpha = 7, \beta = -1, \gamma = 2$
(D) $\alpha = -7, \beta = 1, \gamma = -2$

7 JEE ADV 2022 · PAPER 2 · NUMERICAL · +3, 0

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 ϵ_0 is the permittivity of vacuum. In terms of these physical constants, the dimension of the magnetic field is $[B] = [e]^\alpha [m_e]^\beta [h]^\gamma [k]^\delta$. The value of $\alpha + \beta + \gamma + \delta$ is _____.

8 JEE ADV 2021 · PAPER 1 · +3, -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 on the left shows the reading of this calipers with no gap between its two jaws, where the Vernier zero is to the left of the main-scale zero and the 5th Vernier division coincides with a main-scale division. The figure on the right shows the reading with a solid sphere held between the jaws, where the Vernier zero coincides with the 3.1 cm main-scale mark. The correct diameter of the sphere is



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- (A) 3.07 cm (B) 3.11 cm
(C) 3.15 cm (D) 3.17 cm

9 JEE ADV 2021 · PAPER 2 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

A physical quantity $\vec{S}$ is defined as $\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$, where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of $\vec{S}$ are the same as the dimensions of which of the following quantity(ies)?

(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)

$$\frac{\text{Power}}{\text{Area}}$$

10 JEE ADV 2020 · PAPER 2 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

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:

$$[\text{position}] = [X^\alpha]$$

$$[\text{Speed}] = [X^\beta]$$

$$[\text{acceleration}] = [X^p]$$

$$[\text{Linear momentum}] = [X^q]$$

$$[\text{force}] = [X^r]$$

Then which of the following are correct?

- (A) $\alpha + p = 2\beta$ (B) $p + q - r = \beta$
(C) $p - q + r = \alpha$ (D) $p + q + r = \beta$

11 JEE ADV 2019 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -1

Let us consider a system of units in which mass and angular momentum are dimensionless. If length has dimension of L , which of the following statement(s) is/are correct?

- (A) The dimension of energy is L^{-2}
(B) The dimension of force is L^{-3}
(C) The dimension of power is L^{-5}
(D) The dimension of linear momentum is L^{-1}

12 JEE ADV 2018 · PAPER 1 · +3, -1

The relation between $[\epsilon_0]$ and $[\mu_0]$ is

- (A) $[\mu_0] = [\epsilon_0][L]^2[T]^{-2}$
(B) $[\mu_0] = [\epsilon_0][L]^{-2}[T]^2$
(C) $[\mu_0] = [\epsilon_0]^{-1}[L]^2[T]^{-2}$
(D) $[\mu_0] = [\epsilon_0]^{-1}[L]^{-2}[T]^2$

13 JEE ADV 2018 · PAPER 2 · NUMERICAL · +3, 0

A steel wire of diameter 0.5 mm and Young's modulus $2 \times 10^{11} \text{ Nm}^{-2}$ 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 _____. Take $g = 10 \text{ ms}^{-2}$ and $\pi = 3.2$.

PARAGRAPH
PARAGRAPH "X"

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 $[\epsilon_0]$ and $[\mu_0]$ 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.

There are two questions based on PARAGRAPH "X", the question given below is one of them.

14 JEE ADV 2018 · PAPER 1 · PARAGRAPH · +3, -1

PARAGRAPH "X"

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 $[\epsilon_0]$ and $[\mu_0]$ 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.

There are two questions based on PARAGRAPH "X", the question given below is one of them.

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) $[E] = [B][L]^{-1}[T]^{-1}$

PARAGRAPH

PARAGRAPH "A": 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 Δx , Δy and Δz , 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.

15 JEE ADV 2018 · PAPER 1 · +3, -1

PARAGRAPH "A": 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 Δx , Δy and Δz , 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.

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 Δa with $\Delta a/a \ll 1$, then what is the error Δr in determining r ?

- (A) $\frac{\Delta a}{(1+a)^2}$ (B) $\frac{2\Delta a}{(1+a)^2}$
 (C) $\frac{2\Delta a}{(1-a)^2}$ (D) $\frac{2a\Delta a}{(1-a)^2}$

16 JEE ADV 2017 · PAPER 2 · +3, -1

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 $\delta T = 0.01$ seconds and he measures the depth of the well to be $L = 20$ meters. Take the acceleration due to gravity $g = 10 \text{ m/s}^2$ and the velocity of sound is 300 m/s . Then the fractional error in the measurement, $\delta L/L$, is closest to

- (A) 0.2% (B) 1%
 (C) 3% (D) 5%

17 JEE ADV 2016 · PAPER 1 · +3, -1

In a historical experiment to determine Planck's constant, a metal surface was irradiated with light of different wavelengths. The emitted photoelectron energies were measured by applying a stopping potential. The relevant data for the wavelength λ of incident light and the corresponding stopping potential V_0 are given below:

λ (μm)	V_0 (Volt)
0.3	2.0
0.4	1.0
0.5	0.4

Given that $c = 3 \times 10^8$ m/s and $e = 1.6 \times 10^{-19}$ C, Planck's constant, in units of J s, found from such an experiment is

- (A) 6.0×10^{-34} (B) 6.4×10^{-34}
(C) 6.6×10^{-34} (D) 6.8×10^{-34}

18 JEE ADV 2016 · PAPER 1 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

A length-scale ℓ depends on the permittivity ϵ of a dielectric material, Boltzmann constant k_B , 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 ℓ is(are) dimensionally correct?

(A)

$$\ell = \sqrt{\frac{nq^2}{\epsilon k_B T}}$$

(B)

$$\ell = \sqrt{\frac{\epsilon k_B T}{nq^2}}$$

(C)

$$\ell = \sqrt{\frac{q^2}{\epsilon n^{2/3} k_B T}}$$

(D)

$$\ell = \sqrt{\frac{q^2}{\epsilon n^{1/3} k_B T}}$$

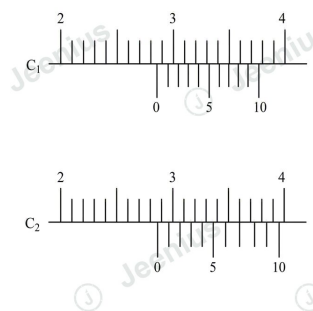
19 JEE ADV 2016 · PAPER 2 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

In an experiment to determine the acceleration due to gravity g , the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57 s, 0.54 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?

- (A) The error in the measurement of r is 10%
(B) The error in the measurement of T is 3.57%
(C) The error in the measurement of T is 2%
(D) The error in the determined value of g is 11%

20 JEE ADV 2016 · PAPER 2 · +3, -1

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 C_1 has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper C_2 has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. In both figures, the 7th Vernier division coincides with a main scale division. The measured values in cm by calipers C_1 and C_2 respectively, are



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- (A) 2.87 and 2.86 (B) 2.87 and 2.87
(C) 2.87 and 2.83 (D) 2.85 and 2.82

21 JEE ADV 2015 · PAPER 1 · ONE OR MORE CORRECT · +4, -2

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:

- (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.

22 JEE ADV 2015 · PAPER 1 · ONE OR MORE CORRECT · +4, -2

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).

- (A) $M \propto \sqrt{c}$ (B) $M \propto \sqrt{G}$
 (C) $L \propto \sqrt{h}$ (D) $L \propto \sqrt{G}$

23 JEE ADV 2015 · PAPER 2 · NUMERICAL · +4, 0

The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t)$, where $\alpha = 0.2 \text{ s}^{-1}$. 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 $t = 5 \text{ s}$ is

24 JEE ADV 2015 · PAPER 2 · ONE OR MORE CORRECT · +4, PARTIAL +1, -2

In terms of potential difference V , electric current I , permittivity ϵ_0 , permeability μ_0 and speed of light c , the dimensionally correct equation(s) is(are)

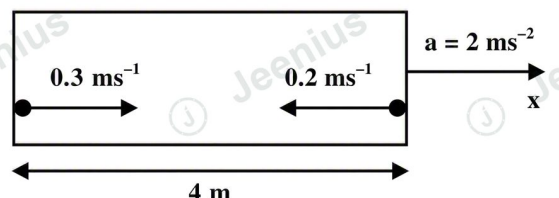
- (A) $\mu_0 I^2 = \epsilon_0 V^2$ (B) $\epsilon_0 I = \mu_0 V$
 (C) $I = \epsilon_0 c V$ (D) $\mu_0 c I = \epsilon_0 V$

25 JEE ADV 2014 · PAPER 1 · NUMERICAL · +3, 0

During Searle's experiment, zero of the Vernier scale lies between $3.20 \times 10^{-2} \text{ m}$ and $3.25 \times 10^{-2} \text{ m}$ of the main scale. The 20th 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 $3.20 \times 10^{-2} \text{ m}$ and $3.25 \times 10^{-2} \text{ m}$ of the main scale but now the 45th 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 $8 \times 10^{-7} \text{ m}^2$. The least count of the Vernier scale is $1.0 \times 10^{-5} \text{ m}$. The maximum percentage error in the Young's modulus of the wire is

26 JEE ADV 2014 · PAPER 1 · NUMERICAL · +3, 0

To find the distance d over which a signal can be seen clearly in foggy conditions, a railways engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ 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



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27 JEE ADV 2013 · PAPER 1 · +3, -1

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 24th division of the Vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is

- (A) 5.112 cm (B) 5.124 cm
 (C) 5.136 cm (D) 5.148 cm

28 JEE ADV 2013 · PAPER 2 · ONE OR MORE CORRECT · +4, -1

Using the expression $2d \sin \theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90° . The wavelength λ is exactly known and the error in θ is constant for all values of θ . As θ increases from 0° ,

- (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.

29 JEE ADV 2013 · PAPER 2 · MATCHING · +3, -1

Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
P. Boltzmann Constant	1. $[ML^2T^{-1}]$
Q. Coefficient of viscosity	2. $[ML^{-1}T^{-1}]$
R. Planck Constant	3. $[MLT^{-3}K^{-1}]$
S. Thermal conductivity	4. $[ML^2T^{-2}K^{-1}]$

Codes:

- (A) P-3, Q-1, R-2, S-4 (B) P-3, Q-2, R-1, S-4
(C) P-4, Q-2, R-1, S-3 (D) P-4, Q-1, R-2, S-3

30 JEE ADV 2012 · PAPER 1 · +3, -1

In the determination of Young's modulus $Y = \frac{4MLg}{\pi ld^2}$ by using Searle's method, a wire of length $L = 2$ m and diameter $d = 0.5$ mm is used. For a load $M = 2.5$ kg, an extension $l = 0.25$ 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 are:

- (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 .

31 JEE ADV 2011 · PAPER 2 · +3, -1

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

- (A) 0.9% (B) 2.4%
(C) 3.1% (D) 4.2%

Answer key · Units and Measurements

1 C	2 D	3 B	4 A	5 3	6 A
7 4	8 C	9 B, D	10 A, B	11 A, B, D	12 D
13 3.00	14 C	15 B	16 B	17 B	18 B, D
19 A, B, D	20 C	21 B, C	22 A, C, D	23 4	24 A, C
25 8	26 3	27 B	28 D	29 C	30 A
31 C	32 A, C	33 D	34 B		

Solutions · Units and Measurements**1 Answer: C**

Ref 14953

Medium ~1.5 min Vernier calipers and least count

32 JEE ADV 2010 · PAPER 1 · ONE OR MORE CORRECT · +4, -1

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?

- (A) Error ΔT in measuring T , the time period, is 0.05 seconds
(B) Error ΔT 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%

33 JEE ADV 2010 · PAPER 2 · +3, -1

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

- (A) 0.02 mm (B) 0.05 mm
(C) 0.1 mm (D) 0.2 mm

34 JEE ADV 2008 · PAPER 1 · +3, -1

Students I, II and III perform an experiment for measuring the acceleration due to gravity g using a simple pendulum. They use different lengths of the pendulum and/or record time for different number of oscillations. The observations are shown in the table.

Least count for length = 0.1 cm

Least count for time = 0.1 s

Student	Length of the pendulum (cm)	Number of oscillations n	Total time for n oscillations (s)	Time period (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

- If E_I , E_{II} and E_{III} are the percentage errors in g , i.e., $\left(\frac{\Delta g}{g} \times 100\right)$ for students I, II and III, respectively, then
(A) $E_I = 0$ (B) E_I is minimum
(C) $E_I = E_{II}$ (D) E_{II} is maximum

QUICK APPROACH Start by finding the values of one main scale division and one Vernier scale division, then calculate the least count of the Vernier calipers.

For the given Vernier scale, 10 Vernier scale divisions are equal to 7 mm.

$$10 \text{ VSD} = 7 \text{ mm}$$

So one Vernier scale division is:

$$1 \text{ VSD} = \frac{7}{10} \text{ mm}$$

$$1 \text{ VSD} = 0.7 \text{ mm}$$

One main scale division is:

$$1 \text{ MSD} = 1 \text{ mm}$$

The difference between one main scale division and one Vernier scale division is:

$$1 \text{ MSD} - 1 \text{ VSD} = 1 - 0.7 \text{ mm}$$

$$1 \text{ MSD} - 1 \text{ VSD} = 0.3 \text{ mm}$$

From Figure 2, the main scale reading is:

$$\text{MSR} = 1 \text{ mm}$$

Also, the first Vernier scale marking coincides with a main scale division, so the Vernier reading is:

$$\text{Vernier reading} = 0.3 \text{ mm}$$

Therefore, the total measured diameter is:

$$D = 1 + 0.3 \text{ mm}$$

$$D = 1.3 \text{ mm}$$

Converting mm to cm:

$$1 \text{ cm} = 10 \text{ mm}$$

$$D = \frac{1.3}{10} \text{ cm}$$

$$D = 0.13 \text{ cm}$$

Hence, the correct option is C.

COMMON TRAPS

- **Using 0.1 mm standard least count instead of deriving it from 10 VSD = 7 mm.** Here the exact phrase is "The Vernier scale has 10 divisions equal to 7 mm." So $1 \text{ VSD} = 0.7 \text{ mm}$ and $\text{LC} = 1 \text{ MSD} - 1 \text{ VSD} = 1 - 0.7 = 0.3 \text{ mm}$. *Avoid it:* Before using any LC, compute it from the scale relation stated in the question, not from memory.
- **Taking 1 VSD itself as the Vernier reading.** The solution step says "Vernier reading = 0.3 mm" because the first coinciding mark contributes $1 \times \text{LC}$, not $1 \times \text{VSD}$. *Avoid it:* Use Vernier reading = coinciding division number $\times$ least count. Do not use coinciding division number $\times$ VSD length.

REVISE Always compute 1 VSD and LC from the given vernier relation before reading the instrument. · Write the reading as $\text{MSR} + n \times \text{LC}$, with units attached to every term.

2 Answer: D

Ref 14955

Easy ~1 min Significant figures and unit conversion

The volume of a strip with uniform rectangular cross section is length multiplied by breadth multiplied by thickness.

Given length:

$$l = 10.5 \text{ cm}$$

This has 3 significant figures.

Convert breadth into cm:

$$1 \text{ mm} = 10^{-1} \text{ cm}$$

$$b = 0.05 \text{ mm}$$

$$b = 0.05 \times 10^{-1} \text{ cm}$$

$$b = 5 \times 10^{-3} \text{ cm}$$

The value 0.05 has only 1 significant figure, so breadth has 1 significant figure.

Convert thickness into cm:

$$1 \mu\text{m} = 10^{-4} \text{ cm}$$

$$h = 6.0 \mu\text{m}$$

$$h = 6.0 \times 10^{-4} \text{ cm}$$

This has 2 significant figures.

Now calculate the volume:

$$V = lbh$$

$$V = 10.5 \times 5 \times 10^{-3} \times 6.0 \times 10^{-4}$$

$$V = 315 \times 10^{-7} \text{ cm}^3$$

$$V = 3.15 \times 10^{-5} \text{ cm}^3$$

For multiplication, the final answer must have the same number of significant figures as the measured quantity with

the least number of significant figures. Here the least is 1 significant figure from 0.05 mm.

So round 3.15×10^{-5} to 1 significant figure:

$$V = 3 \times 10^{-5} \text{ cm}^3$$

Therefore, the correct option is D.

COMMON TRAPS

- **Counting the zero in “0.05 mm” as significant.** In “0.05 mm”, the zeros before 5 are not significant; the breadth has exactly 1 significant figure. *Avoid it:* Rewrite 0.05 as 5×10^{-2} mm before counting significant figures; only the coefficient 5 counts.
- **Ignoring the least-significant-measurement rule in multiplication.** For multiplication, the final answer has the same number of significant figures as the measured quantity with the least number of significant figures; here “0.05 mm” has 1 significant figure. *Avoid it:* Before multiplying, write a small table: 10.5 cm $\rightarrow$ 3 s.f.; 0.05 mm $\rightarrow$ 1 s.f.; $6.0 \mu\text{m} \rightarrow$ 2 s.f.; answer must be 1 s.f.

REVISE Practise converting mm and μm to cm using chain conversions rather than memorised shortcuts. · Rules for leading zeros, trailing zeros after decimal points, and significant figures in scientific notation.

3 Answer: B

Ref 14999

Easy ~1.5 min Dimensional analysis of thermoelectric quantities

The quantity S is e.m.f. produced per unit temperature difference, so it is the Seebeck coefficient.

$$[S] = \frac{[\text{e.m.f.}]}{[\text{temperature}]}$$

The dimension of e.m.f. or potential difference is

$$[V] = [ML^2T^{-3}I^{-1}]$$

Therefore,

$$[S] = [ML^2T^{-3}I^{-1}K^{-1}]$$

Electrical conductivity is reciprocal of resistivity. Since resistance has dimension

$$[R] = [ML^2T^{-3}I^{-2}]$$

Resistivity is resistance multiplied by length, so

$$[\rho] = [ML^3T^{-3}I^{-2}]$$

Hence conductivity is

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

Thermal conductivity is defined from heat conduction relation

$$\frac{Q}{t} = \kappa A \frac{\Delta T}{l}$$

So,

$$[\kappa] = \frac{[Q/t][l]}{[A][\Delta T]}$$

Now,

$$[Q/t] = [ML^2T^{-3}]$$

Thus,

$$[\kappa] = \frac{[ML^2T^{-3}][L]}{[L^2][K]}$$

$$[\kappa] = [MLT^{-3}K^{-1}]$$

Now find the dimension of Z .

$$Z = \frac{S^2\sigma}{\kappa}$$

$$[Z] = \frac{[ML^2T^{-3}I^{-1}K^{-1}]^2[M^{-1}L^{-3}T^3I^2]}{[MLT^{-3}K^{-1}]}$$

First simplify the numerator.

$$[S^2] = [M^2L^4T^{-6}I^{-2}K^{-2}]$$

$$[S^2\sigma] = [M^2L^4T^{-6}I^{-2}K^{-2}][M^{-1}L^{-3}T^3I^2]$$

$$[S^2\sigma] = [MLT^{-3}K^{-2}]$$

Now divide by $[\kappa]$.

$$[Z] = \frac{[MLT^{-3}K^{-2}]}{[MLT^{-3}K^{-1}]}$$

$$[Z] = [K^{-1}]$$

Therefore, the correct option is B.

COMMON TRAPS

- **Treating S as e.m.f., not e.m.f. per unit temperature difference.** A quantity described as “per unit temperature difference” must be divided by temperature dimension K , so $[S] = [ML^2T^{-3}I^{-1}K^{-1}]$. *Avoid it:* Underline every “per unit ...” phrase and write it as a denominator before substituting into Z .
- **Forgetting that S is squared in Z .** Every exponent in the formula applies to all base dimensions: $[S^2] = [M^2L^4T^{-6}I^{-2}K^{-2}]$. *Avoid it:* Expand $[S^2]$ explicitly before multiplying by $[\sigma]$.

REVISE Dimensions of voltage, resistance, resistivity, conductivity, heat current, and thermal conductivity as a connected set. · Use a five-column exponent table for M, L, T, I, K in thermoelectric dimensional-analysis questions.

4 Answer: A

Ref 14849

Medium ~2 min Dimensional Analysis

For the product $e^\alpha \epsilon_0^\beta h^\gamma c^\delta$ to be dimensionless, the net powers of M , L , T , and A must each be zero.

Dimensions of electronic charge are:

$$[e] = [AT]$$

Using Coulomb's law, the dimensions of permittivity of free space are:

$$[\epsilon_0] = [M^{-1}L^{-3}T^4A^2]$$

Dimensions of Planck's constant are:

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

Dimensions of speed of light are:

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

Therefore,

$$[e^\alpha \epsilon_0^\beta h^\gamma c^\delta] = [AT]^\alpha [M^{-1}L^{-3}T^4A^2]^\beta [ML^2T^{-1}]^\gamma [LT^{-1}]^\delta$$

Now compare powers of fundamental dimensions.

For A :

$$\alpha + 2\beta = 0$$

For M :

$$-\beta + \gamma = 0$$

So,

$$\gamma = \beta$$

For L :

$$-3\beta + 2\gamma + \delta = 0$$

Substitute $\gamma = \beta$:

$$-3\beta + 2\beta + \delta = 0$$

$$\delta = \beta$$

For T :

$$\alpha + 4\beta - \gamma - \delta = 0$$

Substitute $\gamma = \beta$ and $\delta = \beta$:

$$\alpha + 2\beta = 0$$

This is same as the equation from the power of A .

Thus,

$$\alpha = -2\beta$$

$$\gamma = \beta$$

$$\delta = \beta$$

Let

$$\beta = -n$$

Then,

$$\alpha = 2n$$

$$\gamma = -n$$

$$\delta = -n$$

Hence,

$$(\alpha, \beta, \gamma, \delta) = (2n, -n, -n, -n)$$

So, the correct option is A.

COMMON TRAPS

• Using wrong dimension for electronic charge.

Electronic charge has dimensions of charge, $[Q]=[AT]$, so e^α contributes $A^\alpha T^\alpha$. *Avoid it:* Before writing equations, expand each quantity into M, L, T, A and verify charge includes both A and T.

• Incorrect sign/powers in permittivity dimension.

Since $F = q_1q_2/(4\pi\epsilon_0 r^2)$, $\epsilon_0 = q^2/(Fr^2)$, giving $[\epsilon_0] = A^2T^2/(MLT^{-2} \times L^2) = M^{-1}L^{-3}T^4A^2$. *Avoid it:* Derive ϵ_0 in one line from Coulomb's law and check that ϵ_0 has A^2 and T^4 , not negative powers.

REVISE Re-derive $[\epsilon_0]$ from Coulomb's law before memorizing it.

Write four separate exponent equations for M, L, T, A and solve them symbolically before looking at options.

5 Answer: 3

Ref 14905

Easy ~1 min Errors in measurement and propagation of errors

For a cone, the volume is given by

$$V = \frac{1}{3}\pi r^2 h$$

Since diameter $d = 2r$, we can write the volume in terms of diameter as

$$V = \frac{1}{3}\pi \left(\frac{d}{2}\right)^2 h$$

$$V = \frac{\pi d^2 h}{12}$$

So the volume depends on diameter and height as

$$V \propto d^2 h$$

For maximum fractional error, powers get multiplied with their respective fractional errors and then added:

$$\frac{\Delta V}{V} = 2 \frac{\Delta d}{d} + \frac{\Delta h}{h}$$

The least count of the scale is 2 mm.

$$2 \text{ mm} = 0.2 \text{ cm}$$

The measured diameter and height are both 20.0 cm, so

$$d = 20.0 \text{ cm}$$

$$h = 20.0 \text{ cm}$$

Taking the maximum absolute error in each measurement equal to the least count:

$$\Delta d = 0.2 \text{ cm}$$

$$\Delta h = 0.2 \text{ cm}$$

Thus,

$$\frac{\Delta d}{d} = \frac{0.2}{20.0}$$

$$\frac{\Delta d}{d} = \frac{1}{100}$$

Similarly,

$$\frac{\Delta h}{h} = \frac{0.2}{20.0}$$

$$\frac{\Delta h}{h} = \frac{1}{100}$$

Substitute in the error formula:

$$\frac{\Delta V}{V} = 2 \left(\frac{1}{100} \right) + \frac{1}{100}$$

$$\frac{\Delta V}{V} = \frac{3}{100}$$

Percentage error is

$$\frac{\Delta V}{V} \times 100 = 3$$

Therefore, the maximum percentage error in the volume is 3%.

COMMON TRAPS

- **Using radius error instead of diameter error without halving correctly.** If using d , $V \propto d^2 h$. If using r , $r = d/2 = 10.0 \text{ cm}$ and $\Delta r = \Delta d/2 = 0.1 \text{ cm}$ if radius is derived from diameter; the fractional error remains $\Delta r/r = \Delta d/d = 0.01$. *Avoid it:* Circle the measured variables and rewrite the formula only in those variables before applying error propagation.

- **Taking least count 2 mm as 2 cm.** $2 \text{ mm} = 0.2 \text{ cm}$, not 2 cm . *Avoid it:* Convert all measurements to the same unit before forming fractional errors.

REVISE Practise rewriting formulas in terms of measured variables before error propagation. · Unit conversions between mm and cm in least-count problems.

6 Answer: A

Ref 14799

Medium ~1.5 min Dimensional Analysis

Young's modulus has the dimensions of stress.

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

The dimensions of the given quantities are:

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

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

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

Given:

$$Y = c^\alpha h^\beta G^\gamma$$

Taking dimensions on both sides:

$$ML^{-1}T^{-2} = (LT^{-1})^\alpha (ML^2T^{-1})^\beta (M^{-1}L^3T^{-2})^\gamma$$

Now combine powers of M , L , and T .

Power of M on the right side:

$$\beta - \gamma$$

Power of L on the right side:

$$\alpha + 2\beta + 3\gamma$$

Power of T on the right side:

$$-\alpha - \beta - 2\gamma$$

Equating powers with $ML^{-1}T^{-2}$, we get:

$$\beta - \gamma = 1$$

$$\alpha + 2\beta + 3\gamma = -1$$

$$-\alpha - \beta - 2\gamma = -2$$

The third equation can be written as:

$$\alpha + \beta + 2\gamma = 2$$

From the first equation:

$$\beta = 1 + \gamma$$

Substitute this in the second equation:

$$\alpha + 2(1 + \gamma) + 3\gamma = -1$$

$$\alpha + 2 + 5\gamma = -1$$

$$\alpha + 5\gamma = -3$$

Substitute $\beta = 1 + \gamma$ in the third equation:

$$\alpha + (1 + \gamma) + 2\gamma = 2$$

$$\alpha + 3\gamma = 1$$

Now subtract:

$$\alpha + 5\gamma = -3$$

$$\alpha + 3\gamma = 1$$

This gives:

$$2\gamma = -4$$

$$\gamma = -2$$

Then:

$$\beta = 1 + \gamma$$

$$\beta = -1$$

Using:

$$\alpha + 3\gamma = 1$$

$$\alpha + 3(-2) = 1$$

$$\alpha = 7$$

Therefore:

$$\alpha = 7, \beta = -1, \gamma = -2$$

Hence, the correct option is A.

7 Answer: 4

Ref 15153

Hard ~3 min Dimensional analysis using electromagnetic constants

QUICK APPROACH Start by expressing the dimensions of each given constant in terms of the fundamental quantities M , L , T , and Q , then use dimensional analysis to equate powers for the magnetic field $[B]$.

Use fundamental dimensions in terms of mass M , length L , time T , and charge Q .

The dimension of charge is:

$$[e] = Q$$

The dimension of electron mass is:

$$[m_e] = M$$

Planck's constant has dimension of angular momentum or energy multiplied by time:

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

From Coulomb's law:

$$F = k \frac{q_1 q_2}{r^2}$$

So,

$$[k] = \frac{[F][r]^2}{[q]^2}$$

$$[k] = \frac{(MLT^{-2})L^2}{Q^2}$$

$$[k] = ML^3T^{-2}Q^{-2}$$

Now find the dimension of magnetic field using Lorentz force:

$$F = qvB$$

Therefore,

$$[B] = \frac{[F]}{[q][v]}$$

$$[B] = \frac{MLT^{-2}}{Q \cdot LT^{-1}}$$

$$[B] = MT^{-1}Q^{-1}$$

Given:

$$[B] = [e]^\alpha [m_e]^\beta [h]^\gamma [k]^\delta$$

Substitute dimensions:

$$MT^{-1}Q^{-1} = Q^\alpha M^\beta (ML^2T^{-1})^\gamma (ML^3T^{-2}Q^{-2})^\delta$$

Collect powers of M , L , T , and Q :

$$MT^{-1}Q^{-1} = M^{\beta+\gamma+\delta} L^{2\gamma+3\delta} T^{-\gamma-2\delta} Q^{\alpha-2\delta}$$

Equating powers of dimensions, we get:

$$\beta + \gamma + \delta = 1$$

$$2\gamma + 3\delta = 0$$

$$-\gamma - 2\delta = -1$$

$$\alpha - 2\delta = -1$$

From the time equation:

$$\gamma + 2\delta = 1$$

So,

$$\gamma = 1 - 2\delta$$

Substitute in the length equation:

$$2(1 - 2\delta) + 3\delta = 0$$

$$2 - 4\delta + 3\delta = 0$$

$$\delta = 2$$

Then,

$$\gamma = 1 - 2(2)$$

$$\gamma = -3$$

From the charge equation:

$$\alpha - 2(2) = -1$$

$$\alpha = 3$$

From the mass equation:

$$\beta + (-3) + 2 = 1$$

$$\beta = 2$$

Therefore,

$$\alpha + \beta + \gamma + \delta = 3 + 2 - 3 + 2$$

$$\alpha + \beta + \gamma + \delta = 4$$

Final answer: 4

8 Answer: C

Ref 15179

Medium ~1.5 min Vernier calipers: least count and zero error

The main scale smallest division is given as:

$$1MSD = 0.1$$

cm.

Ten Vernier scale divisions correspond to nine main scale

divisions:

$$10VSD = 9MSD$$

So,

$$10VSD = 0.9$$

cm.

Therefore,

$$1VSD = 0.09$$

cm.

The least count of the Vernier calipers is:

$$LC = 1MSD - 1VSD$$

$$LC = 0.1 - 0.09$$

$$LC = 0.01$$

cm.

Now consider the left figure, where the jaws are closed. The Vernier zero lies to the left of the main-scale zero, so the zero error is negative. The 5th Vernier division coincides with a main-scale division. For a negative zero error, the magnitude is:

$$(10 - 5)LC = 5LC$$

Hence the zero error is:

$$e = -5LC$$

$$e = -5(0.01)$$

$$e = -0.05$$

cm.

Now consider the right figure with the sphere between the jaws. The Vernier zero coincides with the 3.1 cm mark on the main scale, so the observed reading is:

$$R = 3.10$$

cm.

The correct reading is obtained by subtracting the zero error:

$$D = R - e$$

$$D = 3.10 - (-0.05)$$

$$D = 3.15$$

cm.

Therefore, the correct diameter of the sphere is 3.15 cm.

9 Answer: B, D

Ref 15238

Medium ~2 min Dimensional analysis using electromagnetic quantities

Find the dimensions of $\vec{S}$ from those of E , B and μ_0 , then compare each option.

$$\text{Step 1. } [E] = \frac{[F]}{[q]} = \frac{MLT^{-2}}{AT} = MLT^{-3}A^{-1}.$$

$$\text{Step 2. From } F = BIL: [B] = \frac{MLT^{-2}}{AL} = MT^{-2}A^{-1}. \text{ From } B = \frac{\mu_0 I}{2\pi r}: [\mu_0] = \frac{[B][r]}{[I]} = MLT^{-2}A^{-2}.$$

$$\text{Step 3. } [S] = \frac{[E][B]}{[\mu_0]} = \frac{(MLT^{-3}A^{-1})(MT^{-2}A^{-1})}{MLT^{-2}A^{-2}} = MT^{-3}.$$

$$\text{Step 4. Energy/(Charge} \times \text{Current)} = \frac{ML^2T^{-2}}{AT \cdot A} = ML^2T^{-3}A^{-2}, \text{ no match. Force/(Length} \times \text{Time)} = \frac{MLT^{-2}}{LT} = MT^{-3}, \text{ a match. Energy/Volume} = ML^{-1}T^{-2}, \text{ no match. Power/Area} = \frac{ML^2T^{-3}}{L^2} = MT^{-3}, \text{ a match.}$$

Answer: (B) Force/(Length $\times$ Time) and (D) Power/Area**10 Answer: A, B**

Ref 15036

Medium ~1.5 min Dimensional Analysis

We are given that every physical quantity is expressed as a power of one base quantity X .

Given:

$$[position] = [X^\alpha]$$

$$[speed] = [X^\beta]$$

$$[acceleration] = [X^p]$$

$$[linear\ momentum] = [X^q]$$

$$[force] = [X^r]$$

Now check each option dimensionally.

For option A, use the relation between acceleration, distance and speed:

$$[acceleration][position] = [speed]^2$$

Substituting the powers of X :

$$[X^p][X^\alpha] = [X^\beta]^2$$

$$[X^{p+\alpha}] = [X^{2\beta}]$$

Therefore:

$$p + \alpha = 2\beta$$

So option A is correct.

For option B, consider the quantity:

$$\frac{[acceleration][linear\ momentum]}{[force]}$$

Using standard dimensions:

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

$$[linear\ momentum] = MLT^{-1}$$

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

Thus:

$$\frac{[acceleration][linear\ momentum]}{[force]} = \frac{(LT^{-2})(MLT^{-1})}{MLT^{-2}}$$

$$\frac{[acceleration][linear\ momentum]}{[force]} = LT^{-1}$$

This is the dimension of speed. Hence:

$$\frac{[X^p][X^q]}{[X^r]} = [X^\beta]$$

$$[X^{p+q-r}] = [X^\beta]$$

Therefore:

$$p + q - r = \beta$$

So option B is correct.

For option C:

 $p - q + r$ corresponds to the dimensions of:

$$\frac{[acceleration][force]}{[linear\ momentum]}$$

Using standard dimensions:

$$\frac{(LT^{-2})(MLT^{-2})}{MLT^{-1}} = LT^{-3}$$

This is not the dimension of position. Hence:

$$p - q + r \neq \alpha$$

So option C is incorrect.

For option D, the combination $p + q + r$ corresponds to multiplying acceleration, linear momentum and force. This does not give the dimension of speed in general.

Therefore the correct options are A and B.

11 Answer: A, B, D

Ref 14505

Medium ~2 min Dimensional Analysis

Given that mass is dimensionless, we have:

$$[M] = 1$$

Angular momentum has dimensions:

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

Since angular momentum is also dimensionless:

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

Using $[M] = 1$:

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

So,

$$[T] = L^2$$

Now calculate each option.

Energy has dimensions:

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

Substitute $[M] = 1$ and $[T] = L^2$:

$$[E] = L^2(L^2)^{-2}$$

$$[E] = L^2L^{-4}$$

$$[E] = L^{-2}$$

So option A is correct.

Force has dimensions:

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

$$[F] = L(L^2)^{-2}$$

$$[F] = LL^{-4}$$

$$[F] = L^{-3}$$

So option B is correct.

Power has dimensions:

$$[P] = [ML^2T^{-3}]$$

$$[P] = L^2(L^2)^{-3}$$

$$[P] = L^2L^{-6}$$

$$[P] = L^{-4}$$

The given option says L^{-5} , so option C is incorrect.

Linear momentum has dimensions:

$$[p] = [MLT^{-1}]$$

$$p = L(L^2)^{-1}$$

$$p = L^{-1}$$

So option D is correct.

Therefore, the correct options are A, B and D.

COMMON TRAPS

- **Treating “mass and angular momentum are dimensionless” as only mass dimensionless.** Since angular momentum has usual dimension $[ML^2T^{-1}]$ and is dimensionless, with $[M]=1$ we must have $[L^2T^{-1}] = 1$, hence $[T] = L^2$. *Avoid it:* Before checking options A–D, write all new base dimensions explicitly: $[M]=1$ and $[T] = L^2$, while $[L]=L$.
- **Solving angular momentum constraint with inverted time dimension.** With $[M] = 1$, $L^2T^{-1} = 1$ means $T^{-1} = L^{-2}$; therefore $T = L^2$, not L^{-2} . *Avoid it:* After isolating, invert both sides carefully: if $T^{-1} = L^{-2}$, then $T = L^2$.

REVISE Standard dimensions: angular momentum $[ML^2T^{-1}]$, energy $[ML^2T^{-2}]$, force $[MLT^{-2}]$, power $[ML^2T^{-3}]$, linear momentum $[MLT^{-1}]$. • Practice converting non-standard base dimensions by deriving replacement rules like T^{-1} , T^{-2} , T^{-3} in terms of L before attempting options.

12 Answer: D

Ref 14409

Easy ~1 min Dimensional analysis of electromagnetic constants

QUICK APPROACH Start by using the relation between the speed of light and electromagnetic constants, specifically $c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$, and then apply dimensional analysis on both sides.

For electromagnetic waves in vacuum, the speed of light is related to the permittivity of free space ϵ_0 and permeability of free space μ_0 by

$$c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$$

Squaring both sides gives

$$c^2 = \frac{1}{\mu_0\epsilon_0}$$

Therefore,

$$\mu_0\epsilon_0 = \frac{1}{c^2}$$

Now the dimensional formula of speed is

$$[c] = [L][T]^{-1}$$

So,

$$[c^2] = [L]^2 [T]^{-2}$$

Hence,

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

Using $\mu_0 \epsilon_0 = 1/c^2$,

$$[\mu_0][\epsilon_0] = [L]^{-2} [T]^2$$

Solving for $[\mu_0]$,

$$[\mu_0] = [\epsilon_0]^{-1} [L]^{-2} [T]^2$$

This matches option D.

COMMON TRAPS

- **Using the reciprocal wave-speed relation incorrectly.**

For EM waves in vacuum, $c^2 = 1/(\mu_0 \epsilon_0)$, not $\mu_0 \epsilon_0$. *Avoid it:* Before using the formula, check whether larger $\mu_0 \epsilon_0$ should make wave speed smaller; it should, so the product must be in the denominator.

- **Forgetting to divide by $[\epsilon_0]$ when solving for $[\mu_0]$.** If $xy = A$, then $x = A/y = y^{-1}A$ dimensionally. *Avoid it:* Circle the multiplied factor $[\epsilon_0]$ and explicitly write the division step: $[\mu_0] = [L]^{-2} [T]^2 / [\epsilon_0]$.

REVIEW $c = 1/\sqrt{\mu_0 \epsilon_0}$ and its squared form $\mu_0 \epsilon_0 = 1/c^2$. Practice reciprocal dimensional formulas by changing signs of all exponents.

13 Answer: 3.00

Ref 14453

Medium ~3 min Young's modulus and vernier scale reading

QUICK APPROACH Start by calculating the extension of the wire using Young's modulus formula relating stress and strain under the applied load.

The increase in load produces an additional extension in the steel wire.

Increase in force:

$$F = \Delta mg$$

$$F = 1.2 \times 10$$

$$F = 12 \text{ N}$$

For a wire, Young's modulus is

$$Y = \frac{F\ell}{A\Delta\ell}$$

So the extension is

$$\Delta\ell = \frac{F\ell}{AY}$$

The area of cross-section of the wire is

$$A = \frac{\pi d^2}{4}$$

Hence,

$$\Delta\ell = \frac{4F\ell}{\pi d^2 Y}$$

Given diameter:

$$d = 0.5 \text{ mm}$$

$$d = 0.5 \times 10^{-3} \text{ m}$$

$$d = 5 \times 10^{-4} \text{ m}$$

Substitute the values:

$$\Delta\ell = \frac{4 \times 12 \times 1}{3.2 \times (5 \times 10^{-4})^2 \times 2 \times 10^{11}}$$

$$\Delta\ell = \frac{48}{3.2 \times 25 \times 10^{-8} \times 2 \times 10^{11}}$$

$$\Delta\ell = 3 \times 10^{-4} \text{ m}$$

$$\Delta\ell = 0.3 \text{ mm}$$

Now, for the vernier scale:

$$10 \text{ VSD} = 9 \text{ MSD}$$

Therefore,

$$1 \text{ VSD} = \frac{9}{10} \text{ MSD}$$

Since 1 MSD = 1 mm,

$$1 \text{ VSD} = 0.9 \text{ mm}$$

Least count is

$$LC = 1 \text{ MSD} - 1 \text{ VSD}$$

$$LC = 1 - 0.9$$

$$LC = 0.1 \text{ mm}$$

The vernier zero shifts by 0.3 mm. The coinciding vernier division number is

$$n = \frac{0.3}{0.1}$$

$$n = 3$$

Therefore, the 3rd vernier scale division coincides with a main scale division.

Final answer: 3.00

14 Answer: C

Ref 14406

Easy ~1 min Dimensional analysis of electric and magnetic fields

Electric field is defined as force per unit charge.

$$E = \frac{F}{q}$$

So the force on a charge q in an electric field is

$$F_E = qE$$

For a charge moving with speed v perpendicular to a magnetic field, the magnetic force is

$$F_B = qvB$$

Both expressions represent force, so their dimensions must be the same.

$$[qE] = [qvB]$$

Cancel the common dimension of charge $[q]$ from both sides.

$$[E] = [v][B]$$

The dimension of velocity is

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

Therefore,

$$[E] = [B][L][T]^{-1}$$

Hence, the correct option is C.

COMMON TRAPS

- **Using reciprocal speed instead of speed.** Velocity is displacement per time, so its dimension is " $[L][T]^{-1}$ ", not " $[L]^{-1}[T]$ ". *Avoid it:* Before substituting dimensions, say the unit aloud: m/s means metre divided by second, i.e. length/time.
- **Forgetting the negative exponent on time.** Since velocity = distance/time, time appears in the denominator: " $[T]^{-1}$ ". *Avoid it:* When a quantity is 'per unit time', immediately write " T^{-1} ".

REVISE Memorize and derive the core formulas: $F_E = qE$ and $F_B = qvB \sin \theta$. · Practice translating SI units like m/s into dimensional powers $[L][T]^{-1}$.

15 Answer: B

Ref 14407

Medium ~2 min Propagation of errors using differentiation

We need the error in r when only a has a small measurement error Δa .

The given relation is:

$$r = \frac{1-a}{1+a}$$

For small errors, the absolute error in a dependent quantity is

found using first-order differentiation:

$$\Delta r = \left| \frac{dr}{da} \right| \Delta a$$

Differentiate r with respect to a using the quotient rule.

$$\frac{dr}{da} = \frac{(1+a) \frac{d}{da}(1-a) - (1-a) \frac{d}{da}(1+a)}{(1+a)^2}$$

$$\frac{d}{da}(1-a) = -1$$

$$\frac{d}{da}(1+a) = 1$$

So,

$$\frac{dr}{da} = \frac{(1+a)(-1) - (1-a)(1)}{(1+a)^2}$$

$$\frac{dr}{da} = \frac{-1-a-1+a}{(1+a)^2}$$

$$\frac{dr}{da} = \frac{-2}{(1+a)^2}$$

The magnitude of the error is taken, so:

$$\Delta r = \left| \frac{-2}{(1+a)^2} \right| \Delta a$$

$$\Delta r = \frac{2\Delta a}{(1+a)^2}$$

Therefore, the correct option is B.

COMMON TRAPS

- **Reporting relative error as absolute error (Option C).** The question asks "what is the error Δr ", not the relative error $\Delta r/r$. After finding relative error, multiply by r . *Avoid it:* Label every error expression as either absolute or relative before comparing with options.
- **Missing the factor 2 from quotient-rule differentiation (Option A).** Since a appears in both numerator and denominator, both derivatives $d(1-a)/da = -1$ and $d(1+a)/da = 1$ contribute. *Avoid it:* Before differentiating, circle every occurrence of the measured variable a . There are two occurrences here.

REVISE First-order propagation: $\Delta f = |df/dx| \Delta x$ for one measured variable. · Practice quotient-rule differentiation where the same variable appears in numerator and denominator.

16 Answer: B

Ref 14344

Medium ~2 min Propagation of errors in indirect measurement

QUICK APPROACH Apply the formula for propagation of errors and start by expressing the total time as the sum of fall time and sound travel time before differentiating with respect to depth.

Let the measured total time be T . It consists of two parts: the time taken by the stone to fall through depth L , and the time taken by sound to travel back upward through the same distance.

For free fall from rest:

$$L = \frac{1}{2}gt_1^2$$

$$t_1 = \sqrt{\frac{2L}{g}}$$

Time taken by sound:

$$t_2 = \frac{L}{v}$$

Here $v = 300$ m/s. Therefore,

$$T = \sqrt{\frac{2L}{g}} + \frac{L}{v}$$

To find the error in L due to error in T , differentiate with respect to L :

$$\frac{dT}{dL} = \frac{1}{\sqrt{2gL}} + \frac{1}{v}$$

Hence,

$$\delta L = \frac{\delta T}{\frac{1}{\sqrt{2gL}} + \frac{1}{v}}$$

Substitute $L = 20$ m, $g = 10$ m/s², $v = 300$ m/s, and $\delta T = 0.01$ s.

$$\sqrt{2gL} = \sqrt{2 \times 10 \times 20}$$

$$\sqrt{2gL} = 20$$

So,

$$\frac{1}{\sqrt{2gL}} = \frac{1}{20}$$

$$\frac{1}{v} = \frac{1}{300}$$

Therefore,

$$\frac{dT}{dL} = \frac{1}{20} + \frac{1}{300}$$

$$\frac{dT}{dL} = \frac{16}{300}$$

Now,

$$\delta L = \frac{0.01}{16/300}$$

$$\delta L = 0.1875 \text{ m}$$

Fractional error:

$$\frac{\delta L}{L} = \frac{0.1875}{20}$$

$$\frac{\delta L}{L} = 0.009375$$

Percentage error:

$$\frac{\delta L}{L} \times 100 = 0.9375\%$$

This is closest to 1%.

Hence, the correct option is B.

COMMON TRAPS

- **Using fractional time error directly as fractional depth error.** For indirect measurement, use $\delta T = (dT/dL)\delta L$, not automatically $\delta L/L = \delta T/T$. *Avoid it:* Before using fractional errors, check whether the relation is a simple power law in the measured variable. Here $T = \sqrt{2L/g} + L/v$, a sum, so differentiate.
- **Ignoring the sound travel time term.** The measured interval is explicitly "between dropping a stone and receiving the sound", so total time includes both fall time and sound return time. *Avoid it:* Underline every event in the measured interval: start = drop, end = hearing sound. Count all time segments between them.

REVISE Indirect error propagation using derivatives: if measured variable $T = f(L)$, then $\delta L = \delta T / |f'(L)|$. Practise translating word problems into timelines before writing equations, especially echo/sound-delay problems.

17 Answer: B

Ref 14187

Medium ~2 min Photoelectric Effect

For photoelectric effect, the maximum kinetic energy of emitted photoelectrons is equal to the stopping potential energy.

$$eV_0 = h\nu - \phi$$

Since frequency and wavelength are related by:

$$\nu = \frac{c}{\lambda}$$

So the photoelectric equation becomes:

$$eV_0 = \frac{hc}{\lambda} - \phi$$

Use two data points so that the work function ϕ gets eliminated. Take:

$$\lambda_1 = 0.3 \mu\text{m}$$

$$V_1 = 2.0 \text{ V}$$

$$\lambda_2 = 0.4 \mu\text{m}$$

$$V_2 = 1.0 \text{ V}$$

For the two wavelengths:

$$eV_1 = \frac{hc}{\lambda_1} - \phi$$

$$eV_2 = \frac{hc}{\lambda_2} - \phi$$

Subtracting the second equation from the first:

$$e(V_1 - V_2) = hc \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2} \right)$$

Now simplify the bracket:

$$\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2}$$

Therefore:

$$e(V_1 - V_2) = hc \frac{\lambda_2 - \lambda_1}{\lambda_1 \lambda_2}$$

Solving for h :

$$h = \frac{e(V_1 - V_2)\lambda_1 \lambda_2}{c(\lambda_2 - \lambda_1)}$$

Convert wavelengths from μm to m:

$$\lambda_1 = 0.3 \times 10^{-6} \text{ m}$$

$$\lambda_2 = 0.4 \times 10^{-6} \text{ m}$$

$$\lambda_2 - \lambda_1 = 0.1 \times 10^{-6} \text{ m}$$

Also:

$$V_1 - V_2 = 1.0 \text{ V}$$

Substitute values:

$$h = \frac{(1.6 \times 10^{-19})(1.0)(0.3 \times 10^{-6})(0.4 \times 10^{-6})}{(3 \times 10^8)(0.1 \times 10^{-6})}$$

Multiply the numerical factors in the numerator:

$$1.6 \times 0.3 \times 0.4 = 0.192$$

The power of ten in the numerator is:

$$10^{-19} \times 10^{-6} \times 10^{-6} = 10^{-31}$$

So numerator is:

$$0.192 \times 10^{-31}$$

Denominator is:

$$3 \times 0.1 \times 10^8 \times 10^{-6}$$

$$= 0.3 \times 10^2$$

$$= 30$$

Hence:

$$h = \frac{0.192 \times 10^{-31}}{30}$$

$$h = 0.0064 \times 10^{-31}$$

$$h = 6.4 \times 10^{-34} \text{ J s}$$

Therefore, the correct answer is option B.

COMMON TRAPS

- **Not converting micrometre wavelengths to metre.** All quantities in h calculation must be SI: wavelength in metre, potential in volt, charge in coulomb, speed in m/s. *Avoid it:* Before substituting, rewrite every table value with its SI unit explicitly.
- **Forgetting the electron charge factor e .** Photoelectron maximum kinetic energy is eV_0 in joules, not V_0 joules. *Avoid it:* Always write the starting equation $eV_0 = hc/\lambda - \phi$ before slope calculations.

REVIEW Practise deriving $h = e(V_1 - V_2)\lambda_1\lambda_2/[c(\lambda_2 - \lambda_1)]$ from $eV_0 = hc/\lambda - \phi$. Do unit-only checks for photoelectric-effect calculations.

18 Answer: B, D

Ref 14194

Medium ~2 min Dimensional analysis

QUICK APPROACH Start by writing down the dimensions of each quantity: permittivity, Boltzmann constant times temperature (energy), number density, and charge; then use dimensional analysis to check which expressions yield length dimensions.

We need to check which expressions have the dimension of length.

Let force, charge, and length be represented by F , Q , and L respectively.

Boltzmann constant times temperature has the dimension of energy.

$$[k_B T] = FL$$

From Coulomb's law, permittivity has dimension:

$$[\epsilon] = \frac{Q^2}{FL^2}$$

Number per unit volume has dimension:

$$[n] = L^{-3}$$

Charge has dimension:

$$[q] = Q$$

Now check each option.

For option A:

$$\left[\frac{nq^2}{\epsilon k_B T} \right] = \frac{L^{-3} Q^2}{\left(\frac{Q^2}{FL^2} \right) (FL)}$$

$$\left[\frac{nq^2}{\epsilon k_B T} \right] = \frac{L^{-3} Q^2}{Q^2 L^{-1}}$$

$$\left[\frac{nq^2}{\epsilon k_B T} \right] = L^{-2}$$

Therefore,

$$[\ell] = \sqrt{L^{-2}}$$

$$[\ell] = L^{-1}$$

This is not length, so option A is incorrect.

For option B:

$$\left[\frac{\epsilon k_B T}{nq^2} \right] = \frac{\left(\frac{Q^2}{FL^2} \right) (FL)}{L^{-3} Q^2}$$

$$\left[\frac{\epsilon k_B T}{nq^2} \right] = \frac{Q^2 L^{-1}}{Q^2 L^{-3}}$$

$$\left[\frac{\epsilon k_B T}{nq^2} \right] = L^2$$

Therefore,

$$[\ell] = \sqrt{L^2}$$

$$[\ell] = L$$

This is dimensionally correct, so option B is correct.

For option C:

$$[n^{2/3}] = (L^{-3})^{2/3}$$

$$[n^{2/3}] = L^{-2}$$

Now,

$$\left[\frac{q^2}{\epsilon n^{2/3} k_B T} \right] = \frac{Q^2}{\left(\frac{Q^2}{FL^2} \right) (L^{-2}) (FL)}$$

$$\left[\frac{q^2}{\epsilon n^{2/3} k_B T} \right] = \frac{Q^2}{Q^2 L^{-3}}$$

$$\left[\frac{q^2}{\epsilon n^{2/3} k_B T} \right] = L^3$$

Therefore,

$$[\ell] = \sqrt{L^3}$$

$$[\ell] = L^{3/2}$$

This is not length, so option C is incorrect.

For option D:

$$[n^{1/3}] = (L^{-3})^{1/3}$$

$$[n^{1/3}] = L^{-1}$$

Now,

$$\left[\frac{q^2}{\epsilon n^{1/3} k_B T} \right] = \frac{Q^2}{\left(\frac{Q^2}{FL^2} \right) (L^{-1}) (FL)}$$

$$\left[\frac{q^2}{\epsilon n^{1/3} k_B T} \right] = \frac{Q^2}{Q^2 L^{-2}}$$

$$\left[\frac{q^2}{\epsilon n^{1/3} k_B T} \right] = L^2$$

Therefore,

$$[\ell] = \sqrt{L^2}$$

$$[\ell] = L$$

This is dimensionally correct, so option D is correct.

Hence, the correct options are B and D.

Medium ~3 min Errors in measurement and propagation of errors

The measured value of r is (10 ± 1) mm. Therefore, the percentage error in r is

$$\frac{\Delta r}{r} \times 100 = \frac{1}{10} \times 100$$

$$\frac{\Delta r}{r} \times 100 = 10\%$$

So statement A is correct.

Now find the mean value of the measured time periods.

$$T_{\text{mean}} = \frac{0.52 + 0.56 + 0.57 + 0.54 + 0.59}{5}$$

$$T_{\text{mean}} = \frac{2.78}{5}$$

$$T_{\text{mean}} = 0.556 \text{ s}$$

$$T_{\text{mean}} \approx 0.56 \text{ s}$$

The absolute deviations from the mean are:

$$|0.52 - 0.556| = 0.036$$

$$|0.56 - 0.556| = 0.004$$

$$|0.57 - 0.556| = 0.014$$

$$|0.54 - 0.556| = 0.016$$

$$|0.59 - 0.556| = 0.034$$

The mean absolute error is

$$\Delta T_{\text{mean}} = \frac{0.036 + 0.004 + 0.014 + 0.016 + 0.034}{5}$$

$$\Delta T_{\text{mean}} = 0.0208 \text{ s}$$

$$\Delta T_{\text{mean}} \approx 0.02 \text{ s}$$

The least count of the watch is 0.01 s, which is smaller than the mean absolute error, so we take

$$\Delta T = 0.02 \text{ s}$$

Percentage error in T is

$$\frac{\Delta T}{T} \times 100 = \frac{0.02}{0.56} \times 100$$

$$\frac{\Delta T}{T} \times 100 = 3.57\%$$

So statement B is correct and statement C is incorrect.

Now use the given formula to calculate the error in g .

$$T = 2\pi \sqrt{\frac{7(R-r)}{5g}}$$

Squaring both sides,

$$T^2 = 4\pi^2 \frac{7(R-r)}{5g}$$

Rearranging for g ,

$$g = \frac{28\pi^2}{5} \cdot \frac{R-r}{T^2}$$

Thus, g depends directly on $(R-r)$ and inversely on T^2 . Hence the fractional error in g is

$$\frac{\Delta g}{g} = \frac{\Delta(R-r)}{R-r} + 2 \frac{\Delta T}{T}$$

Since $R-r$ is a difference, the absolute error is the sum of absolute errors:

$$\Delta(R-r) = \Delta R + \Delta r$$

$$\Delta(R-r) = 1 + 1$$

$$\Delta(R-r) = 2 \text{ mm}$$

Also,

$$R-r = 60 - 10$$

$$R-r = 50 \text{ mm}$$

Therefore,

$$\frac{\Delta g}{g} = \frac{2}{50} + 2 \left(\frac{0.02}{0.56} \right)$$

$$\frac{\Delta g}{g} = 0.04 + 0.0714$$

$$\frac{\Delta g}{g} = 0.1114$$

Percentage error in g is

$$\frac{\Delta g}{g} \times 100 = 11.14\%$$

This is approximately 11%. Hence statement D is correct.

Therefore, the correct statements are A, B and D.

COMMON TRAPS

- **Using the least count 0.01 s as the total time error.**

When repeated readings are given, compare the mean absolute error with the least count; here the solution states the mean absolute error is 0.0208 s, which is larger than 0.01 s, so $\Delta T = 0.02$ s. *Avoid it:* Compute the mean and mean absolute deviation before using the least count. Use the larger relevant uncertainty if instructed/standardly applied.

- **Treating $\Delta T = 0.02$ s as 2%.** Percentage error is $(\Delta T/T) \times 100$, not $\Delta T \times 100$ unless $T = 1$ unit. Here $(0.02/0.56) \times 100 = 3.57\%$. *Avoid it:* Always write units beside absolute error; 0.02 s is not a percent.

REVISE Absolute vs percentage error using the exact distinction between 0.02 s and 3.57%. · Practice propagation rules for sums/differences separately from products/powers.

20 Answer: C

Ref 14246

Medium ~1.5 min Vernier calipers

The main scale has 1 cm divided into 10 equal divisions, so one main scale division is 0.1 cm.

For caliper C_1 :

10 Vernier scale divisions correspond to 9 main scale divisions.

So one Vernier scale division is 0.09 cm.

The least count is the difference between one main scale division and one Vernier scale division.

$$LC = 0.1 - 0.09$$

$$LC = 0.01 \text{ cm}$$

From the figure, the Vernier zero is just after 2.8 cm on the main scale, so the main scale reading is 2.8 cm.

The 7th Vernier division coincides.

Vernier contribution is:

$$7LC = 7 \times 0.01$$

$$7LC = 0.07 \text{ cm}$$

Therefore, the reading of C_1 is:

$$2.8 + 0.07 = 2.87 \text{ cm}$$

For caliper C_2 :

10 Vernier scale divisions correspond to 11 main scale divisions.

So one Vernier scale division is 0.11 cm. This is a reverse Vernier, since one Vernier division is larger than one main scale division.

The least count is:

$$LC = 0.11 - 0.10$$

$$LC = 0.01 \text{ cm}$$

From the figure, the zero lies between 2.8 cm and 2.9 cm. For a reverse Vernier, take the next main scale mark and subtract the Vernier contribution.

The next main scale mark is 2.9 cm.

The 7th Vernier division coincides, so the correction is:

$$7LC = 0.07 \text{ cm}$$

Thus, the reading of C_2 is:

$$2.9 - 0.07 = 2.83 \text{ cm}$$

Hence, the measured values are 2.87 cm and 2.83 cm.

COMMON TRAPS

- **Treating reverse Vernier C_2 like ordinary Vernier.** For a reverse Vernier, the reading is taken from the next main-scale mark and the Vernier contribution is subtracted: $2.9 - 0.07 = 2.83$ cm. *Avoid it:* After computing 1 VSD, compare it with 1 MSD. If $VSD > MSD$, label it reverse and use next MSD minus coincidence $\times LC$.

- **Using 2.8 cm as main scale reading for C_2 instead of the next main-scale mark.** In reverse Vernier, because the vernier divisions are larger, the zero position is inferred from the next main-scale mark: here 2.9 cm, not 2.8 cm. *Avoid it:* Circle the words “reverse Vernier” or compute $VSD > MSD$; then write base = next main scale mark before substituting.

REVISE The difference between 1 MSD, 1 VSD, and least count; keep them in separate written lines. · For every Vernier problem, first compare 1 VSD and 1 MSD to decide direct vs reverse before applying the reading formula.

21 Answer: B, C

Ref 14052

Medium ~3 min Least count of Vernier callipers and screw gauge

For the Vernier callipers, 1 cm on the main scale is divided into 8 equal divisions.

So, one main scale division is

$$\frac{1}{8} \text{ cm}$$

Converting to mm,

$$1 \text{ cm} = 10 \text{ mm}$$

Therefore,

$$1 \text{ MSD} = \frac{10}{8} \text{ mm}$$

$$1 \text{ MSD} = 1.25 \text{ mm}$$

It is given that 5 Vernier scale divisions coincide with 4 main scale divisions.

So,

$$5 \text{ VSD} = 4 \text{ MSD}$$

$$1 \text{ VSD} = \frac{4}{5} \text{ MSD}$$

$$1 \text{ VSD} = \frac{4}{5} \times 1.25 \text{ mm}$$

$$1 \text{ VSD} = 1.00 \text{ mm}$$

Least count of Vernier callipers is the difference between one main scale division and one Vernier scale division.

$$\text{LC}_V = 1 \text{ MSD} - 1 \text{ VSD}$$

$$\text{LC}_V = 1.25 - 1.00 \text{ mm}$$

$$\text{LC}_V = 0.25 \text{ mm}$$

Now consider the screw gauge. It has 100 divisions on the circular scale.

Least count of screw gauge is

$$\text{LC}_S = \frac{\text{pitch}}{100}$$

Also, one complete rotation moves the screw by two divisions on the linear scale. If one division of the linear scale is L , then

$$\text{pitch} = 2L$$

Case 1: Pitch of screw gauge is twice the least count of the Vernier callipers.

$$\text{pitch} = 2\text{LC}_V$$

$$\text{pitch} = 2 \times 0.25 \text{ mm}$$

$$\text{pitch} = 0.50 \text{ mm}$$

Therefore, least count of screw gauge is

$$\text{LC}_S = \frac{0.50}{100} \text{ mm}$$

$$\text{LC}_S = 0.005 \text{ mm}$$

So option B is correct and option A is incorrect.

Case 2: Least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers.

$$L = 2\text{LC}_V$$

$$L = 2 \times 0.25 \text{ mm}$$

$$L = 0.50 \text{ mm}$$

Since one complete rotation moves the screw by two divisions on the linear scale,

$$\text{pitch} = 2L$$

$$\text{pitch} = 2 \times 0.50 \text{ mm}$$

$$\text{pitch} = 1.00 \text{ mm}$$

Thus, the least count of screw gauge is

$$\text{LC}_S = \frac{1.00}{100} \text{ mm}$$

$$\text{LC}_S = 0.01 \text{ mm}$$

So option C is correct and option D is incorrect.

Hence, the correct options are B and C.

22 Answer: A, C, D

Ref 14057

Medium ~1.5 min Dimensional analysis and Planck units

Use dimensional analysis. The dimensions are $[h] = ML^2T^{-1}$, $[c] = LT^{-1}$ and $[G] = M^{-1}L^3T^{-2}$. For the unit of length, assume $L = h^a c^b G^d$. Equating powers of M, L, T : $a - d = 0$, $2a + b + 3d = 1$, and $-a - b - 2d = 0$. From $a = d$ and $b = -3a$, substituting in the length equation gives $2a - 3a + 3a = 1$, so $a = \frac{1}{2}$ and $d = \frac{1}{2}$. Hence $L = \left(\frac{hG}{c^3}\right)^{1/2}$, so $L \propto \sqrt{h}$ and $L \propto \sqrt{G}$. For the unit of mass, assume $M = h^a c^b G^d$. Equating powers gives $a - d = 1$, $2a + b + 3d = 0$, and $-a - b - 2d = 0$. Solving gives $a = \frac{1}{2}$, $b = \frac{1}{2}$, $d = -\frac{1}{2}$. Therefore $M = \left(\frac{hc}{G}\right)^{1/2}$, so $M \propto \sqrt{c}$ and $M \propto \frac{1}{\sqrt{G}}$. Thus the correct options are A, C and D.

23 Answer: 4

Ref 14111

Medium ~2 min Error propagation

QUICK APPROACH Apply the concept of error propagation by taking the logarithm of the energy expression and then differentiating to relate fractional errors in A and t to that in $E(t)$.

Given:

$$E(t) = A^2 e^{-\alpha t}$$

Take logarithm:

$$\ln E = 2 \ln A - \alpha t$$

For maximum fractional error:

$$\frac{\Delta E}{E} = 2 \frac{\Delta A}{A} + \alpha \Delta t$$

The percentage error in A is:

$$\frac{\Delta A}{A} \times 100 = 1.25\%$$

So contribution due to A^2 is:

$$2 \times 1.25\% = 2.50\%$$

Now time is:

$$t = 5 \text{ s}$$

Percentage error in time is 1.50%, so:

$$\Delta t = \frac{1.50}{100} \times 5$$

$$\Delta t = 0.075 \text{ s}$$

Contribution from exponential term is:

$$\alpha \Delta t = 0.2 \times 0.075$$

$$\alpha \Delta t = 0.015$$

As percentage:

$$0.015 \times 100 = 1.50\%$$

Total percentage error is:

$$2.50\% + 1.50\% = 4.00\%$$

Final answer: 4

COMMON TRAPS

- **Treating the minus sign in the exponent as reducing the error.** For maximum fractional error, add absolute contributions: $|2\Delta A/A| + |\alpha\Delta t|$. *Avoid it:* After logarithmic differentiation, replace each differential contribution by its absolute value before adding errors.
- **Using the time percentage error directly as seconds.** Since the question also says "at $t = 5 \text{ s}$ ", $\Delta t = (1.50/100) \times 5 = 0.075 \text{ s}$. *Avoid it:* Before substituting into $\alpha\Delta t$, check that Δt is in seconds because α is in s^{-1} .

REVISE Logarithmic differentiation for error propagation, especially powers and exponentials. · Practice converting percentage error to absolute error before substituting into formulas with units.

24 Answer: A, C

Ref 14116

Medium ~2 min Dimensional analysis of electromagnetic quantities

Use fundamental dimensions M, L, T, A .

The dimensions of the quantities are:

$$[I] = A$$

$$[V] = ML^2T^{-3}A^{-1}$$

From Coulomb's law, permittivity has dimension:

$$[\epsilon_0] = M^{-1}L^{-3}T^4A^2$$

From magnetic force or inductance relations, permeability has dimension:

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

Also,

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

Now check each option.

Option A:

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

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

$$[\epsilon_0 V^2] = (M^{-1}L^{-3}T^4A^2)(M^2L^4T^{-6}A^{-2})$$

$$[\epsilon_0 V^2] = MLT^{-2}$$

Both sides have the same dimensions, so option A is dimensionally correct.

Option B:

$$[\epsilon_0 I] = (M^{-1}L^{-3}T^4A^2)(A)$$

$$[\epsilon_0 I] = M^{-1}L^{-3}T^4A^3$$

$$[\mu_0 V] = (MLT^{-2}A^{-2})(ML^2T^{-3}A^{-1})$$

$$[\mu_0 V] = M^2L^3T^{-5}A^{-3}$$

The dimensions are different, so option B is incorrect.

Option C:

$$[\epsilon_0 cV] = (M^{-1}L^{-3}T^4A^2)(LT^{-1})(ML^2T^{-3}A^{-1})$$

$$[\epsilon_0 cV] = A$$

This is the dimension of current I , so option C is dimensionally correct.

Option D:

$$[\mu_0 cI] = (MLT^{-2}A^{-2})(LT^{-1})(A)$$

$$[\mu_0 cI] = ML^2T^{-3}A^{-1}$$

This is the dimension of potential difference V .

But the right side is:

$$[\epsilon_0 V] = (M^{-1}L^{-3}T^4A^2)(ML^2T^{-3}A^{-1})$$

$$[\epsilon_0 V] = L^{-1}TA$$

The two sides are different, so option D is incorrect.

Therefore, the correct options are A and C.

COMMON TRAPS

- **Treating the symbol V as velocity/volume instead of potential difference.** Potential difference = work/charge, so $[V] = [W]/[q] = ML^2T^{-2}/(AT) = ML^2T^{-3}A^{-1}$. *Avoid it:* Before checking options A–D, rewrite every symbol with its physical meaning: V = voltage, I = current, c = speed.
- **Forgetting the squares in option A.** Dimensional powers must be applied to the entire dimension: $[I^2] = A^2$ and $[V^2] = M^2L^4T^{-6}A^{-2}$. *Avoid it:* Circle exponents in each option before substituting dimensions; write $[V^2] = [V]^2$, not $[V]$.

REVISE Memorise or rederive: $[V] = ML^2T^{-3}A^{-1}$, $[\epsilon_0] = M^{-1}L^{-3}T^4A^2$, $[\mu_0] = MLT^{-2}A^{-2}$, $[c] = LT^{-1}$. · Practise deriving ϵ_0 from Coulomb's law and μ_0 from force per unit length between parallel currents.

25 Answer: 8

Ref 13926

Hard ~2 min Young's modulus and error analysis in Searle's experiment

For a wire, Young's modulus is given by

$$Y = \frac{FL}{A\Delta l}$$

Here the uncertainty relevant from the given data is in the extension Δl measured using the Vernier scale.

Initial reading of Vernier:

$$R_1 = 3.20 \times 10^{-2} + 20 \times 10^{-5} \text{ m}$$

Final reading of Vernier:

$$R_2 = 3.20 \times 10^{-2} + 45 \times 10^{-5} \text{ m}$$

Extension of the wire:

$$\Delta l = R_2 - R_1$$

$$\Delta l = 25 \times 10^{-5} \text{ m}$$

$$\Delta l = 2.5 \times 10^{-4} \text{ m}$$

Each Vernier reading can have a maximum error equal to one least count. Since extension is obtained by subtracting two readings, the maximum absolute error in extension is

$$\delta(\Delta l) = 2 \times 1.0 \times 10^{-5} \text{ m}$$

$$\delta(\Delta l) = 2.0 \times 10^{-5} \text{ m}$$

Since Y is inversely proportional to Δl , the percentage error in Y due to extension is

$$\frac{\delta Y}{Y} \times 100 = \frac{\delta(\Delta l)}{\Delta l} \times 100$$

$$\frac{\delta Y}{Y} \times 100 = \frac{2.0 \times 10^{-5}}{2.5 \times 10^{-4}} \times 100$$

$$\frac{\delta Y}{Y} \times 100 = 8$$

Therefore, the maximum percentage error in Young's modulus is 8.

26 Answer: 3

Ref 13929

Medium ~1.5 min Dimensional analysis

Assume the distance depends on density, intensity and frequency as

$$d \propto \rho^a S^b f^c$$

Now write dimensions of each quantity.

$$[d] = L$$

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

Intensity is power per unit area. Power has dimension ML^2T^{-3} , so

$$[S] = MT^{-3}$$

Frequency has dimension

$$[f] = T^{-1}$$

Therefore,

$$L = (ML^{-3})^a (MT^{-3})^b (T^{-1})^c$$

Comparing powers of M , L and T :

$$a + b = 0$$

$$-3a = 1$$

$$-3b - c = 0$$

From the length equation,

$$a = -\frac{1}{3}$$

Using the mass equation,

$$b = \frac{1}{3}$$

The question says that d is proportional to $S^{1/n}$, so

$$\frac{1}{n} = b$$

$$\frac{1}{n} = \frac{1}{3}$$

$$n = 3$$

Therefore, the required value of n is 3.

27 Answer: B

Ref 13819

Easy ~1 min Vernier Callipers and Least Count

The main scale reading is the value just before the zero of the Vernier scale. Since the Vernier zero lies between 5.10 cm and 5.15 cm, the main scale reading is:

$$MSR = 5.10 \text{ cm}$$

The main scale division is the difference between consecutive main scale marks:

$$1 \text{ MSD} = 0.05 \text{ cm}$$

Given that 50 Vernier scale divisions are equivalent to 2.45 cm, one Vernier scale division is:

$$1 \text{ VSD} = \frac{2.45}{50} \text{ cm}$$

$$1 \text{ VSD} = 0.049 \text{ cm}$$

Least count is the difference between one main scale division and one Vernier scale division:

$$LC = 1 \text{ MSD} - 1 \text{ VSD}$$

$$LC = 0.05 - 0.049 \text{ cm}$$

$$LC = 0.001 \text{ cm}$$

The 24th Vernier division coincides with a main scale division, so the Vernier scale reading is:

$$VSR = 24 \times LC$$

$$VSR = 24 \times 0.001 \text{ cm}$$

$$VSR = 0.024 \text{ cm}$$

Therefore, the diameter is:

$$D = MSR + VSR$$

$$D = 5.10 + 0.024 \text{ cm}$$

$$D = 5.124 \text{ cm}$$

Hence, the correct option is B.

COMMON TRAPS

- **Taking the upper main scale mark as MSR.** For a Vernier callipers direct reading with no zero error, main scale reading is the main scale division just before the Vernier zero. *Avoid it:* Before adding Vernier reading, underline the phrase "lies between" and write: left mark = MSR, right mark only tells one MSD spacing.
- **Using 1 MSD as 0.1 cm instead of 0.05 cm.** In this problem, consecutive main scale marks shown are 5.10 cm and 5.15 cm, so $1 \text{ MSD} = 5.15 - 5.10 = 0.05 \text{ cm}$. *Avoid it:* Always compute MSD from the two adjacent main-scale labels given in the question before using a memorized value.

REVISE Always write the three-line structure for Vernier readings: MSR, LC, VSR before final reading. · In every Vernier problem, compute 1 MSD and 1 VSD from the given data instead of using a memorized standard instrument.

28 Answer: D

Ref 13871

Medium ~2 min Error propagation in trigonometric measurement

Given relation:

$$2d \sin \theta = \lambda$$

Since λ is exactly known,

$$d = \lambda / (2 \sin \theta)$$

Take logarithm on both sides:

$$\ln d = \ln(\lambda/2) - \ln(\sin \theta)$$

Differentiate to estimate fractional error:

$$\Delta d/d = -\cot \theta \Delta \theta$$

Taking magnitude,

$$|\Delta d|/d = \cot \theta |\Delta \theta|$$

The error in θ is constant, so $|\Delta \theta|$ is constant.

As θ increases from 0° to 90° , $\cot \theta$ decreases continuously from a very large value to 0.

Therefore, the fractional error in d decreases.

Now for absolute error:

$$|\Delta d| = d \cot \theta |\Delta \theta|$$

Using:

$$d = \lambda / (2 \sin \theta)$$

$$|\Delta d| = \lambda \cos \theta |\Delta \theta| / (2 \sin^2 \theta)$$

This also decreases as θ increases from 0° to 90° , so the absolute error does not remain constant and does not increase.

Hence only option D is correct.

COMMON TRAPS

- **Treating constant angular error as constant error in d.** Since $d = \lambda/(2 \sin \theta)$, the sensitivity of d to θ is not constant; $|\Delta d| = |dd/d\theta| |\Delta \theta| = \lambda \cos \theta |\Delta \theta|/(2 \sin^2 \theta)$. *Avoid it:* Whenever the measured quantity is transformed by a nonlinear function such as $\sin \theta$, compute the derivative before deciding whether the resulting error is constant.
- **Forgetting to take magnitude of the negative sign.** Error is reported as magnitude: " $|dd/d = \cot \theta |\Delta \theta|$ ". The negative sign only says d decreases when θ increases. *Avoid it:* After differentiation, convert to absolute/fractional error using magnitudes before comparing options.

REVISE Logarithmic differentiation for error propagation, especially trigonometric functions. · Practice converting angular errors from degrees to radians before using derivatives.

29 Answer: C

Ref 13886

Easy ~1 min Dimensional analysis of physical constants

We find the dimensions of each physical quantity one by one.

For Boltzmann constant k , use the kinetic energy relation:

$$KE = \frac{3}{2} kT$$

Dimension of energy is

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

Temperature has dimension

$$[T] = [K]$$

So,

$$[k] = \frac{[ML^2T^{-2}]}{[K]}$$

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

Thus P matches 4.

For coefficient of viscosity η , use Stokes' law:

$$F = 6\pi\eta rv$$

Ignoring dimensionless constants,

$$[F] = [\eta][r][v]$$

$$[MLT^{-2}] = [\eta][L][LT^{-1}]$$

$$[\eta] = [ML^{-1}T^{-1}]$$

Thus Q matches 2.

For Planck constant h , use

$$E = hf$$

Frequency has dimension

$$[f] = [T^{-1}]$$

So,

$$[h] = \frac{[E]}{[f]}$$

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

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

Thus R matches 1.

For thermal conductivity K' , use Fourier's law of heat conduction:

$$\frac{dQ}{dt} = \frac{K' A \Delta T}{\Delta x}$$

Power has dimension

$$\left[\frac{dQ}{dt}\right] = [ML^2T^{-3}]$$

Area has dimension

$$[A] = [L^2]$$

Temperature difference has dimension

$$[\Delta T] = [K]$$

Length has dimension

$$[\Delta x] = [L]$$

Therefore,

$$[K'] = \frac{[ML^2T^{-3}][L]}{[L^2][K]}$$

$$[K'] = [MLT^{-3}K^{-1}]$$

Thus S matches 3.

The correct matching is:

P-4, Q-2, R-1, S-3

Correct option: C.

COMMON TRAPS

- **Confusing Boltzmann constant with thermal conductivity because both use K symbols.** Boltzmann constant k has dimension energy/temperature from $KE = 3/2 kT$, i.e. $[ML^2T^{-2}K^{-1}]$. Thermal conductivity has dimension power per (area $\times$ temperature gradient), i.e. $[MLT^{-3}K^{-1}]$. *Avoid it:* Whenever K appears in square brackets, treat it as temperature dimension kelvin, not a variable name; derive P using $KE = 3/2 kT$ and S using Fourier's law separately.
- **Using momentum/action dimensions incorrectly for Planck constant.** From $E = hf$, $h = E/f = [ML^2T^{-2}]/[T^{-1}] = [ML^2T^{-1}]$. Equivalently $h = p\lambda = [MLT^{-1}][L]$. *Avoid it:* Check that Planck constant has the dimension of action/angular momentum, not viscosity.

REVISE Standard dimensions: Boltzmann constant = energy/temperature, Planck constant = energy $\times$ time, viscosity = stress/(velocity gradient), thermal conductivity = heat current length/(area temperature difference). · For each matching item, derive the dimension before looking at options; then map to 1–4.

30 Answer: A

Ref 13694

Medium ~1.5 min

Propagation of errors in Young's modulus measurement

Young's modulus is given by:

$$Y = \frac{4MLg}{\pi ld^2}$$

For error propagation, only the dependence on l and d is needed.

$$Y \propto \frac{1}{ld^2}$$

Taking fractional error contributions due to l and d separately:

Contribution due to error in l :

$$\frac{\Delta Y_l}{Y} = \frac{\Delta l}{l}$$

Contribution due to error in d :

$$\frac{\Delta Y_d}{Y} = 2 \frac{\Delta d}{d}$$

Both the screw gauge and micrometer have the same pitch and same number of circular scale divisions. Therefore their least counts are the same.

$$\text{Least count} = \frac{0.5}{100} \text{ mm}$$

$$\text{Least count} = 0.005 \text{ mm}$$

Hence the absolute errors in measuring d and l are the same.

Let:

$$\Delta d = \Delta l = \Delta$$

Now compare the two contributions.

For $l = 0.25 \text{ mm}$:

$$\frac{\Delta Y_l}{Y} = \frac{\Delta}{0.25}$$

$$\frac{\Delta Y_l}{Y} = 4\Delta$$

For $d = 0.5 \text{ mm}$:

$$\frac{\Delta Y_d}{Y} = 2 \frac{\Delta}{0.5}$$

$$\frac{\Delta Y_d}{Y} = 4\Delta$$

Thus, the contributions to the maximum probable error due to measurements of d and l are equal.

Therefore, the correct option is A.

COMMON TRAPS

- **Ignoring the square on diameter in the error contribution.** For a power law x^n , the fractional error contribution is $|n| \Delta x/x$. Since d is squared in the denominator, the coefficient is 2. *Avoid it:* Before substituting values, rewrite only the relevant part as $Y \propto l^{-1}d^{-2}$ and mark the powers -1 and -2 .
- **Comparing absolute errors instead of fractional contributions.** Error contribution in Y depends on relative error and power: $\Delta l/l$ and $2\Delta d/d$, not just Δl and Δd . *Avoid it:* Always compute $\Delta x/x$ for each measured variable before comparing contributions.

REVISE Propagation of errors in products and powers: for x^n , contribution is $|n| \Delta x/x$. · Practice distinguishing absolute error, least count, and fractional/percentage error.

31 Answer: C

Ref 13657

Medium ~1.5 min Errors in measurement using screw gauge

Least count of the screw gauge is pitch divided by number of circular scale divisions.

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

$$LC = 0.01 \text{ mm}$$

The measured diameter is the main scale reading plus the circular scale reading multiplied by least count.

$$d = 2.5 + 20 \times 0.01 \text{ mm}$$

$$d = 2.7 \text{ mm}$$

For a sphere, density is mass divided by volume.

$$\rho = \frac{m}{V}$$

$$V = \frac{\pi d^3}{6}$$

So,

$$\rho = \frac{6m}{\pi d^3}$$

Thus density depends directly on mass and inversely on the cube of diameter.

$$\frac{\Delta \rho}{\rho} = \frac{\Delta m}{m} + 3 \frac{\Delta d}{d}$$

Given relative percentage error in mass is 2%.

The absolute error in diameter is taken as the least count of the screw gauge.

$$\Delta d = 0.01 \text{ mm}$$

Percentage error in diameter is

$$\frac{\Delta d}{d} \times 100 = \frac{0.01}{2.7} \times 100$$

$$\frac{\Delta d}{d} \times 100 = 0.370\%$$

Therefore percentage error in density is

$$2 + 3 \times 0.370 = 3.11\%$$

This is approximately 3.1%.

Hence, the correct option is C.

32 Answer: A, C

Ref 13487

Medium ~1.5 min Error propagation in simple pendulum experiment

The length of the pendulum is given to be exactly 1 m, so the error in length is zero.

The stopwatch least count is 1 sec. Hence, the error in measuring the total time for 20 oscillations is taken as:

$$\Delta t = 1 \text{ sec}$$

The total recorded time is:

$$t = 40 \text{ sec}$$

The time period is the time for one oscillation:

$$T = \frac{t}{20}$$

$$T = \frac{40}{20}$$

$$T = 2 \text{ sec}$$

The error in the time period is the error in total time divided by the number of oscillations:

$$\Delta T = \frac{\Delta t}{20}$$

$$\Delta T = \frac{1}{20}$$

$$\Delta T = 0.05 \text{ sec}$$

So statement A is true and statement B is false.

For a simple pendulum:

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

Squaring both sides:

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

Therefore:

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

Since L is exact, only T contributes to the percentage error in g .

For error propagation:

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

Substitute the values:

$$\frac{\Delta g}{g} = 2 \times \frac{0.05}{2}$$

$$\frac{\Delta g}{g} = 0.05$$

Percentage error in g is:

$$0.05 \times 100 = 5\%$$

So statement C is true and statement D is false.

Final answer: A,C

COMMON TRAPS

- **Taking stopwatch least count as the error in one time period.** The least count error applies to the directly measured total time $t = 40$ s; since $T = t/20$, the propagated error is $\Delta T = \Delta t/20 = 0.05$ s. *Avoid it:* Label direct and derived quantities separately: t_{total} is directly measured; T is calculated.
- **Computing percentage error in g without the square dependence on T .** For a power law $g \propto T^{-2}$, fractional error magnitude is $2 \Delta T/T$. *Avoid it:* Rewrite formulas as powers before applying error propagation.

REVISE Least count error for repeated-period measurements. · Fractional error propagation in product, quotient, and power-law formulas.

33 Answer: D

Ref 13543

Easy ~1 min Vernier calipers least count

The main scale has marks separated by 1 mm, so one main scale division is:

$$1 \text{ MSD} = 1 \text{ mm}$$

It is given that 20 Vernier scale divisions coincide with 16 main scale divisions.

Therefore, the length of 20 Vernier scale divisions is:

$$20 \text{ VSD} = 16 \text{ MSD}$$

Since $1 \text{ MSD} = 1 \text{ mm}$:

$$20 \text{ VSD} = 16 \text{ mm}$$

So one Vernier scale division is:

$$1 \text{ VSD} = \frac{16}{20} \text{ mm}$$

$$1 \text{ VSD} = 0.8 \text{ mm}$$

For a Vernier calipers, the least count is the difference between one main scale division and one Vernier scale division:

$$\text{Least count} = 1 \text{ MSD} - 1 \text{ VSD}$$

$$\text{Least count} = 1 - 0.8 \text{ mm}$$

$$\text{Least count} = 0.2 \text{ mm}$$

Hence, the correct option is D.

COMMON TRAPS

- **Applying the shortcut $LC = 1 \text{ MSD}/\text{number of VSD}$ blindly.** The shortcut $LC = 1 \text{ MSD}/n$ works only when n VSD equals $(n - 1)$ MSD. Here $20 \text{ VSD} = 16 \text{ MSD}$, so $1 \text{ VSD} = 16/20 = 0.8 \text{ mm}$ and $LC = 1 - 0.8 = 0.2 \text{ mm}$. *Avoid it:* Before using any shortcut, write the given coincidence relation explicitly and calculate 1 VSD.
- **Reversing the coincidence relation.** The sentence means length of 20 Vernier divisions equals length of 16 main scale divisions: $20 \text{ VSD} = 16 \text{ MSD}$. *Avoid it:* Attach the unit label VSD/MSD to each number directly under the phrase: 20 goes with Vernier, 16 goes with main scale.

REVISE Practise writing worded Vernier relations as equations with VSD/MSD labels. · Memorise the condition under which $LC = 1 \text{ MSD}/n$ is valid.

34 Answer: B

Ref 13196

Medium ~2 min Error propagation in simple pendulum experiment

QUICK APPROACH Start by applying the formula for error propagation in the measurement of acceleration due to gravity using the simple pendulum relation and percentage errors in length and time measurements.

For a simple pendulum, the time period is related to acceleration due to gravity by

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

Squaring and rearranging,

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

Since $T = \frac{t}{n}$ and n has no measurement error,

$$\frac{\Delta T}{T} = \frac{\Delta t}{t}$$

For percentage error in g ,

$$\frac{\Delta g}{g} = \frac{\Delta l}{l} + 2 \frac{\Delta T}{T}$$

Therefore,

$$E = \left(\frac{\Delta l}{l} + 2 \frac{\Delta t}{t} \right) \times 100$$

Least count of length is 0.1 cm, so

$$\Delta l = 0.1 \text{ cm}$$

Least count of time is 0.1 s, so

$$\Delta t = 0.1 \text{ s}$$

For student I:

$$E_I = \left(\frac{0.1}{64.0} + 2 \frac{0.1}{128.0} \right) \times 100$$

$$E_I = (0.0015625 + 0.0015625) \times 100$$

$$E_I = 0.3125\%$$

For student II:

$$E_{II} = \left(\frac{0.1}{64.0} + 2 \frac{0.1}{64.0} \right) \times 100$$

$$E_{II} = (0.0015625 + 0.003125) \times 100$$

$$E_{II} = 0.46875\%$$

For student III:

$$E_{III} = \left(\frac{0.1}{20.0} + 2 \frac{0.1}{36.0} \right) \times 100$$

$$E_{III} = (0.005 + 0.005555) \times 100$$

$$E_{III} \approx 1.0555\%$$

Thus,

$$E_I < E_{II} < E_{III}$$

So E_I is minimum.

COMMON TRAPS

- **Using number of oscillations instead of total time in time-error term.** Since $T = t/n$ and n has no measurement error, $\Delta T/T = \Delta t/t$. *Avoid it:* In the error term, divide stopwatch least count 0.1 s by the recorded total time for n oscillations, not by n .
- **Forgetting the factor 2 in the time-period error.** For a power x^a , fractional error contribution is $|a| \Delta x/x$; hence T^2 contributes $2\Delta T/T$. *Avoid it:* Write $g = 4\pi^2 l T^{-2}$ and mark exponents before error calculation.

REVISE Logarithmic differentiation for error propagation in power-law formulae. · Practise distinguishing directly measured quantities from derived quantities in experiment tables.



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