



JEEEnius AI

PREVIOUS YEAR QUESTIONS · 2019–2026

JEE Main

Chapter-wise PYQs

Physics**2019–2026**

Questions from 8 years · plus AIEEE 2002–2012 appendix

Chapter-wise previous year questions with full solutions · Appendix:
AIEEE 2002–2012

3,390

QUESTIONS

243

FIGURES

20

CHAPTERS



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JEE Main Chapter-wise PYQs · Physics

Chapter-wise previous year questions with full solutions · Appendix: AIEEE 2002–2012

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How to use this book

- **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, date and shift, 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

2002 71	2003 87	2004 84	2005 6	2006 51	2007 41	2008 27	2009 20	2010 24	2011 31	2012 24	2019 382	2020 287
2021 303	2022 284	2023 479	2024 355	2025 389	2026 445							



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2,924 questions

Physics

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Units and Measurements	114	81
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PHYSICS · CHAPTER 1

Units and Measurements

114 questions · 2026 16 2025 15 2024 23 2023 16 2022 11 2021 13 2020 9 2019 11

1 JEE MAIN 2026

Dimensions of universal gravitational constant (G) in terms of Planck's constant (h), distance (L), mass (M) and time (T) are:

- (A) $hTL M^{-2}$ (B) $hT^{-1}LM^{-2}$
(C) hTL^2M^{-2} (D) $h^{-1}T^{-1}LM^{-2}$

2 JEE MAIN 2026

In a screw gauge the zero of main scale reference line coincides with the fifth division of the circular scale when two studs are in contact. There are 100 divisions in the circular scale and pitch of the screw gauge is 0.1 mm. When the diameter of a sphere is measured, the reading of main scale is 5 mm and 50th division of circular scale coincides with the reference line of main scale. The diameter of the sphere is _____ mm.

- (A) 5.045 (B) 5.055
(C) 5.450 (D) 5.550

3 JEE MAIN 2026 · NUMERICAL

The diameter of a wire measured by a screw gauge of least count 0.001 cm is 0.08 cm. The length measured by a scale of least count 0.1 cm is 150 cm. When a weight of 100 N is applied to the wire, the extension in length is 0.5 cm, measured by a micrometer of least count 0.001 cm. The error in the measured Young's modulus is $\alpha \times 10^9$ N/m. Find α .

- (A) 1.65×10^9 N/m (B) 1.70×10^9 N/m
(C) 0.165×10^9 N/m (D) 16.5×10^9 N/m

4 JEE MAIN 2026

Match the quantities in List-I with their dimensions in List-II:

List-I:

- A. Planck's constant
B. Stopping potential
C. Work function
D. Threshold frequency

List-II:

- I. ML^2T^{-2}
II. T^{-1}
III. ML^2T^{-1}
IV. $ML^2T^{-3}A^{-1}$

Choose the correct matching option.

- (A) A-III, B-IV, C-I, D-II (B) A-I, B-II, C-III, D-IV
(C) A-IV, B-III, C-I, D-II (D) A-I, B-IV, C-III, D-II

5 JEE MAIN 2026 · ONE OR MORE CORRECT

Match List-I with List-II where h (Planck's constant), G (gravitational constant) and c (speed of light in vacuum) are taken as fundamental units.

List-I:

- A. Meter (L)
B. Second (S)
C. Kilogram (M)
D. Kelvin (K)

List-II:

- I. $\sqrt{h c / G}$
II. $\sqrt{G h / c^5}$
III. $\sqrt{k^2 L^2 c^3 / (G h)}$
IV. $\sqrt{G h / c^3}$

Choose the correct matching option.

- (1) A-II, B-IV, C-I, D-III (2) A-IV, B-II, C-I, D-III
(3) A-IV, B-I, C-II, D-III (4) A-III, B-I, C-II, D-IV

6 JEE MAIN 2026

In a Vernier calipers, when both jaws touch each other, the zero of the Vernier scale is shifted to the right of the zero of the main scale and the 7th Vernier division coincides with a main scale reading. If 1 main scale division = 1 mm and there are 10 Vernier scale divisions, then the Vernier caliper has:

- (A) 0.07 cm negative zero error (B) 0.7 cm negative zero error
(C) 0.07 cm positive zero error (D) 0.7 cm positive zero error

7 JEE MAIN 2026

L , C and R represents inductance, capacitance and resistance respectively. The dimensional formula $ML^2T^{-4}A^{-2}$ corresponds to which of the following?

- (A) $R / \sqrt{LC}$ (B) $R / (LC)$
(C) $C / \sqrt{LR}$ (D) $(1/R) \cdot \sqrt{(L/C)}$

8 JEE MAIN 2026

The density ρ of a uniform cylinder is determined by measuring its mass m , length l and diameter d . The measured values of m , l and d are 97.42 ± 0.02 g, 8.35 ± 0.05 mm and 20.20 ± 0.02 mm respectively. Calculated percentage fractional error in ρ is _____.

- (A) 0.63% (B) 0.82%
(C) 0.72% (D) 0.25%

9 JEE MAIN 2026

Consider a modified Bernoulli equation:

$$(P + \frac{A}{Bt^2}) + \rho g(h + Bt) + \frac{1}{2}\rho v^2 = \text{constant}$$

If t has the dimension of time, then the dimensions of A and B are respectively:

- (A) $[M L T^{-1}]$ and $[M^0 L T^{-1}]$ (B) $[M L^0 T^{-1}]$ and $[M^0 L T^{-1}]$
 (C) $[M L T^{-1}]$ and $[M^0 L T]$ (D) $[M T^{-1}]$ and $[M^0 L T]$

10 JEE MAIN 2026

In an experiment the values of two spring constants were measured as $k_1 = (10 \pm 0.2) \text{ N/m}$ and $k_2 = (20 \pm 0.3) \text{ N/m}$. If these springs are connected in parallel, then the percentage error in the equivalent spring constant is:

- (A) 1.67% (B) 1.33%
 (C) 2.67% (D) 2.33%

11 JEE MAIN 2026

Keeping significant figures in view, the sum of the physical quantities 52.01 m, 153.2 m and 0.123 m is:

- (A) 205.33 m (B) 205.333 m
 (C) 205.3 m (D) 205 m

12 JEE MAIN 2026

If ϵ , E and t represent the free space permittivity, electric field and time respectively, then the unit of $\frac{\epsilon E}{t}$ is:

- (A) A·m (B) A/m^2
 (C) A/m (D) $A \cdot m^2$

13 JEE MAIN 2026

Four persons measure the length of a rod as 20.00 cm, 19.75 cm, 17.01 cm and 18.25 cm. The relative error in the measurement of the average length of the rod is:

- (A) 0.06 (B) 0.08
 (C) 0.24 (D) 0.18

14 JEE MAIN 2026

In a screw gauge, the zero of the circular scale lies 3 divisions above the horizontal pitch line when their metallic studs are brought in contact. Using this instrument the thickness of a sheet is measured. If the pitch scale reading is 1 mm and the circular scale reading is 51 divisions, find the correct thickness of the sheet. (Least count = 0.01 mm)

- (A) 1.50 mm (B) 1.48 mm
 (C) 1.51 mm (D) 1.54 mm

15 JEE MAIN 2026

In a vernier callipers, 50 vernier scale divisions are equal to 48 main scale divisions. If one main scale division = 0.05 mm, then the least count of the vernier callipers is _____ mm.

- (A) 0.02 (B) 0.002
 (C) 0.005 (D) 0.05

16 JEE MAIN 2026

In an experiment, a set of readings are obtained as follows: 1.24 mm, 1.25 mm, 1.23 mm, 1.21 mm. The expected least count of the instrument used in recording these readings is (mm):

- (A) 0.1 (B) 0.01
 (C) 0.001 (D) 0.05

17 JEE MAIN 2025

The expression given below shows the variation of velocity (v) with time (t), $v = At^2 + \frac{Bt}{C+t}$. The dimension of ABC is:

- (1) $[M^0 L^1 T^{-3}]$ (2) $[M^0 L^2 T^{-2}]$
 (3) $[M^0 L^1 T^{-2}]$ (4) $[M^0 L^2 T^{-3}]$

18 JEE MAIN 2025 · MATCHING

Match List - I with List - II.

List - I:

- (A) Permeability of free space
 (B) Magnetic field
 (C) Magnetic moment
 (D) Torsional constant

List - II:

- (I) ML^2T^{-2}
 (II) $MT^{-2}A^{-1}$
 (III) $MLT^{-2}A^{-2}$
 (IV) L^2A

Choose the correct answer from the options given below:

- (1) (A)-(IV), (B)-(III), (C)-(I), (D)-(II)
 (2) (A)-(III), (B)-(II), (C)-(IV), (D)-(I)
 (3) (A)-(I), (B)-(IV), (C)-(II), (D)-(III)
 (4) (A)-(II), (B)-(I), (C)-(III), (D)-(IV)

19 JEE MAIN 2025

The position of a particle moving on x-axis is given by $x(t) = A \sin t + B \cos^2 t + Ct^2 + D$, where t is time. The dimension of $\frac{ABC}{D}$ is

- (1) L^2T^{-2} (2) L^2
 (3) L (4) L^3T^{-2}

20 JEE MAIN 2025 · NUMERICAL

In a measurement, it is asked to find modulus of elasticity per unit torque applied on the system. The measured quantity has dimension of $M^a L^b T^c$. If $b = -3$, the value of c is _____

21 JEE MAIN 2025 · NUMERICAL

A tiny metallic rectangular sheet has length and breadth of 5 mm and 2.5 mm, respectively. Using a specially designed screw gauge which has pitch of 0.75 mm and 15 divisions in the circular scale, you are asked to find the area of the sheet. In this measurement, the maximum fractional error will be $\frac{x}{100}$ where x is _____.

22 JEE MAIN 2025 · ONE OR MORE CORRECT

Choose the correct statements. (A) Weight of a substance is the amount of matter present in it. (B) Mass is the force exerted by gravity on an object. (C) Volume is the amount of space occupied by a substance. (D) Temperatures below 0°C are possible in Celsius scale, but in Kelvin scale negative temperature is not possible. (E) Precision refers to the closeness of various measurements for the same quantity. Choose the correct answer from the options given below:

- (1) (A), (D) and (E) Only (2) (C), (D) and (E) Only
(3) (A), (B) and (C) Only (4) (B), (C) and (D) Only

23 JEE MAIN 2025

The pair of physical quantities not having same dimensions is:

- (1) Pressure and Young's modulus
(2) Surface tension and impulse
(3) Torque and energy
(4) Angular momentum and Planck's constant

24 JEE MAIN 2025

The maximum percentage error in the measurement of density of a wire is [Given, mass of wire = (0.60 ± 0.003) g, radius of wire = (0.50 ± 0.01) cm, length of wire = (10.00 ± 0.05) cm]

- (1) 8 (2) 5
(3) 4 (4) 7

25 JEE MAIN 2025

Given a charge q , current I and permeability of vacuum μ_0 . Which of the following quantity has the dimension of momentum?

- (A) $\mu_0 q I$ (B) $q I$
(C) $\mu_0 q^2$ (D) $\mu_0 I^2$

26 JEE MAIN 2025 · MATCHING

Match the quantities in List I with their correct SI units in List II:

List I: A. Heat capacity of body B. Specific heat capacity of body C. Latent heat D. Thermal conductivity

List II: I. Jkg^{-1} II. JK^{-1} III. $\text{Jkg}^{-1}\text{K}^{-1}$ IV. $\text{Jm}^{-1}\text{K}^{-1}\text{s}^{-1}$

Choose the correct matching.

- (A) A - II, B - III, C - I, D - IV (B) A - III, B - II, C - I, D - IV
(C) A - I, B - III, C - II, D - IV (D) A - II, B - I, C - III, D - IV

27 JEE MAIN 2025

Match the following physical quantities with their SI units:

Quantities: A. Heat capacity B. Specific heat capacity C. Latent heat D. Thermal conductivity

Units: I. JK^{-1} II. $\text{Jkg}^{-1}\text{K}^{-1}$ III. Jkg^{-1} IV. $\text{Jm}^{-1}\text{s}^{-1}\text{K}^{-1}$

Which of the following is correct?

- (A) A - I, B - II, C - III, D - IV (B) A - III, B - IV, C - I, D - II
(C) A - II, B - III, C - IV, D - I (D) A - IV, B - I, C - II, D - III

28 JEE MAIN 2025 · ONE OR MORE CORRECT

A physical quantity C is related to four other quantities p , q , r and s as follows: $C = \frac{pq^2}{r^3\sqrt{s}}$. The percentage errors in the measurement of p , q , r and s are 1%, 2%, 3% and 2% respectively. The percentage error in the measurement of C will be _____ %.

- (A) 9% (B) 12%
(C) 15% (D) 18%

29 JEE MAIN 2025

In an electromagnetic system, the quantity representing the ratio of electric flux and magnetic flux has dimension of $M^P L^Q T^R A^S$. The values of 'Q' and 'R' are:

- (A) (3, -5) (B) (1, -1)
(C) (-2, 2) (D) (-2, 1)

30 JEE MAIN 2025 · APRIL S1

In an electromagnetic system a quantity defined as ratio of electric dipole moment and magnetic dipole moment has dimension of $[M^P L^Q T^R A^S]$. Then P, Q are:

- (A) 0, -1 (B) 1, -1
(C) -1, 0 (D) -1, 1

31 JEE MAIN 2025

A quantity Q is given by $Q = x^{-2}y^3z^{-2/5}$. X, Y and Z are independent parameters which have fractional errors of 0.1, 0.2 and 0.5 respectively in measurement. The maximum fractional error of Q is:

- (A) 0.7 (B) 0.6
(C) 0.8 (D) 0.1

32 JEE MAIN 2024

There are 100 divisions on the circular scale of a screw gauge of pitch 1 mm. With no measuring quantity in between the jaws, the zero of the circular scale lies 5 divisions below the reference line. The diameter of a wire is then measured using this screw gauge. It is found that 4 linear scale divisions are clearly visible while 60 divisions on circular scale coincide with the reference line. The diameter of the wire is:

- (A) 4.60 mm (B) 4.65 mm
(C) 3.35 mm (D) 4.55 mm

33 JEE MAIN 2024

A vernier calipers has 20 divisions on the vernier scale, which coincides with 19th division on the main scale. The least count of the instrument is 0.1 mm. One main scale division is equal to ____ mm.

- (1) 0.5 (2) 2
(3) 5 (4) 1

34 JEE MAIN 2024

Time periods of oscillation of the same simple pendulum measured using four different measuring clocks were recorded as 4.62 s, 4.632 s, 4.6 s and 4.64 s. The arithmetic mean of these readings in correct significant figure is:

- (A) 5 s (B) 4.623 s
(C) 4.6 s (D) 4.62 s

35 JEE MAIN 2024

The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 'A' $\times 10^{12}$ hertz and that has a radiant intensity in that direction of $\frac{1}{B}$ watt per steradian. 'A' and 'B' are respectively

- (1) 540 and 683 (2) 450 and 683
(3) 450 and $\frac{1}{683}$ (4) 540 and $\frac{1}{683}$

36 JEE MAIN 2024

Given below are two statements : Statement (I) : Dimensions of specific heat is $[L^2T^{-2}K^{-1}]$. Statement (II) : Dimensions of gas constant is $[ML^2T^{-1}K^{-1}]$. In the light of the above statements, choose the most appropriate answer from the options given below.

- (1) Both statement (I) and statement (II) are correct
(2) Statement (I) is correct but statement (II) is incorrect
(3) Both statement (I) and statement (II) are incorrect
(4) Statement (I) is incorrect but statement (II) is correct

37 JEE MAIN 2024

What is the dimensional formula of ab^{-1} in the equation $(P + \frac{a}{V^2})(V - b) = RT$, where letters have their usual meaning.

- (1) $[M^{-1}L^5T^3]$ (2) $[M^6L^7T^4]$
(3) $[M L^2T^{-2}]$ (4) $[M^0L^3T^{-2}]$

38 JEE MAIN 2024 · ASSERTION-REASON

Given below are two statements: one is labelled as Assertion(A) and the other is labelled as Reason (R).

Assertion (A): In Vernier calliper if positive zero error exists, then while taking measurements, the reading taken will be more than the actual reading.

Reason (R): The zero error in Vernier Calliper might have happened due to manufacturing defect or due to rough handling.

In the light of the above statements, choose the correct answer from the options given below:

- (1) Both (A) and (R) are correct and (R) is the correct explanation of (A)
(2) Both (A) and (R) are correct but (R) is not the correct explanation of (A)
(3) (A) is true but (R) is false
(4) (A) is false but (R) is true

39 JEE MAIN 2024

If G be the gravitational constant and u be the energy density then which of the following quantity have the dimensions as that of the $\sqrt{uG}$?

- (1) Pressure gradient per unit mass (2) Gravitational potential
(3) Energy per unit mass (4) Force per unit mass

40 JEE MAIN 2024

The dimensional formula of angular impulse is:

- (1) $[M L^{-2}T^{-1}]$ (2) $[M L^2T^{-2}]$
(3) $[M LT^{-1}]$ (4) $[M L^2T^{-1}]$

41 JEE MAIN 2024

10 divisions on the main scale of a Vernier calliper coincide with 11 divisions on the Vernier scale. If each division on the main scale is of 5 units, the least count of the instrument is:

- (A) $\frac{1}{2}$ (B) $\frac{10}{11}$
(C) $\frac{50}{11}$ (D) $\frac{5}{11}$

42 JEE MAIN 2024

To find the spring constant (k) of a spring experimentally, a student commits 2% positive error in the measurement of time and 1% negative error in measurement of mass. The percentage error in determining value of k is:

- (1) 5% (2) 1%
(3) 3% (4) 4%

43 JEE MAIN 2024

While measuring diameter of wire using screw gauge the following readings were noted. Main scale reading is 1 mm and circular scale reading is equal to 42 divisions. Pitch of screw gauge is 1 mm and it has 100 divisions on circular scale. The diameter of the wire is $\frac{x}{50}$ mm. The value of x is:

- (1) 21 (2) 142
(3) 71 (4) 42

44 JEE MAIN 2024

A clock has 75 cm, 60 cm long second hand and minute hand respectively. In 30 minutes duration the tip of second hand will travel x distance more than the tip of minute hand. The value of x in meter is nearly (Take $\pi = 3.14$):

- (1) 140.5 (2) 118.9
(3) 139.4 (4) 220.0

45 JEE MAIN 2024 · MATCHING

Match List - I with List - II.

List - I (Number)

- (A) 1001
(B) 010.1
(C) 100.100
(D) 0.0010010

List - II (Significant figure)

- (I) 3
(II) 4
(III) 5
(IV) 6

Choose the correct answer from the options given below:

- (1) (A)-(I), (B)-(II), (C)-(III), (D)-(IV)
(2) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)
(3) (A)-(III), (B)-(IV), (C)-(II), (D)-(I)
(4) (A)-(IV), (B)-(III), (C)-(I), (D)-(II)

46 JEE MAIN 2024

The diameter of a sphere is measured using a vernier caliper whose 9 divisions of main scale are equal to 10 divisions of vernier scale. The shortest division on the main scale is equal to 1 mm. The main scale reading is 2 cm and second division of vernier scale coincides with a division on main scale. If mass of the sphere is 8.635 g, the density of the sphere is:

- (1) 2.0 g/cm^3 (2) 1.7 g/cm^3
(3) 2.2 g/cm^3 (4) 2.5 g/cm^3

47 JEE MAIN 2024

In a vernier caliper, when both jaws touch each other, zero of the vernier scale shifts towards left and its 4th division coincides exactly with a certain division on main scale. If 50 vernier scale divisions equal to 49 main scale divisions and zero error in the instrument is 0.04 mm then how many main scale divisions are there in 1 cm?

- (1) 10 (2) 5
(3) 20 (4) 40

48 JEE MAIN 2024

Young's modulus is determined by the equation given by $Y = 49000 \frac{M}{l} \frac{g}{\text{cm}^2}$ where M is the mass and l is the extension of wire used in the experiment. Now error in Young modulus (Y) is estimated by taking data from $M - l$ plot in graph paper. The smallest scale divisions are 5 g and 0.02 cm along load axis and extension axis respectively. If the value of M and l are 500 g and 2 cm respectively then percentage error of Y is:

- (1) 0.5% (2) 2%
(3) 0.02% (4) 0.2%

49 JEE MAIN 2024

If 50 Vernier divisions are equal to 49 main scale divisions of a travelling microscope and one smallest reading of main scale is 0.5 mm, the Vernier constant of travelling microscope is:

- (1) 0.1 mm (2) 0.1 cm
(3) 0.01 mm (4) 0.01 mm

50 JEE MAIN 2024

One main scale division of a vernier caliper is equal to m units. If n^{th} division of main scale coincides with $(n + 1)^{\text{th}}$ division of vernier scale, the least count of the vernier caliper is:

- (1) $\frac{n \cdot m}{n+1}$ (2) $\frac{1}{n+1}$
(3) $\frac{m}{n+1}$ (4) $\frac{m}{n(n+1)}$

51 JEE MAIN 2024

The de-Broglie wavelength associated with a particle of mass m and energy E is $h/\sqrt{2mE}$. The dimensional formula for Planck's constant is:

- (1) $[ML^2T^{-1}]$ (2) $[M^{-1}LT^{-2}]$
(3) $[MLT^{-2}]$ (4) $[M^2L^2T^{-2}]$

52 JEE MAIN 2024

Least count of a vernier caliper is $\frac{1}{20N}$ cm. The value of one division on the main scale is 1 mm. Then the number of divisions of main scale that coincide with N divisions of vernier scale is:

- (1) $(2N - 1)$ (2) $\frac{2N-1}{2N}$
(3) $\frac{2N-1}{2}$ (4) $\frac{2N-1}{20N}$

53 JEE MAIN 2024

In an expression $a \times 10^b$:

- (A) b is order of magnitude for $a \geq 5$
(B) b is order of magnitude for $a < 5$
(C) a is order of magnitude for $b \leq 5$
(D) b is order of magnitude for $5 < a \leq 10$

54 JEE MAIN 2024 · 27 JAN S1

Given below are two statements:

Statement (I): Planck's constant and angular momentum have the same dimensions.

Statement (II): Linear momentum and moment of force have the same dimensions.

In light of the above statements, choose the correct answer from the options given below:

- (1) Statement I is true but Statement II is false
- (2) Both Statement I and Statement II are false
- (3) Both Statement I and Statement II are true
- (4) Statement I is false but Statement II is true

55 JEE MAIN 2023

If the velocity of light c , universal gravitational constant G and Planck's constant h are chosen as fundamental quantities. The dimensions of mass in the new system is:

- (1) $[h^{\frac{1}{2}} c^{\frac{1}{2}} G^{\frac{1}{2}}]$
- (2) $h^1 c^1 G^{-1}$
- (3) $[h^{-\frac{1}{2}} c^{-\frac{2}{2}} G^{\frac{1}{2}}]$
- (4) $[h^{\frac{1}{2}} c^{-\frac{3}{2}} G^{-\frac{1}{2}}]$

56 JEE MAIN 2023

If force F , velocity V and time T are considered as fundamental physical quantities, then dimensional formula of density will be:

- (1) FV^4T^{-6}
- (2) $FV^{-4}T^{-2}$
- (3) $F^2V^{-2}T^6$
- (4) $FV^{-2}T^2$

57 JEE MAIN 2023 · MATCHING

Match List I with List II.

List I:

- A. Planck's constant (h)
- B. Stopping potential (V_s)
- C. Work function (ϕ)
- D. Momentum (p)

List II:

- I. $[M^1 L^2 T^{-2}]$
- II. $[M^1 L^1 T^{-1}]$
- III. $[M^1 L^2 T^{-1}]$
- IV. $[M^1 L^2 T^{-3} A^{-1}]$

Choose the correct answer from the options given below:

- (A) A - III, B - I, C - II, D - IV
- (B) A - III, B - IV, C - I, D - II
- (C) A - II, B - IV, C - III, D - I
- (D) A - I, B - III, C - IV, D - II

58 JEE MAIN 2023 · MATCHING

Match List I with List II:

List I

- A. Angular momentum
- B. Torque
- C. Stress
- D. Pressure gradient

List II

- I. $[ML^2T^{-2}]$
- II. $[ML^{-2}T^{-2}]$
- III. $[ML^2T^{-1}]$
- IV. $[ML^{-1}T^{-2}]$

Choose the correct answer from the options given below:

- (1) A-I, B-IV, C-III, D-II
- (2) A-III, B-I, C-IV, D-II
- (3) A-II, B-III, C-IV, D-I
- (4) A-IV, B-II, C-I, D-III

59 JEE MAIN 2023 · MATCHING

Match List I with List II:

List I

- A. Surface tension
- B. Pressure
- C. Viscosity
- D. Impulse

List II

- I. $kg\ m^{-1}\ s^{-1}$
- II. $kg\ m\ s^{-1}$
- III. $kg\ m^{-1}\ s^{-2}$
- IV. $kg\ s^{-2}$

Choose the correct answer from the options given below:

- (1) A-IV, B-III, C-II, D-I
- (2) A-IV, B-III, C-I, D-II
- (3) A-III, B-IV, C-I, D-II
- (4) A-II, B-I, C-III, D-IV

60 JEE MAIN 2023

A cylindrical wire of mass (0.4 ± 0.01) g has length (8 ± 0.04) cm and radius (6 ± 0.03) mm. The maximum error in its density will be

- (1) 3.5%
- (2) 5%
- (3) 1%
- (4) 4%

61 JEE MAIN 2023

The speed of a wave produced in water is given by $\nu = \lambda^a g^b \rho^c$. Where λ , g and ρ are wavelength of wave, acceleration due to gravity and density of water respectively. The values of a , b and c respectively, are

- (1) 1, -1, 0
- (2) 1/2, 0, 1/2
- (3) 1, 1, 0
- (4) 1/2, 1/2, 0

62 JEE MAIN 2023 · NUMERICAL

A travelling microscope is used to determine the refractive index of a glass slab. If 40 divisions are there in 1 cm on main scale and 50 Vernier scale divisions are equal to 49 main scale divisions, then least count of the travelling microscope is $\times 10^{-6}$ m.

63 JEE MAIN 2023

The equation of a circle is given by $x^2 + y^2 = a^2$, where a is the radius. If the equation is modified to change the origin other than (0, 0), then find out the correct dimensions of A and B in a new equation:

$$(x - At)^2 + \left(y - \frac{t}{B}\right)^2 = a^2$$

The dimensions of t is given as $[T^{-1}]$.

- (1) $A = [L^{-1}T]$, $B = [LT^{-1}]$ (2) $A = [LT]$, $B = [L^{-1}T^{-1}]$
 (3) $A = [L^{-1}T^{-1}]$, $B =$ (4) $A = [L^{-1}T^{-1}]$, $B = [LT]$
 $[LT^{-1}]$

64 JEE MAIN 2023 · 25 JAN S1 · MATCHING

Match List I with List II:

List I

- A. Young's Modulus (Y)
 B. Co-efficient of Viscosity (η)
 C. Planck's Constant (h)
 D. Work Function (ϕ)

List II

- I. $[ML^{-1}T^{-1}]$
 II. $[ML^2T^{-1}]$
 III. $[ML^{-1}T^{-2}]$
 IV. $[ML^2T^{-2}]$

Choose the correct answer from the options given below:

- (1) A-II, B-III, C-IV, D-I (2) A-III, B-I, C-II, D-IV
 (3) A-I, B-III, C-IV, D-II (4) A-I, B-II, C-III, D-IV

65 JEE MAIN 2023 · 29 JAN S1 · MATCHING

Match List I with List II:

List I (Physical Quantity)

- A. Pressure gradient
 B. Energy density
 C. Electric Field
 D. Latent heat

List II (Dimensional Formula)

- I. $[M^0L^2T^{-2}]$
 II. $[M^1L^{-1}T^{-2}]$
 III. $[M^1L^{-2}T^{-2}]$
 IV. $[M^1L^1T^{-3}A^{-1}]$

Choose the correct answer from the options given below:

- (1) A-III, B-II, C-I, D-IV (2) A-II, B-III, C-IV, D-I
 (3) A-III, B-II, C-IV, D-I (4) A-II, B-III, C-I, D-IV

66 JEE MAIN 2023 · 30 JAN S2 · MATCHING

Match List I with List II

List I

- A. Torque
 B. Energy density
 C. Pressure gradient
 D. Impulse

List II

- I. $kg\ m^{-1}\ s^{-2}$
 II. $kg\ m\ s^{-1}$
 III. $kg\ m^{-2}\ s^{-2}$
 IV. $kg\ m^2\ s^{-2}$

Choose the correct answer from the options given below :

- (A) A-IV, B-III, C-I, D-II (B) A-I, B-IV, C-III, D-II
 (C) A-IV, B-I, C-II, D-III (D) A-IV, B-I, C-III, D-II

67 JEE MAIN 2023 · 31 JAN S1

If R , X_L and X_C represent resistance, inductive reactance and capacitive reactance. Then which of the following is dimensionless:

- (1) $R\ X_L\ X_C$ (2) $\frac{R}{\sqrt{X_L X_C}}$
 (3) $\frac{R}{X_L X_C}$ (4) $R\ \frac{X_L}{X_C}$

68 JEE MAIN 2023 · 8 APR S2 · MATCHING

Match List I with List II

List I

- A. Torque
 B. Stress
 C. Pressure gradient
 D. Coefficient of viscosity

List II

- I. $ML^{-2}T^{-2}$
 II. ML^2T^{-2}
 III. $ML^{-1}T^{-1}$
 IV. $ML^{-1}T^{-2}$

Choose the correct answer from the options given below :

- (1) A-III, B-IV, C-I, D-II (2) A-II, B-I, C-IV, D-III
 (3) A-II, B-IV, C-I, D-III (4) A-IV, B-II, C-III, D-I

69 JEE MAIN 2023 · 10 APR S2

In an experiment with vernier callipers of least count 0.1 mm, when two jaws are joined together the zero of vernier scale lies right to the zero of the main scale and 6th division of vernier scale coincides with the main scale division. While measuring the diameter of a spherical bob, the zero of vernier scale lies in between 3.2 cm and 3.3 cm marks and 4th division of vernier scale coincides with the main scale division. The diameter of bob is measured as

- (1) 3.22 cm (2) 3.18 cm
 (3) 3.26 cm (4) 3.25 cm

70 JEE MAIN 2023 · 11 APR S1

Given below are two statements:

Statement I: Astronomical unit (Au), Parsec (Pc) and Light year (ly) are units for measuring astronomical distances.

Statement II: $\text{Au} < \text{Parsec (Pc)} < \text{ly}$

In the light of the above statements, choose the most appropriate answer from the options given below:

- (1) Both Statements I and Statements II are incorrect
- (2) Statements I is correct but Statements II is incorrect
- (3) Both Statements I and Statements II are correct
- (4) Statements I is incorrect but Statements II is correct

71 JEE MAIN 2022 · 26 JUL S1 · NUMERICAL

In an experiment to determine the Young's modulus of a wire of a length exactly 1 m, the extension in the length of the wire is measured as 0.4 mm with an uncertainty of ± 0.02 mm when a load of 1 kg is applied. The diameter of the wire is measured as 0.4 mm with an uncertainty of ± 0.01 mm. The error in the measurement of Young's modulus (ΔY) is found to be $x \times 10^{10} \text{ N m}^{-2}$. The value of x is _____. (take $g = 10 \text{ m s}^{-2}$)

72 JEE MAIN 2022 · 27 JUL S1

A torque meter is calibrated to reference standards of mass, length and time each with 5% accuracy. After calibration, the measured torque with this torque meter will have net accuracy of

- (1) 15%
- (2) 25%
- (3) 75%
- (4) 5%

73 JEE MAIN 2022 · 29 JUL S1

Given below are two statements: One is labelled as Assertion (A) and other is labelled as Reason (R)

Assertion (A): Time period of oscillation of a liquid drop depends on surface tension (S), if density of the liquid is ρ and radius of the drop is r , then

$$T = K \sqrt{\frac{\rho r^3}{S}}$$

is dimensionally correct, where K is dimensionless.

Reason (R): Using dimensional analysis we get R.H.S. having different dimension than that of time period. In the light of above statements, choose the correct answer from the options given below.

- (1) Both (A) and (R) are true and (R) is the correct explanation of (A)
- (2) Both (A) and (R) are true but (R) is not the correct explanation of (A)
- (3) (A) is true but (R) is false
- (4) (A) is false but (R) is true

74 JEE MAIN 2022

If momentum P , area A and time T are taken as fundamental quantities, then the dimensional formula for coefficient of viscosity is

- (1) $PA^{-1}T^0$
- (2) PAT^{-1}
- (3) $PA^{-1}T^{-1}$
- (4) $PA^{-1}T^{-1}$

75 JEE MAIN 2022

In a Vernier Caliper 10 divisions of Vernier scale is equal to the 9 divisions of main scale. When both jaws of Vernier calipers touch each other, the zero of the Vernier scale is shifted to the left of zero of the main scale and 4th Vernier scale division exactly coincides with the main scale reading. One main scale division is equal to 1 mm. While measuring diameter of a spherical body, the body is held between two jaws. It is now observed that zero of the Vernier scale lies between 30 and 31 divisions of main scale reading and 6th Vernier scale division exactly coincides with the main scale reading. The diameter of the spherical body will be:

- (1) 3.02 cm
- (2) 3.06 cm
- (3) 3.10 cm
- (4) 3.20 cm

76 JEE MAIN 2022

Velocity (v) and acceleration (a) in two systems of units 1 and 2 are related as $v_2 = \frac{n}{m^2} v_1$ and $a_2 = \frac{a_1}{mn}$ respectively. Here m and n are constants. The relations for distance and time in two systems respectively are

- (A) $\frac{n^3}{m^3} L_1 = L_2$ and $\frac{n^2}{m} T_1 = T_2$
- (B) $L_1 = \frac{n^4}{m^2} L_2$ and $T_1 = \frac{n^2}{m} T_2$
- (C) $L_1 = \frac{n^2}{m} L_2$ and $T_1 = \frac{n^4}{m^2} T_2$
- (D) $\frac{n^2}{m} L_1 = L_2$ and $\frac{n^4}{m^2} T_1 = T_2$

77 JEE MAIN 2022

The SI unit of a physical quantity is Pascal-sec. The dimensional formula of this quantity will be

- (A) ML^2T^{-1}
- (B) $M^{-1}L^3T^0$
- (C) $ML^{-1}T^{-1}$
- (D) $ML^{-1}T^{-2}$

78 JEE MAIN 2022 · NUMERICAL

The Vernier constant of Vernier callipers is 0.1 mm and it has zero error of (-0.05 cm) . While measuring diameter of a sphere, the main scale reading is 1.7 cm and coinciding vernier division is 5. The corrected diameter will be _____ $\times 10^{-2} \text{ cm}$.

79 JEE MAIN 2022

The distance of the Sun from earth is $1.5 \times 10^{11} \text{ m}$ and its angular diameter is $2000''$ when observed from the earth. The diameter of the Sun will be

- (A) $2.45 \times 10^{10} \text{ m}$
- (B) $1.45 \times 10^{10} \text{ m}$
- (C) $1.45 \times 10^9 \text{ m}$
- (D) $0.14 \times 10^9 \text{ m}$

80 JEE MAIN 2022

A screw gauge of pitch 0.5 mm is used to measure the diameter of uniform wire of length 6.8 cm, the main scale reading is 1.5 mm and circular scale reading is 7. The calculated curved surface area of wire to appropriate significant figures is

[Screw gauge has 50 divisions on the circular scale]

- (1) 6.8 cm^2 (2) 3.4 cm^2
(3) 3.9 cm^2 (4) 2.4 cm^2

81 JEE MAIN 2022

If $Z = \frac{A^2 B^3}{C^4}$, then the relative error in Z will be

- (1) $\frac{2\Delta A}{A} + \frac{3\Delta B}{B} + \frac{4\Delta C}{C}$
(2) $\frac{\Delta A}{A} + \frac{\Delta B}{B} + \frac{\Delta C}{C}$
(3) $\frac{2\Delta A}{A} + \frac{3\Delta B}{B} - \frac{4\Delta C}{C}$
(4) $\frac{\Delta A}{A} + \frac{\Delta B}{B} + \frac{\Delta C}{C}$

82 JEE MAIN 2021 · 18 MAR S1

The time period of a simple pendulum is given by $T = 2\pi\sqrt{\frac{L}{g}}$. The measured value of the length of the pendulum is 10 cm known to a 1 mm accuracy. The time for 200 oscillations of the pendulum is found to be 100 seconds using a clock of 1 s resolution. The percentage accuracy in the determination of g using this pendulum is x . The value of x to the nearest integer is:

- (1) 2% (2) 3%
(3) 5% (4) 4%

83 JEE MAIN 2021

In a Screw Gauge, fifth division of the circular scale coincides with the reference line when the ratchet is closed. There are 50 divisions on the circular scale, and the main scale moves by 0.5 mm on a complete rotation. For a particular observation the reading on the main scale is 5 mm and the 20th division of the circular scale coincides with reference line. Calculate the true reading.

- (1) 5.20 mm (2) 5.00 mm
(3) 5.15 mm (4) 5.25 mm

84 JEE MAIN 2021

If E , L , M and G denote the quantities as energy, angular momentum, mass and constant of gravitation respectively, then the dimensions of P in the formula $P = EL^2 M^{-5} G^{-2}$ are:

- (1) $[M^1 L^1 T^{-2}]$ (2) $[M^0 L^1 T^0]$
(3) $[M^{-1} L^{-1} T^2]$ (4) $[M^0 L^0 T^0]$

85 JEE MAIN 2021

The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. Measured value of L is 1.0 m from meter scale having a minimum division of 1 mm and time of one complete oscillation is 1.95 s measured from stopwatch of 0.01 s resolution. The percentage error in the determination of g will be:

- (1) 1.03% (2) 1.33%
(3) 1.30% (4) 1.13%

86 JEE MAIN 2021

Which of the following is not a dimensionless quantity?

- (1) Power factor
(2) Quality factor
(3) Permeability of free space (μ_0)
(4) Relative magnetic permeability (μ_r)

87 JEE MAIN 2021

One main scale division of a vernier callipers is a cm and n^{th} division of the vernier scale coincide with $(n-1)^{\text{th}}$ division of the main scale. The least count of the callipers in mm is:

- (1) $\frac{10a}{(n-1)10n}$ (2) $\frac{10a}{(n-1)}$
(3) $\frac{(n-1)10n}{a}$ (4) $\frac{10a}{n}$

88 JEE MAIN 2021

The vernier scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement it was noted that 0 on the vernier scale lies between 8.5 cm and 8.6 cm. Vernier coincidence is 6, then the correct value of measurement is cm. (least count = 0.01 cm)

- (1) 8.36 cm (2) 8.54 cm
(3) 8.58 cm (4) 8.56 cm

89 JEE MAIN 2021 · MATCHING

Match List-(I) with List-(II).

List-(I)

- (a) R_H (Rydberg constant)
(b) h (Planck's constant)
(c) μ_B (Magnetic field energy density)
(d) η (coefficient of viscosity)

List-(II)

- (i) $\text{kg m}^{-1} \text{s}^{-1}$
(ii) $\text{kg m}^2 \text{s}^{-1}$
(iii) m^{-1}
(iv) $\text{kg m}^{-1} \text{s}^{-2}$

Choose the most appropriate answer from the options given below:

- (1) (a) - (iv), (b) - (ii), (c) - (i), (d) - (iii)
(2) (a) - (ii), (b) - (iii), (c) - (iv), (d) - (i)
(3) (a) - (iii), (b) - (ii), (c) - (iv), (d) - (i)
(4) (a) - (iii), (b) - (ii), (c) - (i), (d) - (iv)

90 JEE MAIN 2021 · MATCHING

Match List I with List II.

List-I

- a. Capacitance, C
- b. Permittivity of free space, ϵ_0
- c. Permeability of free space, μ_0
- d. Electric field, E

List-II

- i. $M^1 L^1 T^{-3} A^{-1}$
- ii. $M^{-1} L^{-3} T^4 A^2$
- iii. $M^{-1} L^{-2} T^4 A^2$
- iv. $M^1 L^1 T^{-2} A^{-2}$

Choose the correct answer from the options given below

- (1) (a) → (iii), (b) → (ii), (c) → (iv), (d) → (i)
- (2) (a) → (iii), (b) → (iv), (c) → (ii), (d) → (i)
- (3) (a) → (iv), (b) → (ii), (c) → (iii), (d) → (i)
- (4) (a) → (i), (b) → (iii), (c) → (ii), (d) → (iv)

91 JEE MAIN 2021

If force (F), length (L) and time (T) are taken as the fundamental quantities. Then what will be the dimension of density?

- (1) $[F L^{-4} T^2]$
- (2) $[F L^{-3} T^3]$
- (3) $[F L^{-3} T^2]$
- (4) $[F L^{-5} T^2]$

92 JEE MAIN 2021 · MATCHING

Match List - I with List - II:

List - I

- (a) h (Planck's constant)
- (b) E (kinetic energy)
- (c) V (electric potential)
- (d) P (linear momentum)

List - II

- (i) MLT^{-1}
- (ii) ML^2T^{-1}
- (iii) ML^2T^{-2}
- (iv) $ML^2I^{-1}T^{-3}$

Choose the correct answer from the options given below:

- (1) (a) → (ii), (b) → (iii), (c) → (iv), (d) → (i)
- (2) (a) → (i), (b) → (ii), (c) → (iv), (d) → (iii)
- (3) (a) → (iii), (b) → (ii), (c) → (iv), (d) → (i)
- (4) (a) → (iii), (b) → (iv), (c) → (ii), (d) → (i)

93 JEE MAIN 2021

A ball weighing 10 g is moving with a velocity of $90ms^{-1}$. If the uncertainty in its velocity is 5%, then the uncertainty in its position is $x \times 10^{-33}$ m. (Rounded off to the nearest integer) [Given: $h = 6.63 \times 10^{-34} Js$]

- (A) 1
- (B) 2
- (C) 3
- (D) 4

94 JEE MAIN 2021

If time (t), velocity (v), and angular momentum (l) are taken as the fundamental units. Then the dimension of mass (m) in terms of t, v and l is:

- (1) $[t^{-1}v^{-1}l^{-2}]$
- (2) $[t^1v^2l^{-1}]$
- (3) $[t^{-2}v^{-1}l^1]$
- (4) $[t^{-1}v^{-2}l^1]$

95 JEE MAIN 2020

Amount of solar energy received on the earth's surface per unit area per unit time is defined as a solar constant.

Dimension of solar constant is:

- (1) ML^2T^{-2}
- (2) MLT^{-2}
- (3) $M^2L^0T^{-1}$
- (4) ML^0T^{-3}

96 JEE MAIN 2020

If speed V, area A, and force F are chosen as fundamental units, then the dimension of Young's modulus will be:

- (1) $FA^{-1}V^0$
- (2) FA^2V^{-1}
- (3) FA^2V^{-3}
- (4) $FA^{-2}V^{-2}$

97 JEE MAIN 2020

The least count of the main scale of a vernier callipers is 1 mm. Its vernier scale is divided into 10 divisions and coincide with 9 divisions of the main scale. When jaws are touching each other, the 7th division of vernier scale coincides with a division of main scale and the zero of vernier scale is lying right side of the zero of main scale. When this vernier is used to measure length of a cylinder the zero of the vernier scale between 3.1 cm and 3.2 cm and 4th VSD coincides with a main scale division. The length of the cylinder is : (VSD is vernier scale division)

- (1) 3.21 cm
- (2) 2.99 cm
- (3) 3.2 cm
- (4) 3.07 cm

98 JEE MAIN 2020

A screw gauge has 50 divisions on its circular scale. The circular scale is 4 units ahead of the pitch scale marking, prior to use. Upon one complete rotation of the circular scale, a displacement of 0.5 mm is noticed on the pitch scale. The nature of zero error involved, and the least count of the screw gauge, are respectively:

- (A) Negative, 2 μm
- (B) Positive, 10 μm
- (C) Positive, 0.1 μm
- (D) Positive, 0.1 mm

99 JEE MAIN 2020

If momentum (P), area (A) and time (T) are taken to be the fundamental quantities then the dimensional formula for energy is:

- (1) $[PA^{-1}T^{-2}]$ (2) $[PA^{1/2}T^{-1}]$
 (3) $[P^2AT^{-2}]$ (4) $[P^{1/2}AT^{-1}]$

100 JEE MAIN 2020

A quantity x is given by (IFv^2/WL^4) in terms of moment of inertia I, force F, velocity v, work W and Length L. The dimensional formula for x is same as that of:

- (1) Planck's constant (2) Force constant
 (3) Energy density (4) Coefficient of viscosity

101 JEE MAIN 2020

A student measuring the diameter of a pencil of circular cross-section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.45 mm, 5.65 mm. The average of these four readings is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as:

- (1) $(5.5375 \pm 0.0739) \text{ mm}$ (2) $(5.538 \pm 0.074) \text{ mm}$
 (3) $(5.54 \pm 0.07) \text{ mm}$ (4) $(5.5375 \pm 0.0740) \text{ mm}$

102 JEE MAIN 2020

A screw gauge advances by 3mm in 6 rotations. There are 50 divisions on circular scale. Find least count of screw gauge?

- (1) 0.002 cm (2) 0.001 cm
 (3) 0.01 cm (4) 0.02 cm

103 JEE MAIN 2020

The dimensional formula of $\sqrt{\frac{hc^5}{G}}$ is

- (1) $[ML^2T^{-3}]$ (2) $[ML^2T^{-2}]$
 (3) $[ML^{-2}T^2]$ (4) $[MLT^{-2}]$

104 JEE MAIN 2019

If Surface tension (S), Moment of Inertia (I) and Planck's constant (h), were to be taken as the fundamental units, the dimensional formula for linear momentum would be:

- (A) $S^{1/2}I^{1/2}h^0$ (B) $S^{1/2}I^{3/2}h^{-1}$
 (C) $S^{3/2}I^{1/2}h^0$ (D) $S^{1/2}I^{1/2}h^{-1}$

105 JEE MAIN 2019

The force of interaction between two atoms is given by $F = \alpha\beta \exp\left(-\frac{x^2}{\alpha kT}\right)$; where x is the distance, k is the Boltzmann constant and T is temperature and α and β are two constants. The dimensions of β is:

- (1) $M^0L^2T^{-4}$ (2) M^2LT^{-4}
 (3) MLT^{-2} (4) $M^2L^2T^{-2}$

106 JEE MAIN 2019

The density of a material in SI units is 128 kg m^{-3} . In certain units in which the unit of length is 25 cm and the unit of mass is 50 g, the numerical value of density of the material is:

- (1) 410 (2) 16
 (3) 40 (4) 640

107 JEE MAIN 2019

The diameter and height of a cylinder are measured by a meter scale to be $12.6 \pm 0.1 \text{ cm}$ and $34.2 \pm 0.1 \text{ cm}$, respectively. What will be the value of its volume in appropriate significant figures?

- (1) $4264 \pm 81 \text{ cm}^3$ (2) $4264.4 \pm 81.0 \text{ cm}^3$
 (3) $4260 \pm 80 \text{ cm}^3$ (4) $4300 \pm 80 \text{ cm}^3$

108 JEE MAIN 2019

The least count of the main scale of a screw gauge is 1 mm. The minimum number of divisions on its circular scale required to measure $5 \mu\text{m}$ diameter of a wire is:

- (A) 50 (B) 100
 (C) 500 (D) 200

109 JEE MAIN 2019

If speed (V), acceleration (A) and force (F) are considered as fundamental units, the dimension of Young's modulus will be:

- (1) $V^{-2}A^2F^{-2}$ (2) $V^{-2}A^2F^2$
 (3) $V^{-4}A^{-2}F$ (4) $V^{-4}A^2F$

110 JEE MAIN 2019

In the density measurement of a cube, the mass and edge length are measured as $(10.00 \pm 0.10) \text{ kg}$ and $(0.10 \pm 0.01) \text{ m}$, respectively. The error in the measurement of density is:

- (1) 0.31 (2) 0.10
 (3) 0.07 (4) 0.01

111 JEE MAIN 2019

Expression for time in terms of G (universal gravitational constant), h (Planck constant) and c (speed of light) is proportional to:

- (A) $\sqrt{\frac{Gh}{c^3}}$ (B) $\sqrt{\frac{hc^5}{G}}$
 (C) $\sqrt{\frac{Gh}{c^5}}$ (D) $\sqrt{\frac{c^3}{Gh}}$

112 JEE MAIN 2019

The area of a square is 5.29 cm^2 . The area of 7 such squares taking into account the significant figures is:

- (A) 37.03 cm^2 (B) 37.030 cm^2
 (C) 37.0 cm^2 (D) 37 cm^2

113 JEE MAIN 2019

The pitch and the number of divisions, on the circular scale, for a given screw gauge are 0.5 mm and 100 respectively. When the screw gauge is fully tightened without any object, the zero of its circular scale lies 3 divisions below the mean line.

The readings of the main scale and the circular scale, for a thin sheet, are 5.5 mm and 48 respectively, the thickness of this sheet is:

- (1) 5.755 mm (2) 5.740 mm
(3) 5.725 mm (4) 5.950 mm

114 JEE MAIN 2019

Let L , R , C and V represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{L}{RCV}$ in SI units will be:

- (1) $[LTA]$ (2) $[A^{-1}]$
(3) $[LT^2]$ (4) $[LA^{-2}]$

Answer key · Units and Measurements

1 B	2 A	3 A	4 A	5 2	6 C
7 A	8 B	9 B	10 A	11 C	12 B
13 A	14 D	15 B	16 B	17 4	18 2
19 1	20 0	21 3	22 2	23 2	24 2
25 A	26 A	27 A	28 C	29 B	30 A
31 A	32 D	33 2	34 C	35 1	36 2
37 3	38 2	39 4	40 4	41 D	42 1
43 3	44 3	45 2	46 1	47 3	48 2
49 4	50 3	51 1	52 3	53 B	54 1
55 1	56 2	57 B	58 2	59 2	60 4
61 4	62 5	63 2	64 2	65 3	66 D
67 2	68 3	69 2	70 2	71 2	72 2
73 3	74 1	75 3	76 A	77 C	78 180
79 C	80 2	81 1	82 2	83 3	84 4
85 4	86 3	87 4	88 2	89 3	90 1
91 1	92 1	93 A	94 4	95 4	96 1
97 4	98 B	99 2	100 3	101 3	102 2
103 (2)	104 A	105 2	106 3	107 3	108 D
109 4	110 1	111 C	112 C	113 3	114 2

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

Ref 12507

Medium ~1 min Dimensions of Gravitational Constant

QUICK APPROACH Write the dimensions of G from Newton's law of gravitation and of h from $E = h\nu$, then match the powers of M , L and T .

Write G as a product of powers of h , T , L and M , then match the exponents of each base dimension.

Step 1. From $F = Gm_1m_2/r^2$, the dimensions of G are $[M^{-1}L^3T^{-2}]$.

Step 2. Planck's constant is energy times time, so $[h] = [ML^2T^{-1}]$.

Step 3. Let $G = h^a T^b L^c M^d$. Comparing powers:

- mass: $a + d = -1$
- length: $2a + c = 3$
- time: $-a + b = -2$

Step 4. Every option has h to the first power, so take $a = 1$.

Then $d = -2$, $c = 1$ and $b = -1$.

Step 5. Check: $hT^{-1}LM^{-2}$ has dimensions $M^{1-2}L^{2+1}T^{-1-1} = M^{-1}L^3T^{-2}$, which is the dimension of G .

Answer: (B) $hT^{-1}LM^{-2}$

2 Answer: A

Ref 12516

Medium ~1 min Screw gauge (micrometer) — least count and zero error

QUICK APPROACH Start by calculating the least count of the screw gauge, then determine the zero error using the circular scale reading when the studs are in contact.

Least count (LC) = pitch / number of divisions = 0.1 mm / 100 = 0.001 mm.

Zero error: when jaws are closed circular reading = 5 divisions, so zero error = 5 × LC = 5 × 0.001 mm = +0.005 mm.

Observed reading for the sphere = main scale reading + circular reading × LC = 5.000 mm + 50 × 0.001 mm = 5.050 mm.

Corrected reading = observed reading – zero error = 5.050 mm – 0.005 mm = 5.045 mm.

COMMON TRAPS

- **Treating the 5-division zero reading as negative zero error.** Here zero error = $+5 \times \text{LC} = +0.005 \text{ mm}$, so corrected reading = observed reading - zero error = $5.050 - 0.005 = 5.045 \text{ mm}$. *Avoid it:* When jaws/studs are closed, ask: what reading is the instrument showing for a true zero length? If it shows $+0.005 \text{ mm}$, subtract 0.005 from every observed reading.
- **Using pitch directly as least count.** The phrase "There are 100 divisions in the circular scale" must be used: $\text{LC} = \text{pitch} / \text{number of circular divisions} = 0.1 \text{ mm} / 100 = 0.001 \text{ mm}$. *Avoid it:* Before using circular scale readings, write LC explicitly with units and check it is much smaller than the pitch.

REVIEW Practise identifying zero error sign from closed-jaw circular scale diagrams/statements. For every screw gauge problem, write four lines: LC, zero error, observed reading, corrected reading.

3 Answer: A

Ref 12572

Hard ~1.5 min Young's modulus and error propagation

QUICK APPROACH Start by applying the formula for Young's modulus and then use the rules of error propagation to find the relative error in terms of the measurements and their least counts.

Young's modulus for the wire is given by the formula:

$$Y = \frac{4FL}{\pi d^2 e}$$

Relative error (neglecting error in applied load F) is approximated by:

$$\frac{\Delta Y}{Y} = \frac{\Delta L}{L} + 2 \frac{\Delta d}{d} + \frac{\Delta e}{e}$$

Convert given values to SI and uncertainties (using least counts):

$$d = 0.08 \text{ cm} = 8.0 \times 10^{-4} \text{ m}$$

$$\Delta d = 0.001 \text{ cm} = 1.0 \times 10^{-5} \text{ m}$$

$$L = 150 \text{ cm} = 1.50 \text{ m}$$

$$\Delta L = 0.1 \text{ cm} = 1.0 \times 10^{-3} \text{ m}$$

$$e = 0.5 \text{ cm} = 5.0 \times 10^{-3} \text{ m}$$

$$\Delta e = 0.001 \text{ cm} = 1.0 \times 10^{-5} \text{ m}$$

Compute relative uncertainties:

$$\frac{\Delta L}{L} = \frac{1.0 \times 10^{-3}}{1.50} = 6.6667 \times 10^{-4}$$

$$\frac{\Delta d}{d} = \frac{1.0 \times 10^{-5}}{8.0 \times 10^{-4}} = 1.25 \times 10^{-2}$$

$$\frac{\Delta e}{e} = \frac{1.0 \times 10^{-5}}{5.0 \times 10^{-3}} = 2.0 \times 10^{-3}$$

So

$$\frac{\Delta Y}{Y} = 6.6667 \times 10^{-4} + 2(1.25 \times 10^{-2}) + 2.0 \times 10^{-3}$$

$$\frac{\Delta Y}{Y} = 0.00066667 + 0.025 + 0.002 = 0.02766667$$

Now compute Y itself:

$$F = 100 \text{ N}$$

Substitute values:

$$Y = \frac{4 \times 100 \times 1.50}{\pi (8.0 \times 10^{-4})^2 (5.0 \times 10^{-3})}$$

Numerical evaluation gives:

$$Y \approx 5.97 \times 10^{10} \text{ N/m}$$

Hence absolute error:

$$\Delta Y = \frac{\Delta Y}{Y} \times Y = 0.0276667 \times 5.97 \times 10^{10}$$

$$\Delta Y \approx 1.65 \times 10^9 \text{ N/m}$$

$$\text{Therefore } \alpha \approx 1.65 \text{ (error } \approx 1.65 \times 10^9 \text{ N/m)}.$$

4 Answer: A

Ref 12631

Medium ~1 min Dimensional analysis of photoelectric quantities

QUICK APPROACH Start by recalling the dimensional formulas of fundamental physical quantities like energy, frequency, and electric potential, then express each given quantity in terms of these base dimensions.

Find the dimensions of each quantity in List-I from a formula you know.

Step 1. Planck's constant. From $E = h\nu$, $[h] = [E]/[\nu] = ML^2T^{-2}/T^{-1} = ML^2T^{-1}$. This is III.

Step 2. Stopping potential. A potential is energy per charge, and charge has dimensions AT . So $[V] = ML^2T^{-2}/(AT) = ML^2T^{-3}A^{-1}$. This is IV.

Step 3. Work function. It is an energy, so its dimensions are ML^2T^{-2} . This is I.

Step 4. Threshold frequency. A frequency has dimensions T^{-1} . This is II.

The matching is A-III, B-IV, C-I, D-II.

Answer: (A) A-III, B-IV, C-I, D-II

COMMON TRAPS

- **Giving Planck's constant the dimensions of energy.** Planck's constant is energy divided by frequency, so it has one extra power of time: ML^2T^{-1} . *Avoid it:* Write $h = E/\nu$ and divide the dimensions before matching.
 - **Treating stopping potential as an energy.** Stopping potential is a voltage, energy per unit charge, not the energy eV_0 . *Avoid it:* Divide energy by charge AT to get $ML^2T^{-3}A^{-1}$.
- REVIEW** Dimensions of energy, potential, charge and frequency. The photoelectric equation $h\nu = \phi + eV_0$.

5 Answer: 2

Ref 12754

Hard ~1.5 min

QUICK APPROACH Write the dimensions of h , c and G in terms of M , L and T , then simplify each square root in List-II.

Find the dimensions of each expression in List-II using $[h] = ML^2T^{-1}$, $[c] = LT^{-1}$ and $[G] = M^{-1}L^3T^{-2}$.

Step 1. Expression I. $[hc] = ML^3T^{-2}$. Dividing by $[G]$ gives M^2 , and the square root gives M . So I is the kilogram: C-I.

Step 2. Expression II. $[Gh] = L^5T^{-3}$ and $[c^5] = L^5T^{-5}$. The ratio is T^2 , and the square root is T . So II is the second: B-II.

Step 3. Expression IV. $[Gh/c^3] = L^5T^{-3}/(L^3T^{-3}) = L^2$, and the square root is L . So IV is the metre: A-IV.

Step 4. Expression III is the only one that contains the Boltzmann constant k , which links energy to temperature, so it goes with the kelvin: D-III.

The matching is A-IV, B-II, C-I, D-III.

Answer: (2) A-IV, B-II, C-I, D-III

6 Answer: C

Ref 12811

Medium ~1 min Vernier caliper and zero error

QUICK APPROACH Start by understanding the concept of zero error in Vernier calipers and calculate the least count based on the given divisions of main and Vernier scales.

For 10 Vernier divisions, typically 10 VSD = 9 MSD. So VSD = 0.9 mm.

Least count (LC) = 1 MSD - 1 VSD = 1 mm - 0.9 mm = 0.1 mm.

When jaws are closed the 7th Vernier division coincides, so zero reading = $7 \times \text{LC} = 7 \times 0.1 \text{ mm} = 0.7 \text{ mm}$.

0.7 mm = 0.07 cm.

Since the zero of the Vernier is shifted to the right of the main scale zero, the closed-jaws reading is positive → positive zero error.

Hence the zero error is 0.07 cm positive (option C).

COMMON TRAPS

- **Interpreting right shift as negative zero error.** Right of main-scale zero means closed-jaws reading is positive, so zero error is positive; zero correction would be negative. *Avoid it:* Draw the main scale zero and Vernier zero. If the Vernier zero lies to the right, ask: would the caliper display a positive length with no object? If yes, zero error is positive.
- **Writing 7 divisions as 0.7 cm instead of 0.7 mm.** Least count here is 0.1 mm, so $7 \text{ LC} = 0.7 \text{ mm} = 0.07 \text{ cm}$. *Avoid it:* Carry units in every multiplication: $7 \times 0.1 \text{ mm} = 0.7 \text{ mm}$, then divide by 10 to convert mm to cm.

REVIEW Zero error vs zero correction sign conventions for Vernier calipers. · Practice carrying units through LC calculations, especially mm to cm conversion.

7 Answer: A

Ref 12814

Medium ~1 min Dimensional analysis of electrical quantities

QUICK APPROACH Start by expressing the dimensional formulas of inductance (L), capacitance (C), and resistance (R) using the fundamental dimensions derived from voltage and current.

Find dimensions of L, C and R starting from volt and current.

V has dimensions $ML^2T^{-3}A^{-1}$

L (inductance) from $V = L dI/dt$ gives

$$L = ML^2T^{-2}A^{-2}$$

C (capacitance) from $C = Q/V$ and $Q = IT$ gives

$$C = M^{-1}L^{-2}T^4A^2$$

R (resistance) from $R = V/I$ gives

$$R = ML^2T^{-3}A^{-2}$$

Now compute LC:

$$L \cdot C = T^2$$

So $\sqrt{LC} = T$

Therefore

$\frac{R}{\sqrt{LC}}$ has dimensions

$$ML^2T^{-3}A^{-2} \cdot T^{-1}$$

$$= ML^2T^{-4}A^{-2}$$

which matches the required dimensional formula. Hence option A is correct.

COMMON TRAPS

- **Mixing up the inductance L with the length dimension L.** In $ML^2T^{-4}A^{-2}$ the letters are base dimensions; the inductance symbol is a separate quantity. *Avoid it:* Call the inductance L_{ind} in rough work so the two never mix.
- **Forgetting the square root in $\sqrt{LC}$.** LC has dimensions T^2 , so $\sqrt{LC}$ has dimensions T, not T^2 . *Avoid it:* Simplify LC first, then apply any root in the option.

REVIEW Dimensions of R, L and C from circuit formulas. · Why $\sqrt{LC}$ is a time and $\sqrt{L/C}$ a resistance.

8 Answer: B

Ref 12939

Medium ~1 min Error propagation in derived quantities

QUICK APPROACH Write $\rho = \frac{4m}{\pi d^2 l}$ and add the fractional errors, counting the diameter twice.

Use the formula for density of a cylinder and propagate fractional errors.

$$\rho = \frac{4m}{\pi d^2 l}$$

Hence fractional error adds with powers of variables:

$$\frac{\Delta \rho}{\rho} = \frac{\Delta m}{m} + \frac{\Delta l}{l} + 2 \frac{\Delta d}{d}$$

Calculate each term separately:

$$\frac{\Delta m}{m} = \frac{0.02}{97.42}$$

$$\frac{\Delta m}{m} = 2.053 \times 10^{-4}$$

$$\frac{\Delta m}{m} = 0.02053\%$$

$$\frac{\Delta l}{l} = \frac{0.05}{8.35}$$

$$\frac{\Delta l}{l} = 5.988 \times 10^{-3}$$

$$\frac{\Delta l}{l} = 0.5988\%$$

$$\frac{\Delta d}{d} = \frac{0.02}{20.20}$$

$$\frac{\Delta d}{d} = 9.90099 \times 10^{-4}$$

$$\frac{\Delta d}{d} = 0.09901\%$$

Double the diameter term:

$$2\frac{\Delta d}{d} = 0.19802\%$$

Sum the percentage contributions:

$$\frac{\Delta \rho}{\rho} = 0.02053\% + 0.5988\% + 0.19802\%$$

$$\frac{\Delta \rho}{\rho} = 0.81735\% \approx 0.82\%$$

Therefore the correct choice is 0.82% (option B).

COMMON TRAPS

- **Forgetting the factor 2 on the diameter error.** In error propagation for products/powers, the fractional error contribution is multiplied by the absolute value of the power: if $\rho \propto d^{-2}$, contribution is $2\Delta d/d$. *Avoid it:* Before substituting numbers, rewrite the dependency as $\rho \propto m^{-1}l^{-1}d^{-2}$ and mark the powers 1, 1, 2.
- **Using diameter error only once because it is in the denominator.** Each repeated factor contributes separately: $d^2 = d \cdot d$, so its relative error is $\Delta d/d + \Delta d/d$. *Avoid it:* Mentally expand d^2l as $d \times d \times l$ while adding maximum fractional errors.

REVISE The power rule for maximum fractional error: for $Q = x^a y^b z^c$, add $|a|\Delta x/x + |b|\Delta y/y + |c|\Delta z/z$. Practice converting between fractional error and percentage error: multiply by 100 only once.

9 Answer: B

Ref 11149

Medium ~1.5 min Dimensional Analysis

QUICK APPROACH Use the principle of dimensional homogeneity to equate the dimensions of each term in the modified Bernoulli equation to the dimensions of pressure.

Use the principle of dimensional homogeneity: all terms in Bernoulli's equation must have the same dimensions as pressure. The standard Bernoulli equation is $P + \rho gh + \frac{1}{2}\rho v^2 = \text{constant}$, and each term has the dimension of pressure $[ML^{-1}T^{-2}]$.

1. From the term $\rho g(h + Bt)$:

- h has dimension $[L]$.
- Therefore Bt must also have dimension $[L]$.

Since $t = [T]$,

$$[B][T] = [L] \Rightarrow [B] = [LT^{-1}] = [M^0LT^{-1}].$$

2. From the term $(P + \frac{A}{Bt^2})$:

- P has dimension $[ML^{-1}T^{-2}]$.
- Therefore $\frac{A}{Bt^2}$ must also have the same dimension.

First find $[Bt^2]$:

$$[B][t^2] = (LT^{-1})(T^2) = LT.$$

Now,

$$\frac{A}{LT} = ML^{-1}T^{-2}$$

$$\Rightarrow A = (ML^{-1}T^{-2})(LT) = ML^0T^{-1}.$$

Thus,

$$A = [ML^0T^{-1}], \\ B = [M^0LT^{-1}].$$

Hence option B is correct.

COMMON TRAPS

- **Confusion between 'Bt' and 'B*t' units.** Since h and Bt are added, they must have the same dimension. As t is time $[T]$, B must have dimension length/time $[LT^{-1}]$. *Avoid it:* Write dimensional equality explicitly: $[B][T] = [L]$, so $[B] = [LT^{-1}]$.
- **Misinterpretation of the term $A/(Bt^2)$.** Dimensions multiply, so $[Bt^2] = [B][T]^2$; since $[B] = [LT^{-1}]$, multiplying by $[T]^2$ gives $[LT]$. *Avoid it:* Square the time dimension explicitly whenever t^2 appears, not just use t dimension once.

REVISE Focus on dimensional homogeneity principles, especially in adding terms and rearranging equations. Practice squaring and multiplying dimensions involving time and length carefully.

10 Answer: A

Ref 11154

Medium ~1 min Propagation of Errors

QUICK APPROACH Use the propagation of errors rule for addition, where the absolute uncertainties add when quantities are summed.

Springs in parallel add directly:

$$k_{eq} = k_1 + k_2 = 10 + 20 = 30 \text{ N/m}$$

Step 1. Absolute error. For a sum, the absolute errors add:

$$\Delta k_{eq} = \Delta k_1 + \Delta k_2 = 0.2 + 0.3 = 0.5 \text{ N/m}$$

Step 2. Percentage error.

$$\frac{\Delta k_{eq}}{k_{eq}} \times 100 = \frac{0.5}{30} \times 100 \approx 1.67\%$$

Do not add the two percentage errors (2% and 1.5%). That rule is for products and quotients, not for sums.

Answer: (A) 1.67%

COMMON TRAPS

- **Using series-spring formula instead of parallel sum.** For springs in parallel, extensions are same and forces add, so $k = k_1 + k_2$. *Avoid it:* Before substituting, write the physical relation for the given connection: parallel springs $\rightarrow k = k_1 + k_2$; series springs $\rightarrow 1/k = 1/k_1 + 1/k_2$.
- **Adding percentage errors instead of absolute errors for addition.** For $k = k_1 + k_2$, absolute errors add: $\Delta k = \Delta k_1 + \Delta k_2 = 0.5 \text{ N/m}$. Percentage error is found only after dividing by $k = 30 \text{ N/m}$. *Avoid it:* Identify operation first: addition/subtraction $\rightarrow$ add absolute errors; multiplication/division/powers $\rightarrow$ add relative errors.

REVISE Spring combinations: parallel gives larger k , series gives smaller k . · Memorize propagation rules by operation, not by habit: addition/subtraction use absolute errors; multiplication/division use fractional errors.

11 Answer: C

Ref 11210

Easy ~1 min Significant Figures

QUICK APPROACH Start by adding the numbers normally, then use the rule for significant figures in addition which involves rounding the result to the least number of decimal places in the given quantities.

When quantities are added, the result can have only as many decimal places as the term with the fewest decimal places.

Step 1. Decimal places.

- 52.01 m: two
- 153.2 m: one
- 0.123 m: three

The least is one decimal place, set by 153.2 m.

Step 2. Add.

$$52.01 + 153.2 + 0.123 = 205.333 \text{ m}$$

Step 3. Round to one decimal place. 205.333 $\rightarrow$ 205.3 m.

Answer: (C) 205.3 m

12 Answer: B

Ref 11445

Medium ~1 min Dimensional Analysis of Electromagnetic Quantities

QUICK APPROACH Start by writing the SI units of permittivity, electric field, and time, then use dimensional analysis to combine these units step by step.

Step 1. Unit of ϵE . From Gauss's law, the field just outside a charged conductor is $E = \sigma/\epsilon_0$, so $\epsilon_0 E = \sigma$, a charge per unit area. Its unit is C/m^2 .

You can confirm this directly: ϵ_0 has unit $\text{C}^2 \text{N}^{-1} \text{m}^{-2}$ and E has unit N/C , so

$$[\epsilon_0 E] = \frac{\text{C}^2}{\text{N m}^2} \cdot \frac{\text{N}}{\text{C}} = \frac{\text{C}}{\text{m}^2}$$

Step 2. Divide by time.

$$\left[\frac{\epsilon_0 E}{t} \right] = \frac{\text{C}}{\text{m}^2 \text{s}} = \frac{\text{A}}{\text{m}^2}$$

This is a current density. It is the same quantity as the

displacement current density $\epsilon_0 \partial E / \partial t$.

Answer: (B) A/m^2

COMMON TRAPS

- **Forgetting the 'per meter' in permittivity unit.** Permittivity has unit farad per metre, not farad: $[\epsilon] = \text{Fm}^{-1} = \text{C}^2/(\text{Nm}^2)$. *Avoid it:* Whenever writing ϵ_0 , explicitly expand F/m before multiplying with E .
- **Using electric field as V/m but dropping the extra metre relation.** Both F/m and V/m contribute one $1/\text{m}$, so $\epsilon E = (\text{F/m})(\text{V/m}) = \text{C/m}^2$. *Avoid it:* Put brackets around compound units: $(\text{F/m})(\text{V/m}) = (\text{FV})/\text{m}^2$.

REVISE Electromagnetic SI conversions: $F = \text{C/V}$, $V = \text{J/C}$, $E = \text{N/C} = \text{V/m}$, $A = \text{C/s}$. · Practise dimensional products using bracketed units to track every denominator.

13 Answer: A

Ref 11517

Medium ~1 min Errors in Measurement

QUICK APPROACH Start by finding the average (mean) length of the rod from the given measurements and then calculate the mean absolute deviation to find the relative error.

First find the average (mean) length:

$$x_{\text{avg}} = \frac{20.00 + 19.75 + 17.01 + 18.25}{4}$$

$$x_{\text{avg}} = \frac{75.01}{4} = 18.7525 \text{ cm}$$

Now calculate absolute deviations:

$$|20.00 - 18.7525| = 1.2475$$

$$|19.75 - 18.7525| = 0.9975$$

$$|17.01 - 18.7525| = 1.7425$$

$$|18.25 - 18.7525| = 0.5025$$

Mean absolute error:

$$\Delta x = \frac{1.2475 + 0.9975 + 1.7425 + 0.5025}{4}$$

$$\Delta x = \frac{4.49}{4} = 1.1225$$

Relative error:

$$\text{Relative error} = \frac{\Delta x}{x_{\text{avg}}} = \frac{1.1225}{18.7525} \approx 0.0598 \approx 0.06$$

Therefore, the relative error in the measurement of the average length is approximately 0.06.

COMMON TRAPS

- **Using range/half-range instead of mean absolute error.** For this question's solution, mean absolute error is used: $\Delta x = (|x_1 - x_{avg}| + |x_2 - x_{avg}| + |x_3 - x_{avg}| + |x_4 - x_{avg}|)/4$, then relative error = $\Delta x / x_{avg}$. *Avoid it:* If the solution asks for average measurement error, compute deviations from x_{avg} for every reading, not just extreme readings.
- **Dividing by number of readings twice or not at all.** Only the sum of absolute deviations is divided by 4 to get $\Delta x = 1.1225$. Relative error is then $\Delta x / x_{avg}$, not sum of deviations/ x_{avg} . *Avoid it:* Label intermediate values: sum deviations = 4.49 cm, mean absolute error = 1.1225 cm, relative error = 1.1225/18.7525.

REVISE Definitions: absolute error, mean absolute error, relative error, percentage error. · Always make a table of reading, |reading - mean|, and then average the deviation column.

14 Answer: D

Ref 11529

Medium ~1 min Screw Gauge and Zero Error

QUICK APPROACH Decide whether a zero above the pitch line gives a positive or a negative zero error, then correct the reading with it.

Step 1. Zero error. With the studs touching, the zero of the circular scale is 3 divisions above the pitch line. The scale has not yet come down to zero, so the gauge reads less than the true value. This is a negative zero error:

$$\text{zero error} = -3 \times 0.01 = -0.03 \text{ mm}, \quad \text{zero correction} = +0.03 \text{ mm}$$

Step 2. Observed reading.

$$\text{PSR} + \text{CSR} \times \text{LC} = 1 + 51 \times 0.01 = 1.51 \text{ mm}$$

Step 3. Corrected thickness.

$$t = \text{observed} - \text{zero error} = 1.51 - (-0.03) = 1.54 \text{ mm}$$

(Rule to remember: circular-scale zero above the line means a negative error, so the correction is added.)

Answer: (D) 1.54 mm

COMMON TRAPS

- **Treating “above the horizontal pitch line” as positive zero error.** For a screw gauge, when the circular-scale zero is above the reference/pitch line at contact, the instrument shows a negative reading. Hence zero error = $-3 \times 0.01 = -0.03$ mm and zero correction = $+0.03$ mm. *Avoid it:* Before calculating the sheet thickness, write two separate lines: zero error = ? and zero correction = $-(\text{zero error})$. Do not directly add/subtract 3 divisions mentally.
- **Ignoring zero error after calculating the observed reading.** The question says the studs are brought in contact and the zero is displaced, so the raw reading is not the final reading. Correct thickness = observed reading + zero correction. *Avoid it:* Circle any phrase about zero position at contact. If such a phrase exists, never choose the observed reading directly.

REVISE The sign convention: circular-scale zero above reference line $\Rightarrow$ negative zero error $\Rightarrow$ positive correction. · Always write PSR, CSR, LC, observed reading, zero error, and corrected reading as separate lines.

15 Answer: B

Ref 11751

Medium ~0.5 min Vernier Callipers and Least Count

QUICK APPROACH Least count is one main scale division minus one vernier scale division; find the vernier division from the given equality.

Let 1 MSD = 0.05 mm. Given 50 VSD = 48 MSD, so 1 VSD = $(48/50)$ MSD = $(24/25)$ MSD.

Least count (L.C.) = 1 MSD - 1 VSD = MSD - $(48/50)$ MSD = $(2/50)$ MSD = $(1/25)$ MSD.

Therefore L.C. = $(1/25) \times 0.05$ mm = 0.002 mm. Hence the correct option is 0.002 mm.

COMMON TRAPS

- **Reversing the equality to compute 1 VSD.** If 50 VSD = 48 MSD, divide both sides by 50 to get 1 VSD = $48/50$ MSD. Since $48/50 < 1$, one VSD is slightly smaller than one MSD, as required for a direct vernier. *Avoid it:* After finding 1 VSD, check that it is less than 1 MSD. If it is greater than 1 MSD here, the ratio has been inverted.
- **Taking least count as 1 VSD or 1 MSD instead of the difference.** For this direct vernier, L.C. = 1 MSD - 1 VSD, not 1 MSD alone and not 1 VSD alone. *Avoid it:* Always write the formula before substituting: LC = 1 MSD - 1 VSD = 0.05 - 0.048 = 0.002 mm.

REVISE The general vernier formula: if n VSD = m MSD, then LC = $((n-m)/n) \times 1$ MSD for a direct vernier. · Practice ratio-to-one-division conversion: from n VSD = m MSD to 1 VSD = m/n MSD.

16 Answer: B

Ref 11897

Easy ~0.5 min Least count / Precision of Instrument

QUICK APPROACH Look at the last decimal place that changes from one reading to the next.

All recorded readings are written to two decimal places in millimetres (e.g. 1.24 mm). That means the instrument reports values to the hundredth of a millimetre, so the smallest division (least count) is 0.01 mm.

COMMON TRAPS

- **Treating two decimal places as 0.001 mm least count.** A reading written as 1.24 mm has its last significant decimal in the hundredths place, so least count is 0.01 mm, not 0.001 mm. *Avoid it:* Identify the place value of the last written digit in every reading.
- **Using spread of readings instead of resolution.** Least count is inferred from the smallest increment the instrument can display/record, not from the spread of repeated measurements. *Avoid it:* For least count questions, first inspect decimal precision before doing arithmetic on readings.

REVISE Place value: tenths = 0.1, hundredths = 0.01, thousandths = 0.001 in the same unit. · Practice distinguishing least count, range, mean absolute error, and rounding of final answers.

17 Answer: 4

Ref 10560

Medium ~2 min Dimensional analysis

QUICK APPROACH Use the rule that only quantities of the same dimension can be added, starting with $C + t$.

Every term added to a velocity must itself be a velocity, and only like quantities can be added.

Step 1. In $C + t$, C is added to a time, so $[C] = T$.

Step 2. At^2 is a velocity: $[A] T^2 = LT^{-1}$, so $[A] = LT^{-3}$.

Step 3. $\frac{Bt}{C+t}$ is a velocity. The ratio $\frac{t}{C+t}$ is dimensionless, so $[B] = LT^{-1}$.

Step 4. Multiply: $[ABC] = LT^{-3} \times LT^{-1} \times T = L^2T^{-3}$.

Answer: (4) $[M^0 L^2 T^{-3}]$

COMMON TRAPS

- **Treating C as a dimensionless constant.** Because C is added to t, it must have the dimension of time. *Avoid it:* Look for sums inside a term first; they fix dimensions directly.
- **Forgetting that the fraction t/(C + t) is dimensionless.** Numerator and denominator both have dimension T, so B alone carries the velocity dimension. *Avoid it:* Simplify ratios of like quantities before solving for a constant.

REVIEW The principle of homogeneity of dimensions. · Practise finding dimensions of constants in formulas.

18 Answer: 2

Ref 10602

Medium ~5 min SI Units

Step 1: Understand the physical quantities and their dimensions:

- Permeability of free space (μ_0) has dimensions $[MLT^{-2}A^{-2}]$. It is related to the magnetic constant used in electromagnetic equations.
- Magnetic field (B) has dimensions $[MT^{-2}A^{-1}]$. This is derived from its definition as a force per unit charge per unit velocity.
- Magnetic moment (M) has dimensions $[L^2A]$. It is defined as the product of current and area.
- Torsional constant is a constant representing the torque per unit twist, and it matches the dimensions $[ML^2T^{-2}]$.

Step 2: Match the dimensions to the given options:

- (A) matches (III),
- (B) matches (II),
- (C) matches (IV),
- (D) matches (I).

Step 3: Look at the provided options and find the consistent matching.

The correct answer is option 2: (A)-(III), (B)-(II), (C)-(IV), (D)-(I).

COMMON TRAPS

- **Reading the letter M as magnetic moment.** In dimensions M means mass, and magnetic moment is current times area, $[L^2A]$. *Avoid it:* Expand each dimension symbol as mass, length, time or current before matching.
- **Giving the torsional constant an extra dimension.** The torsional constant is torque per radian, and an angle has no dimensions, so it is ML^2T^{-2} . *Avoid it:* Remember that an angle in radians is dimensionless.

REVIEW Dimensions of magnetic quantities from their defining formulas.

19 Answer: 1

Ref 10781

Medium ~2 min Dimensional analysis

QUICK APPROACH Start by analyzing the dimensions of each term in the position function using dimensional consistency, noting that each term must have the dimension of length [L].

Step 1: The expression for the position of a particle is $x(t) = A \sin t + B \cos^2 t + Ct^2 + D$. Since $x(t)$ represents position,

and dimensions of position are [L], every term on the right-hand side must also have dimension [L].

Step 2: $A \sin t$ must have dimension [L], so A has dimension [L] because sine is a dimensionless quantity.

Step 3: $B \cos^2 t$ must have dimension [L], so B also has dimension [L], as cosine is dimensionless.

Step 4: Ct^2 must have dimension [L]. Since t^2 has dimension $[T^2]$, C must have dimensions $[L T^{-2}]$.

Step 5: D must have the dimension [L] as it is a position term.

Step 6: Now consider the dimension of $\frac{ABC}{D}$:

- A has dimension [L]
- B has dimension [L]
- C has dimension $[L T^{-2}]$
- D has dimension [L]

Combining gives: $\frac{[L][L][LT^{-2}]}{[L]} = [L^2T^{-2}]$.

Hence, the dimension of $\frac{ABC}{D}$ is L^2T^{-2} .

20 Answer: 0

Ref 10832

Medium ~3 min Dimensional analysis, Applications

QUICK APPROACH Start by writing down the dimensional formulas of modulus of elasticity and torque, then find the dimension of their ratio to identify the exponent values.

Write the dimensions of the modulus of elasticity and of torque, then divide.

Step 1. Modulus of elasticity is stress over strain, and strain has no dimensions. So $[Y] = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$.

Step 2. Torque is force times distance: $[\tau] = MLT^{-2} \times L = ML^2T^{-2}$.

Step 3. "Per unit torque" means divide by torque: $\left[\frac{Y}{\tau}\right] = \frac{ML^{-1}T^{-2}}{ML^2T^{-2}} = M^0L^{-3}T^0$.

Step 4. So $a = 0$, $b = -3$ and $c = 0$. The given $b = -3$ agrees with this, which confirms the working.

Answer: 0

COMMON TRAPS

- **Reading the time power of the modulus alone.** The modulus has T^{-2} , but torque also has T^{-2} , so the powers cancel in the ratio. *Avoid it:* Find the full ratio before reading off c.
- **Writing torque as force per distance.** Torque is force times distance, so $[\tau] = ML^2T^{-2}$. *Avoid it:* Derive torque from $\tau = rF$ each time.

REVIEW Dimensions of stress, modulus and torque. · Subtracting exponents when dividing dimensions.

21 Answer: 3

Ref 10896

Medium ~3 min Measurement errors

QUICK APPROACH Start by calculating the least count of the screw gauge using pitch and number of divisions, then use the

concept of fractional errors in multiplication for area measurement.

Find the least count of the screw gauge, then add the fractional errors of length and breadth.

Step 1. Least count = $\frac{\text{pitch}}{N} = \frac{0.75 \text{ mm}}{15} = 0.05 \text{ mm}$. This is the error in each reading.

Step 2. $\frac{\Delta l}{l} = \frac{0.05}{5} = 0.01$ and $\frac{\Delta b}{b} = \frac{0.05}{2.5} = 0.02$.

Step 3. Area is $A = lb$, a product, so the maximum fractional errors add: $\frac{\Delta A}{A} = 0.01 + 0.02 = 0.03$.

Step 4. Write this as $\frac{x}{100} \cdot 0.03 = \frac{3}{100}$, so $x = 3$.

Answer: 3

COMMON TRAPS

- **Treating the pitch as the least count.** The least count is the pitch divided by the number of circular divisions, here 0.05 mm. *Avoid it:* Write the least count with units before any error work.
- **Adding absolute errors for a product.** For an area, the fractional errors add, not the absolute errors. *Avoid it:* Turn each error into a fraction of its reading first.

REVISE Least count of a screw gauge. · Error rules for products of measurements.

22 Answer: 2

Ref 10917

Easy ~1.5 min Measurement errors

Step 1: Evaluate each statement.

- Statement (A): Incorrect. Weight of a substance is the force due to gravity, not the amount of matter (which is mass).
- Statement (B): Incorrect. Mass is a measure of the amount of matter, not a force. The force due to gravity is weight.
- Statement (C): Correct. Volume is indeed the amount of space occupied by a substance.
- Statement (D): Correct. Negative temperatures are not possible in Kelvin scale.
- Statement (E): Correct. Precision is about the closeness of measurements.

Step 2: Verify the option.

- Correct option has statements (C), (D), and (E).
- Therefore, the correct option is (2).

23 Answer: 2

Ref 11065

Medium ~1.5 min Dimensional analysis

Step 1: Understand the dimensions of each quantity:

Pressure and Young's modulus both have the same dimensions: $[ML^{-1}T^{-2}]$.

Surface tension has dimensions $[MT^{-2}]$, while impulse has dimensions $[MLT^{-1}]$. These are not the same.

Torque and energy both have dimensions of $[ML^2T^{-2}]$.

Angular momentum has dimensions $[ML^2T^{-1}]$, which are the same as Planck's constant $[ML^2T^{-1}]$.

Step 2: Identify the pair with different dimensions:

The pair 'Surface tension and impulse' (option 2) has different dimensions, hence it is the correct answer.

24 Answer: 2

Ref 11080

Medium ~3 min Measurement errors

QUICK APPROACH Start by writing the formula for density and apply the rules of error propagation using differentiation of logarithmic expressions to relate percentage errors in mass, radius, and length to the density error.

Density of a wire of mass m , radius r and length l :

$$\rho = \frac{m}{\pi r^2 l}$$

For a product or quotient, the maximum relative errors add, each multiplied by its power:

$$\frac{\Delta \rho}{\rho} = \frac{\Delta m}{m} + 2 \frac{\Delta r}{r} + \frac{\Delta l}{l}$$

Step 1. Each term:

$$\begin{aligned} \bullet \frac{\Delta m}{m} &= \frac{0.003}{0.60} = 0.005 \\ \bullet 2 \frac{\Delta r}{r} &= 2 \times \frac{0.01}{0.50} = 0.04 \\ \bullet \frac{\Delta l}{l} &= \frac{0.05}{10.00} = 0.005 \end{aligned}$$

Step 2. Sum: $0.005 + 0.04 + 0.005 = 0.05$.

Percentage error = $0.05 \times 100 = 5\%$.

Answer: (2) 5

25 Answer: A

Ref 11997

Medium ~0.5 min Dimensional analysis (μ_0 , charge, current)

QUICK APPROACH Start by writing down the dimensional formulas of charge, current, and permeability of vacuum, then multiply them and simplify to see which gives the dimension of momentum.

Do dimensional analysis. Dimensions: charge q has $[q] = A \cdot s$, current I has $[I] = A$, permeability of vacuum μ_0 has $[\mu_0] = N A^{-2} = kg m s^{-2} A^{-2}$. Now compute the product $[\mu_0 q I] = [\mu_0] [q] [I] = (kg m s^{-2} A^{-2}) (A s) (A) = kg m s^{-1}$, which is the dimension of momentum. Check other options: $[qI] = A^2 s$ (not momentum), $[\mu_0 q^2] = kg m$ (not momentum), $[\mu_0 I^2] = kg m s^{-2}$ (force). Hence $\mu_0 q I$ has the dimension of momentum.

26 Answer: A

Ref 12002

Easy ~1 min

QUICK APPROACH Start by recalling the SI units based on the definitions of heat capacity, specific heat capacity, latent heat, and thermal conductivity.

Heat capacity $C = Q/\Delta T$ so units are energy per temperature: JK^{-1} (II). Specific heat capacity $c = Q/(m \Delta T)$ so units are $Jkg^{-1}K^{-1}$ (III). Latent heat $L = Q/m$ so units are energy per mass: Jkg^{-1} (I). Thermal conductivity k from Fourier's law ($Q/t = k A \Delta T / L$) has units $Wm^{-1}K^{-1}$ which is $Js^{-1}m^{-1}K^{-1}$ (same as $Jm^{-1}K^{-1}s^{-1}$) (IV). Therefore the correct matching is A-II, B-III, C-I, D-IV.

27 Answer: A

Ref 12004

Medium ~1 min

Get each unit from the defining equation of the quantity.

Step 1. Heat capacity is $C = \frac{Q}{\Delta T}$, so its unit is J K^{-1} , which is (I).

Step 2. Specific heat capacity is per unit mass: $s = \frac{Q}{m\Delta T}$, so its unit is $\text{J kg}^{-1} \text{K}^{-1}$, which is (II).

Step 3. Latent heat is $L = \frac{Q}{m}$ with no temperature change, so its unit is J kg^{-1} , which is (III).

Step 4. Fourier's law gives $\frac{Q}{t} = k \frac{A\Delta T}{\ell}$, so $k = \frac{Q\ell}{At\Delta T}$. Its unit is $\frac{\text{J m}}{\text{m}^2 \text{s K}} = \text{J m}^{-1} \text{s}^{-1} \text{K}^{-1}$, which is (IV).

Step 5. The match is A-I, B-II, C-III, D-IV.

Answer: (A) A - I, B - II, C - III, D - IV

COMMON TRAPS

- **Confusing heat capacity with specific heat capacity.** Heat capacity of a body is $C = Q/\Delta T$, so its unit is J K^{-1} . Specific heat capacity is per unit mass, $s = Q/(m\Delta T)$, so its unit is $\text{J kg}^{-1} \text{K}^{-1}$. *Avoid it:* Whenever the word "specific" appears, check for "per kg". If it is absent, do not include kg^{-1} .
- **Putting a temperature factor into latent heat.** Latent heat $L = Q/m$. There is no ΔT term, so there is no K^{-1} in the unit. Its SI unit is J kg^{-1} . *Avoid it:* For phase-change formulas, write $Q = mL$, not $Q = mc\Delta T$. Then solve $L = Q/m$ before checking units.

REVIEW Formula-to-unit derivation rather than memorising only names of units. · Mark the word "specific" as a cue for "per unit mass".

28 Answer: C

Ref 12116

Medium ~1 min Propagation of Errors

Write C as powers: $C = p^1 q^2 r^{-3} s^{-1/2}$. For small, independent percentage errors, percentage error in C = $|1|(\% \text{ error in } p) + |2|(\% \text{ error in } q) + |-3|(\% \text{ error in } r) + |-1/2|(\% \text{ error in } s)$. Substituting: $= 1 \times 1\% + 2 \times 2\% + 3 \times 3\% + (1/2) \times 2\% = 1\% + 4\% + 9\% + 1\% = 15\%$. (Assumes errors are small and combine linearly for powers.)

COMMON TRAPS

- **Not multiplying percentage error by the power of q.** For $C \propto q^n$, fractional/percentage error contribution is $|n|$ times the fractional/percentage error in q. *Avoid it:* Rewrite exactly as " $C = p^1 q^2 r^{-3} s^{-1/2}$ " before substituting errors.
- **Subtracting denominator errors instead of adding absolute contributions.** In maximum error propagation for products/quotients/powers, percentage errors add with absolute values of powers. *Avoid it:* Write vertical bars around powers: $|1|\Delta p\% + |2|\Delta q\% + |-3|\Delta r\% + |-1/2|\Delta s\%$.

REVIEW Logarithmic differentiation for products, quotients, and powers. · Practice making variable-power-error-contribution tables for propagation of error questions.

29 Answer: B

Ref 12237

Medium ~1 min Dimensions and Units / Flux

QUICK APPROACH Start by finding the dimensions of electric flux and magnetic flux separately using the definitions of electric and magnetic fields and then find their ratio's dimensions by dividing one by the other.

Compute dimensions of electric flux Φ_E and magnetic flux Φ_B . Using base dimensions where charge has dimension $[Q] =$

$[A][T]:$

1) Electric field E from $F = qE$ gives $[E] = [F]/[q] = \text{MLT}^{-2}/(\text{AT}) = \text{MLT}^{-3}\text{A}^{-1}$. Electric flux $\Phi_E = E \cdot A$ so $[\Phi_E] = \text{MLT}^{-3}\text{A}^{-1} \times \text{L}^2 = \text{ML}^3\text{T}^{-3}\text{A}^{-1}$.

2) Magnetic field B from Lorentz force $F = qvB$ gives $[B] = [F]/([q][v]) = \text{MLT}^{-2}/(\text{AT} \cdot \text{LT}^{-1}) = \text{MT}^{-2}\text{A}^{-1}$. Magnetic flux $\Phi_B = B \cdot A$ so $[\Phi_B] = \text{MT}^{-2}\text{A}^{-1} \times \text{L}^2 = \text{ML}^2\text{T}^{-2}\text{A}^{-1}$.

3) Ratio Φ_E/Φ_B has dimension: $\frac{\text{ML}^3\text{T}^{-3}\text{A}^{-1}}{\text{ML}^2\text{T}^{-2}\text{A}^{-1}} = \text{L}^1\text{T}^{-1} = \text{M}^0\text{L}^1\text{T}^{-1}\text{A}^0$.

Thus $Q = 1$ and $R = -1$, corresponding to option (1, -1).

COMMON TRAPS

- **Reversing the ratio: magnetic flux divided by electric flux.** Here the required quantity is $\Phi_E/\Phi_B = \text{L}^1\text{T}^{-1}$, so $Q = 1$ and $R = -1$. *Avoid it:* Write the ratio symbolically before substituting dimensions: numerator = electric flux, denominator = magnetic flux.
- **Confusing area symbol A with ampere dimension A.** Area contributes L^2 ; ampere contributes the base dimension A. They are not the same. *Avoid it:* Replace area by S_{area} or L^2 in rough work before dimensional multiplication.

REVIEW Dimensions of charge $q = It = \text{AT}$, electric field from $F = qE$, and magnetic field from $F = qvB$. · Practice exponent subtraction with negative powers in dimensional ratios.

30 Answer: A

Ref 12315

Medium ~1 min Dimensional analysis of dipole moments

Electric dipole moment p has dimension = charge $\times$ length = $[Q][L]$. In SI base dimensions charge $Q = [\text{AT}]$, so $p = [\text{AT}][\text{L}] = [\text{AL T}]$.

Magnetic dipole moment m (for a current loop) has dimension = current $\times$ area = $[A][\text{L}^2] = [\text{AL}^2]$.

Ratio $p/m = [\text{AL T}] / [\text{AL}^2] = [\text{L}^{-1}\text{T}^1]$.

Expressed as $[M^P L^Q T^R A^S]$, this gives $P = 0$ (no mass), $Q = -1$, $R = 1$, $S = 0$. Therefore $P = 0$ and $Q = -1$.

COMMON TRAPS

- **Treating the requested Q as charge instead of the exponent of length.** In " $[M^P L^Q T^R A^S]$ ", P, Q, R, S are exponents. The question asks only for P and Q, i.e., mass exponent and length exponent. Charge is not a separate SI base dimension; charge = current $\times$ time = $[\text{AT}]$. *Avoid it:* Before solving, rewrite the target as: find mass power P and length power Q in the final ratio. Do not assign the charge symbol Q to the option pair.
- **Using magnetic dipole moment as current $\times$ length instead of current $\times$ area.** For a current loop, magnetic dipole moment is $m = I \times$ area, not $I \times$ length. Since area has dimension L^2 , $m = [\text{AL}^2]$. *Avoid it:* Whenever magnetic dipole moment appears, write the defining formula $m = IA_{\text{loop}}$ first; circle the word area and replace it by L^2 .

REVIEW SI base dimensions of charge: charge = current $\times$ time = $[\text{AT}]$. · Memorize the two direct definitions: electric dipole moment $p = ql$ and magnetic dipole moment $m = IA$.

31 Answer: A

Ref 12458

Medium ~1 min Propagation of errors (power-law)

For a product/power law $Q = x^a y^b z^c$ the maximum (worst-case) fractional error is given by $\frac{\Delta Q}{Q} = |a|\frac{\Delta x}{x} + |b|\frac{\Delta y}{y} + |c|\frac{\Delta z}{z}$. Here $a = -2$, $b = 3/2$, $c = -2/5$. Thus

$$\frac{\Delta Q}{Q} = 2 \times 0.1 + \frac{3}{2} \times 0.2 + \frac{2}{5} \times 0.5 = 0.2 + 0.3 + 0.2 = 0.7.$$

Hence the maximum fractional error is 0.7.

COMMON TRAPS

- **Using algebraic signs of negative powers instead of absolute powers.** For "maximum fractional error", add absolute contributions: $|a|\Delta x/x + |b|\Delta y/y + |c|\Delta z/z$. Negative powers affect dependence, not the sign of uncertainty contribution. *Avoid it:* Before substituting numbers, rewrite exponents as magnitudes: $|-2|=2$, $|3/2|=1.5$, $|-2/5|=0.4$.
- **Adding raw fractional errors and ignoring exponents.** In $Q = x^a y^b z^c$, each fractional error is weighted by the magnitude of its exponent. *Avoid it:* Underline every exponent in the given expression and pair it with the corresponding fractional error before adding.

REVISE Memorize the power-law rule with absolute exponents for maximum fractional error. · Always create a variable-exponent-error table before substituting numbers.

32 Answer: D

Ref 9233

Medium ~3 min Measurement errors

QUICK APPROACH Decide the sign of the zero error from where the circular-scale zero sits when the jaws are closed, then subtract it.

Find the least count, read the gauge, then subtract the zero error.

$$\text{Step 1. Least count} = \frac{\text{pitch}}{\text{circular divisions}} = \frac{1 \text{ mm}}{100} = 0.01 \text{ mm}.$$

Step 2. With the jaws closed, the zero of the circular scale lies 5 divisions below the reference line. The reading has already advanced by 5 divisions, so the zero error is positive: $+5 \times 0.01 = +0.05 \text{ mm}$.

Step 3. Observed reading = $4 \times 1 \text{ mm} + 60 \times 0.01 \text{ mm} = 4.60 \text{ mm}$.

Step 4. Corrected diameter = observed reading – zero error = $4.60 - 0.05 = 4.55 \text{ mm}$.

Answer: (D) 4.55 mm

COMMON TRAPS

- **Getting the sign of the zero error wrong.** When the circular zero is below the reference line, the gauge reads more than zero with the jaws closed, so the error is positive. *Avoid it:* Ask whether the gauge over-reads or under-reads at zero, then subtract the error.
- **Adding the zero error instead of subtracting it.** The corrected reading is always observed reading minus zero error, with the error taken with its sign. *Avoid it:* Write true reading = observed reading – zero error before substituting.

REVISE Positive and negative zero error in a screw gauge. · Practise screw-gauge readings with zero error.

33 Answer: 2

Ref 9315

Medium ~2 min Measurement errors

QUICK APPROACH Use the concept of least count of a vernier caliper, where least count equals one main scale division minus one vernier scale division; start by expressing the vernier scale division in terms of the main scale division from the given coincidence.

The least count of a vernier is one main scale division minus one vernier division.

Step 1. Twenty vernier divisions coincide with 19 main scale divisions, so $1 \text{ VSD} = \frac{19}{20} \text{ MSD}$.

Step 2. Least count = $1 \text{ MSD} - 1 \text{ VSD} = \frac{1}{20} \text{ MSD}$.

Step 3. The least count is 0.1 mm. So $\frac{1}{20} \text{ MSD} = 0.1 \text{ mm}$ and $1 \text{ MSD} = 2 \text{ mm}$.

Step 4. Check: $2 \text{ mm} - \frac{19}{20} \times 2 \text{ mm} = 2 - 1.9 = 0.1 \text{ mm}$.

Answer: (2) 2

COMMON TRAPS

- **Taking the main scale division equal to the least count.** The least count is only a fraction $\frac{1}{n}$ of one main scale division. *Avoid it:* Write $\text{LC} = \text{MSD}/n$ and solve for the MSD.
- **Multiplying by 19 instead of 20.** Here n is the number of vernier divisions, which is 20. *Avoid it:* Check that n vernier divisions span $n - 1$ main divisions.

REVISE Least count of vernier callipers.

34 Answer: C

Ref 9324

Easy ~2 min

The four readings are 4.62 s, 4.632 s, 4.6 s and 4.64 s. Their sum is $4.62 + 4.632 + 4.6 + 4.64 = 18.492 \text{ s}$. The arithmetic mean is

$$\frac{18.492}{4} = 4.623$$

s.

For the mean to have correct significant figures, the result must match the precision of the least precise reading. Here, 4.6 s is reported only to one decimal place (precision 0.1 s), while others go to two or three. In addition/subtraction and averaging, the final result cannot exceed the decimal places of the crudest measurement; thus 4.623 s rounds to 4.6 s.

Option D (4.62 s) encodes the common mistake of rounding the calculated mean merely to two decimal places to match the majority of readings, ignoring the limiting precision imposed by the 4.6 s value. This violates the rule that the mean's uncertainty is set by the least accurate datum. Hence the correct choice is [C] 4.6 s.

COMMON TRAPS

- **Keeping all digits of the mean.** The mean 4.623 s cannot be more precise than the least precise reading, 4.6 s. *Avoid it:* Round the mean to the fewest decimal places among the readings.
- **Rounding to the nearest whole second.** 4.6 s has one decimal place, so rounding to 5 s throws away good data. *Avoid it:* Count decimal places, not total digits, for sums.

REVISE Significant figures in addition and averages.

35 Answer: 1

Ref 9326

Medium ~2 min SI Units

This is the SI definition of the candela, so recall the two fixed numbers in it.

Step 1. The candela is defined using monochromatic radiation of frequency $540 \times 10^{12} \text{ Hz}$. This frequency lies in the green part of the spectrum, where the eye is most sensitive. So $A = 540$.

Step 2. The source must have a radiant intensity of $\frac{1}{683}$ watt per steradian in that direction. The question writes this as $\frac{1}{B}$, so $B = 683$, not $\frac{1}{683}$.

Step 3. Only one option has both values: $A = 540$ and $B = 683$. Options with 450 use the wrong frequency, and options with $\frac{1}{683}$ for B confuse B with the radiant intensity itself.

Answer: (1) 540 and 683

36 Answer: 2

Ref 9421

Medium ~3 min Dimensional analysis

To verify the statements, recall the definitions and derive dimensions from fundamental quantities.

Specific heat capacity: $c = \frac{Q}{m\Delta T}$, where Q (heat energy) has $[ML^2T^{-2}]$, mass m has $[M]$, and ΔT has $[K]$. Thus, $[c] = \frac{[ML^2T^{-2}]}{[M][K]} = [L^2T^{-2}K^{-1}]$. Statement (I) is correct.

Universal gas constant from $PV = nRT$: $R = \frac{PV}{nT}$. Pressure P has $[ML^{-1}T^{-2}]$, volume V has $[L^3]$, so PV has $[ML^2T^{-2}]$. With n in moles and T in $[K]$, $[R] = [ML^2T^{-2}K^{-1}mol^{-1}]$. Statement (II) claims $[ML^2T^{-1}K^{-1}]$, which mismatches both the T^{-2} exponent (a common error confusing with power or entropy terms) and omits mol^{-1} . Thus, (II) is incorrect.

Option 3 (both incorrect) encodes the specific mistake of wrongly rejecting Statement (I), perhaps from including spurious mass dimension in specific heat. The correct choice is therefore option (2): Statement (I) is correct but Statement (II) is incorrect.

COMMON TRAPS

- **Using T^{-1} for the gas constant.** The gas constant is energy per mole per kelvin, so it has T^{-2} , not T^{-1} . *Avoid it:* Write $R = PV/(nT)$ and find the dimension of energy.
- **Putting mass into specific heat.** Specific heat is per unit mass, so the mass cancels and leaves $L^2T^{-2}K^{-1}$. *Avoid it:* Divide energy by mass and temperature.

REVIEW Dimensions of specific heat and gas constant.

37 Answer: 3

Ref 9443

Medium ~2 min Dimensional analysis

QUICK APPROACH Use dimensional analysis by equating the term $\frac{a}{V^2}$ to pressure P and start by writing the dimensional formula for pressure and volume.

In the van der Waals equation $(P + \frac{a}{V^2})(V - b) = RT$, added terms must match dimensions, so $[\frac{a}{V^2}] = [P]$. With $[P] = ML^{-1}T^{-2}$ (from force per unit area) and $[V] = L^3$, it follows that $[V^2] = L^6$ and $[a] = [P][V^2] = ML^5T^{-2}$. Subtracted terms match, so $[b] = [V] = L^3$. Therefore, $[ab^{-1}] = [a]/[b] = ML^5T^{-2} \cdot L^{-3} = ML^2T^{-2}$. This is option [3]. Option [1] encodes the common mistake of incorrectly equating a/V^2 dimensions to those of RT/V (mixing in gas constant and temperature factors with wrong exponents).

COMMON TRAPS

- **Giving b the dimensions of pressure.** b is subtracted from V , so $[b] = L^3$. *Avoid it:* Match each added term to the quantity beside it.
- **Taking a as pressure alone.** a/V^2 is a pressure, so $[a] = ML^{-1}T^{-2} \times L^6 = ML^5T^{-2}$. *Avoid it:* Multiply pressure by V^2 to get a .

REVIEW Dimensions of the van der Waals constants.

38 Answer: 2

Ref 9475

Medium ~2 min Measurement errors

QUICK APPROACH Start by recalling the concept of zero error in Vernier calipers and how it affects the measurement reading.

Step 1: Understanding Assertion (A): A positive zero error in a Vernier caliper means that the zero of the Vernier scale coincides with a value greater than zero on the main scale when the jaws are perfectly closed. As a result, any reading taken will appear larger than it actually is by the amount of this zero error.

Step 2: Understanding Reason (R): Zero error can arise due to manufacturing defects or improper handling which can affect the alignment of the scale. This is a true statement but does not explain why a positive zero error would result in a reading larger than the actual value.

Step 3: Conclusion: Both statements A and R are true, but R is not the correct explanation for A because the reason A is correct involves the systematic error caused by the zero alignment being off. Therefore, option 2 is correct.

39 Answer: 4

Ref 9564

Medium ~2 min Dimensional analysis, Applications

QUICK APPROACH Start by using dimensional analysis to find the dimensions of the given expression $\sqrt{uG}$ by substituting the dimensions of the gravitational constant G and energy density u .

Step 1: Determine the dimensions of $\sqrt{uG}$. The gravitational constant G has dimensions $[M^{-1}L^3T^{-2}]$ and u (energy density) has dimensions $[ML^{-1}T^{-2}]$. Thus, uG has dimensions $[M^0L^2T^{-4}]$. Taking the square root gives dimensions $[LT^{-2}]$.

Step 2: Compare with the given options:

- Pressure gradient per unit mass has dimensions $[ML^{-2}T^{-2}]$, which does not match.
- Gravitational potential has dimensions $[L^2T^{-2}]$, which does not match.
- Energy per unit mass has dimensions $[L^2T^{-2}]$, which does not match.
- Force per unit mass has dimensions $[LT^{-2}]$, which matches with $\sqrt{uG}$.

Thus, the correct answer is force per unit mass.

COMMON TRAPS

- **Getting the dimensions of G wrong.** $G = M^{-1}L^3T^{-2}$, so $uG = L^2T^{-4}$ and $\sqrt{uG} = LT^{-2}$. *Avoid it:* Derive G from $F = Gm_1m_2/r^2$.
- **Confusing force per mass with potential.** Force per unit mass is an acceleration, LT^{-2} ; potential is L^2T^{-2} . *Avoid it:* Write the dimension of each option before comparing.

REVIEW Dimensions of G and energy density.

40 Answer: 4

Ref 9602

Medium ~3 min Dimensional analysis

QUICK APPROACH Start by recalling that angular impulse is the product of torque and time, then use the dimensional formula of torque and multiply it by time.

Step 1: Angular impulse is the product of torque and time.

Step 2: Torque is the product of force and distance (moment arm).

Step 3: Force has a dimensional formula of $[M L T^{-2}]$.

Step 4: Distance has a dimensional formula of $[L]$.

Step 5: Therefore, torque has a dimensional formula of $[M L^2 T^{-2}]$.

Step 6: Time has a dimensional formula of $[T]$.

Step 7: Multiplying torque $[M L^2 T^{-2}]$ by time $[T]$ gives $[M L^2 T^{-1}]$.

Therefore, the dimensional formula of angular impulse is $[M L^2 T^{-1}]$.

COMMON TRAPS

- **Using torque alone.** Angular impulse is torque times time, which adds a power of T . *Avoid it:* Write angular impulse as $\tau \Delta t$.
- **Using linear impulse.** Linear impulse is MLT^{-1} ; the angular one has an extra L , ML^2T^{-1} . *Avoid it:* Check whether the quantity is linear or angular.

REVISE Angular impulse and angular momentum.

41 Answer: D

Ref 9665

Medium ~2 min Dimensional analysis, Applications

The least count of a vernier is one main scale division minus one vernier division.

Step 1. Ten main scale divisions coincide with 11 vernier divisions, so 11 VSD = 10 MSD and 1 VSD = $\frac{10}{11}$ MSD.

Step 2. Least count = 1 MSD - 1 VSD = $(1 - \frac{10}{11})$ MSD = $\frac{1}{11}$ MSD.

Step 3. Each main scale division is 5 units. So the least count is $\frac{5}{11}$ units.

Step 4. Check: $\frac{5}{11}$ is smaller than one main scale division, as a least count must be.

Answer: (D) $\frac{5}{11}$

COMMON TRAPS

- **Treating 11 Vernier divisions as 10/11 units directly.** The relation is 10 MSD = 11 VSD. Since 1 MSD = 5 units, 1 VSD = $(10/11)$ MSD = $50/11$ units. Least count is the difference between 1 MSD and 1 VSD. *Avoid it:* After writing any VSD/MSD relation, attach units or scale names to each term: 1 VSD = $(10/11)$ MSD, not $(10/11)$ units.
- **Selecting the Vernier division length as the least count.** For a direct vernier, LC = 1 MSD - 1 VSD, not 1 VSD itself. *Avoid it:* Always write the formula line before substituting: LC = 1 MSD - 1 VSD.

REVISE Always write the coincidence relation with labels, e.g., 10 MSD = 11 VSD. · Keep intermediate quantities labeled: 1 MSD = 5 units, 1 VSD = $50/11$ units, LC = $5/11$ units.

42 Answer: 1

Ref 9710

Medium ~2 min Measurement errors

QUICK APPROACH Use the error propagation formula for multiplication and division to relate percentage errors in time

and mass to the percentage error in the spring constant k .

For a spring and mass, $T = 2\pi\sqrt{m/k}$, so $k = \frac{4\pi^2 m}{T^2}$.

Step 1. Take logarithms and differentiate: $\frac{\Delta k}{k} = \frac{\Delta m}{m} - 2\frac{\Delta T}{T}$. Here the signs of the errors are given, so keep them.

Step 2. The time has a positive error of 2%, so $\frac{\Delta T}{T} = +2\%$. The mass has a negative error of 1%, so $\frac{\Delta m}{m} = -1\%$.

Step 3. Substitute: $\frac{\Delta k}{k} = -1 - 2 \times 2 = -5\%$.

Step 4. Both errors push k the same way, so they do not cancel. The value of k is too small by 5%, so the percentage error is 5%.

Answer: (1) 5%

COMMON TRAPS

- **Using the plus sign for time in the denominator and getting 3%.** For $k \propto mT^{-2}$, signed error is $\delta k/k = \delta m/m - 2\delta T/T$. With $\delta m/m = -1\%$ and $\delta T/T = +2\%$, $\delta k/k = -1 - 4 = -5\%$; the percentage error magnitude is 5%. *Avoid it:* Before substituting, rewrite powers explicitly: $k \propto m^1 T^{-2}$, then multiply each variable's percentage error by its exponent.
- **Treating the final percentage error as algebraic signed sum instead of magnitude/maximum error.** The determined k is lower than the true k by about 5%; the reported percentage error among options is its magnitude, 5%, option 1/A. *Avoid it:* Compute the sign to understand direction, then compare options using magnitude unless the question explicitly asks for 'percentage change with sign' or 'whether overestimated/underestimated'.

REVISE Percentage error propagation using power-law form: if $y \propto a^p b^q$, then signed $\delta y/y = p \delta a/a + q \delta b/b$. · Always separate signed bias from absolute/maximum percentage error.

43 Answer: 3

Ref 9738

Medium ~2 min

QUICK APPROACH Start by calculating the least count of the screw gauge using pitch and number of divisions, then apply the formula for diameter involving main scale reading and circular scale reading.

Step 1: The formula to calculate the diameter using a screw gauge is: Diameter = Main Scale Reading + (Circular Scale Reading $\times$ Least Count).

Step 2: Given, Main scale reading = 1 mm and Circular scale reading = 42 divisions.

Step 3: Least Count (L.C.) = Pitch/Number of divisions on circular scale = $1 \text{ mm}/100 = 0.01 \text{ mm}$.

Step 4: Calculate the contribution from the circular scale reading: $42 \times 0.01 = 0.42 \text{ mm}$.

Step 5: Total reading = Main scale reading + Circular scale reading contribution = $1 + 0.42 = 1.42 \text{ mm}$.

Step 6: According to the problem, $\frac{x}{50} = 1.42$. Solving for x , we get $x = 1.42 \times 50 = 71$.

Thus, the value of x is 71.

COMMON TRAPS

- **Dropping the main scale reading and using only the circular scale.** The correct formula in Step 1 is "Diameter = Main Scale Reading + (Circular Scale Reading $\times$ Least Count)". The "Main scale reading is 1 mm" must be added. *Avoid it:* Before solving for x , write the full reading as $\text{MSR} + \text{CSR} \times \text{LC}$ and tick both given readings: 1 mm and 42 divisions.
- **Confusing denominator 50 in $x/50$ with denominator 100 in least count.** Use 100 only in Step 3: $\text{LC} = 1 \text{ mm}/100 = 0.01 \text{ mm}$. Use 50 only in Step 6: $x/50 = 1.42$. *Avoid it:* Label every denominator: 100 $\rightarrow$ circular divisions; 50 $\rightarrow$ algebraic form of final answer.

REVISE Screw gauge formula as Total reading = $\text{MSR} + \text{CSR} \times \text{LC}$, with $\text{LC} = \text{pitch}/\text{number of circular divisions}$. · Always tag units: mm for main scale and least count, divisions for circular scale, dimensionless for x .

44 Answer: 3

Ref 9757

Medium ~4 min Dimensional analysis, Applications

To find how much more distance the tip of the second hand travels than that of the minute hand in 30 minutes. Convert lengths to meters: length of second hand $r_s = 0.75 \text{ m}$, minute hand $r_m = 0.6 \text{ m}$. Use $\pi = 3.14$.

The second hand completes one full circle every 60 s or 1 min. Therefore, in 30 min it completes 30 revolutions. Angular displacement $\theta_s = 2\pi \times 30 \text{ rad}$, so distance traveled by tip of second hand is $d_s = r_s \theta_s = 0.75 \times 60 \times 3.14 = 141.3 \text{ m}$.

The minute hand completes one full circle every 60 min. Therefore, in 30 min it completes 0.5 revolutions. Angular displacement $\theta_m = 2\pi \times 0.5 = \pi \text{ rad}$, so distance traveled by tip of minute hand is $d_m = 0.6 \times 3.14 = 1.884 \text{ m}$.

Hence, $x = d_s - d_m = 141.3 - 1.884 = 139.416 \text{ m} \approx 139.4 \text{ m}$. Option [2] (118.9) encodes the specific mistake of swapping the hand lengths (misreading "respectively"). The correct option is [3] 139.4.

COMMON TRAPS

- **Taking the minute hand through a full turn.** In 30 minutes the minute hand turns only half a circle. *Avoid it:* Count turns for each hand separately.
- **Using radius in place of circumference.** Distance per turn is $2\pi r$, so the second hand covers $30 \times 2\pi \times 0.75 \text{ m}$. *Avoid it:* Write distance as turns times $2\pi r$.

REVISE Circular motion of clock hands.

45 Answer: 2

Ref 9962

Medium ~3 min Significant Figures

QUICK APPROACH Start counting from the first non-zero digit, and keep trailing zeros that come after a decimal point.

Count significant figures with the standard rules: leading zeros never count, zeros between non-zero digits count, and trailing zeros after a decimal point count.

Step 1. 1001: the zeros lie between non-zero digits, so 4 significant figures, (II).

Step 2. 0.010: the leading zero does not count; 1, 0, 1 do, so 3 significant figures, (I).

Step 3. 100.100: every zero counts here, since the number has

a decimal point and the zeros lie between or after non-zero digits, so 6 significant figures, (IV).

Step 4. 0.0010010: the three leading zeros do not count; 1, 0, 0, 1, 0 do, so 5 significant figures, (III).

Step 5. The match is (A)-(II), (B)-(I), (C)-(IV), (D)-(III).

Answer: (2) (A)-(II), (B)-(I), (C)-(IV), (D)-(III)

COMMON TRAPS

- **Counting leading zeros.** Zeros before the first non-zero digit only fix the decimal place, so they are never significant. *Avoid it:* Strike out leading zeros before counting.
- **Dropping trailing zeros after a decimal point.** In 100.100 and 0.0010010 the trailing zeros record measured precision and are significant. *Avoid it:* Keep every zero to the right of the decimal point that follows a non-zero digit.

REVISE The rules for significant figures. · Practise counting figures in numbers with zeros.

46 Answer: 1

Ref 10063

Medium ~3 min Vernier Caliper

Find the diameter with the vernier, then the volume, then the density.

Step 1. Nine main scale divisions equal ten vernier divisions, so 1 VSD = 0.9 mm. The least count is $1 - 0.9 = 0.1 \text{ mm} = 0.01 \text{ cm}$.

Step 2. The main scale reads 2 cm and the 2nd vernier division coincides. The diameter is $2 + 2 \times 0.01 = 2.02 \text{ cm}$, so $r = 1.01 \text{ cm}$.

Step 3. Volume: $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi (1.01)^3 \approx 4.189 \times 1.030 \approx 4.316 \text{ cm}^3$.

Step 4. Density: $\rho = \frac{8.635}{4.316} \approx 2.0 \text{ g cm}^{-3}$.

Answer: (1) 2.0 g/cm^3

COMMON TRAPS

- **Adding a millimetre vernier reading directly to a centimetre main-scale reading.** Convert before adding: 2 cm = 20 mm, so total = 20 mm + 0.2 mm = 20.2 mm = 2.02 cm. *Avoid it:* Write units beside every number in the addition line; never add bare numbers when units differ.
- **Using diameter as radius in the sphere volume formula.** The vernier caliper measures diameter here; volume of a sphere needs radius, so $R = D/2$ before cubing. *Avoid it:* Circle the word "diameter" in the stem and write $R = D/2$ immediately before the volume calculation.

REVISE The exact vernier-reading template: total reading = $\text{MSR} + n \times \text{LC}$, with all terms in the same unit. · Sphere volume in both forms: $V = (4/3)\pi R^3$ and $V = \pi D^3/6$.

47 Answer: 3

Ref 10150

Medium ~3 min Measurement errors

Given: 50 vernier scale divisions (VSD) = 49 main scale divisions (MSD). Thus, 1 VSD = $(49/50) \text{ MSD}$.

Least count $\text{LC} = 1 \text{ MSD} - 1 \text{ VSD} = (1/50) \text{ MSD}$.

When jaws touch, vernier zero shifts left and its 4th division coincides with a main scale division. This implies negative zero

error with magnitude $4 \times LC$. The instrument's zero error is given as 0.04 mm, so

$$4 \times LC = 0.04$$

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

$$\text{Therefore, MSD} = 50 \times LC = 0.5 \text{ mm}.$$

Number of main scale divisions in 1 cm (= 10 mm) is $10/0.5 = 20$.

(Option 4 corresponds to the common error of taking $LC = \text{MSD}/100$, perhaps from misapplying the $50 \text{ VSD} = 49 \text{ MSD}$ relation or confusing zero-error coincidence with an extra division.)

Thus, the correct option is [3].

COMMON TRAPS

- **Using the wrong count for the zero error.** The vernier zero shifts left and the 4th division coincides, so the zero error is $4LC = 0.04 \text{ mm}$. *Avoid it:* Use the coinciding division as the question states it.
- **Forgetting how least count links to the main scale.** With 50 VSD equal to 49 MSD, $LC = \text{MSD}/50$, so $\text{MSD} = 0.5 \text{ mm}$. *Avoid it:* Write $LC = \text{MSD}/n$ and solve for MSD.

REVISE Zero error and least count of vernier callipers.

48 Answer: 2

Ref 10271

Medium ~2 min Measurement errors

In $Y = 49000 \frac{M}{l}$ the constant has no error, so the fractional error of Y is the sum of those of M and l .

Step 1. The error in each reading is one smallest scale division: $\Delta M = 5 \text{ g}$ and $\Delta l = 0.02 \text{ cm}$.

$$\text{Step 2. } \frac{\Delta M}{M} = \frac{5}{500} = 0.01 \text{ and } \frac{\Delta l}{l} = \frac{0.02}{2} = 0.01.$$

$$\text{Step 3. } \frac{\Delta Y}{Y} = \frac{\Delta M}{M} + \frac{\Delta l}{l} = 0.01 + 0.01 = 0.02.$$

Step 4. As a percentage, the error in Y is $0.02 \times 100 = 2\%$.

Answer: (2) 2%

49 Answer: 4

Ref 10272

Medium ~2 min Measurement errors

The Vernier constant (least count) of the travelling microscope is derived as follows. By definition,

$$VC = 1 \text{ MSD} - 1 \text{ VSD}.$$

Given that 50 Vernier divisions equal 49 main scale divisions,

$$50 \text{ VSD} = 49 \text{ MSD} \Rightarrow 1 \text{ VSD} = \frac{49}{50} \text{ MSD}.$$

Substitute to obtain the decisive step:

$$VC = \text{MSD} - \frac{49}{50} \text{ MSD} = \frac{1}{50} \text{ MSD}.$$

The smallest main scale reading is given as 1 MSD = 0.5 mm, so

$$VC = \frac{0.5}{50} \text{ mm} = 0.01 \text{ mm}.$$

This is option [4]. Option [3] (0.01 cm) encodes the specific mistake of inserting MSD = 0.5 cm (instead of 0.5 mm) into the formula above; that error yields exactly 0.01 cm and is what some students may have been taught. Unit consistency is essential: 0.01 mm = 0.001 cm, so option [3] cannot arise from correct arithmetic with the stated 0.5 mm. The derivation confirms [4] rigorously.

50 Answer: 3

Ref 10300

Medium ~2 min

In a vernier caliper, one main scale division (MSD) equals m units. The given condition states that the n th division of the main scale coincides with the $(n+1)$ th division of the vernier scale. This implies $n \text{ MSD} = (n+1) \text{ vernier scale divisions (VSD)}$.

$$\text{Thus, length of 1 VSD} = \frac{n \cdot m}{n+1}.$$

The least count (LC) is the difference:

$$LC = 1 \text{ MSD} - 1 \text{ VSD} = m - \frac{nm}{n+1} = m \left(1 - \frac{n}{n+1} \right) = m \cdot \frac{1}{n+1} = \frac{m}{n+1}.$$

This derives option [3]. Option [1] ($\frac{nm}{n+1}$) equals 1 VSD, a common error of mistaking VSD length for the least count instead of their difference. Standard formula $LC = \frac{\text{MSD}}{N}$ (where $N = n+1$ here) confirms the result.

51 Answer: 1

Ref 10402

Medium ~3 min Dimensional analysis, Applications

Rearrange the de Broglie relation for h and put in the dimensions.

Step 1. From $\lambda = \frac{h}{\sqrt{2mE}}$ we get $h = \lambda \sqrt{2mE}$. The factor 2 has no dimensions.

Step 2. The dimensions are $[\lambda] = L$, $[m] = M$ and $[E] = ML^2T^{-2}$.

Step 3. $[mE] = M \times ML^2T^{-2} = M^2L^2T^{-2}$, so $[\sqrt{mE}] = MLT^{-1}$. This is momentum, as expected, since $p = \sqrt{2mE}$ for a moving particle.

Step 4. $[h] = L \times MLT^{-1} = ML^2T^{-1}$. This also matches $E = h\nu$, since energy divided by frequency gives the same dimensions.

Answer: (1) $[ML^2T^{-1}]$

COMMON TRAPS

- **Taking the square root of only one mass factor.** $[mE] = [M][ML^2T^{-2}] = [M^2L^2T^{-2}]$, so $\sqrt{mE} = [MLT^{-1}]$. *Avoid it:* Combine all powers first, then halve every exponent under the square root.
- **Confusing Planck constant with energy or force dimensions.** From $E = h\nu$, $[h] = [E]/[\nu] = [ML^2T^{-2}]/[T^{-1}] = [ML^2T^{-1}]$. *Avoid it:* Cross-check h using $E = h\nu$ whenever a de-Broglie route seems confusing.

REVISE Dimensional formulae of energy, momentum, force, frequency, and wavelength. · Practice isolating the required variable before substituting dimensions.

52 Answer: 3

Ref 10403

Medium ~3 min Applications

Least count is one main scale division minus one vernier division. Use it to find the length of N vernier divisions.

Step 1. Least count: $\frac{1}{20N}$ cm = $\frac{1}{2N}$ mm. One main scale division is 1 mm.

Step 2. One vernier division: $1 - \frac{1}{2N} = \frac{2N-1}{2N}$ mm.

Step 3. Length of N vernier divisions: $N \times \frac{2N-1}{2N} = \frac{2N-1}{2}$ mm.

Step 4. Each main scale division is 1 mm, so N vernier divisions coincide with $\frac{2N-1}{2}$ main scale divisions.

Answer: (3) $\frac{2N-1}{2}$

53 Answer: B

Ref 10500

Easy ~1 min Functions

QUICK APPROACH Recall the definition of order of magnitude in scientific notation and how the exponent b relates to the value of a in $a \times 10^b$. Start by considering the range of a for which b correctly represents the order of magnitude.

Step 1: Understand the concept of order of magnitude. The order of magnitude of a number refers to the logarithmic scale measurement. In the context of $a \times 10^b$, where $1 \leq a < 10$, b represents the order of magnitude for this scientific notation.

Step 2: Consider the scenarios given in the options:

- Option A: b is order of magnitude for $a \geq 5$. This is misleading as b should apply where a is less than 5 for correct magnitude.
- Option B: b is order of magnitude for $a < 5$. This is correct.
- Option C: a is order of magnitude for $b \leq 5$. Incorrect because b represents the magnitude, not a .
- Option D: b is order of magnitude for $5 < a \leq 10$. Incorrect because the correct statement would be if $a \leq 5$ for b to serve as the order.

COMMON TRAPS

- **Treating the exponent as the order for every coefficient.** When $a > 5$, the number is rounded up, so the order of magnitude becomes $b + 1$. *Avoid it:* Compare the coefficient with 5 before stating the order of magnitude.
- **Swapping the roles of coefficient and exponent.** The order of magnitude is a power of 10, so it comes from b , not from a . *Avoid it:* Remember that the order of magnitude is the exponent after rounding.

REVISE Order of magnitude and scientific notation.

54 Answer: 1

Ref 10034

Easy ~1 min Dimensional analysis

Step 1: Determine the dimensions of Planck's constant.

Planck's constant (h) has dimensions of $[ML^2T^{-1}]$, which are the same as those of angular momentum.

Step 2: Determine the dimensions of linear momentum and moment of force.

Linear momentum (p) has dimensions of $[MLT^{-1}]$, while the moment of force (torque, τ) has dimensions of $[ML^2T^{-2}]$.

Step 3: Compare the dimensions.

The dimensions of linear momentum and moment of force are not the same.

Therefore, Statement I is true, and Statement II is false.

COMMON TRAPS

- **Treating moment of force as linear momentum because both involve force/motion.** Linear momentum $p = mv$ has dimensions $[MLT^{-1}]$. Moment of force/torque $\tau = rF$ has dimensions $[L][MLT^{-2}] = [ML^2T^{-2}]$. They are not the same. *Avoid it:* For every named quantity, write its defining formula before comparing dimensions.
- **Confusing angular momentum with angular velocity.** Angular momentum has dimensions $[ML^2T^{-1}]$, not $[T^{-1}]$. Angular velocity has dimensions $[T^{-1}]$. *Avoid it:* When seeing "angular momentum", immediately write $L = r \times p = \text{length} \times \text{linear momentum}$.

REVISE Defining formulae: $h = E/\nu$, angular momentum $L = r \times p$, linear momentum $p = mv$, torque $\tau = r \times F$. · Before choosing among assertion-type options, independently mark each statement True/False, then map to the option.

55 Answer: 1

Ref 7605

Medium ~4 min Dimensional analysis, Applications

To find the dimensions of mass when c , G , and h are fundamental, assume $[M] = [h]^a [c]^b [G]^d$.

Standard dimensions: $[c] = LT^{-1}$, $[G] = M^{-1}L^3T^{-2}$ (from $F = Gm_1m_2/r^2$), $[h] = ML^2T^{-1}$ (from $E = h\nu$).

Equating exponents for M, L, T gives the system:

$$a - d = 1$$

$$2a + b + 3d = 0$$

$$-a - b - 2d = 0$$

From the time equation, $b = -a - 2d$. Substitute into length: $a + d = 0$, so $a = -d$. Then $a - d = 1$ yields $-2d = 1$, hence $d = -1/2$, $a = 1/2$, $b = 1/2$.

Thus, $[M] = [h^{1/2}c^{1/2}G^{-1/2}]$, matching option [1]. This is the Planck mass (up to 2π factors). Option [4] encodes the common error of deriving Planck length $\sim h^{1/2}c^{-3/2}G^{1/2}$ instead, with sign and exponent slips on c .

COMMON TRAPS

- **Picking the wrong power of c .** Matching powers gives $c^{1/2}$, so the Planck mass is $\sqrt{hc/G}$. *Avoid it:* Solve the M, L and T equations together.
- **Dropping the square root.** Without the square root, hc/G has dimension M^2 , not M . *Avoid it:* Check the final answer gives exactly M^1 .

REVISE The Planck mass from h , c and G .

56 Answer: 2

Ref 7606

Medium ~3 min Dimensional analysis, Applications

QUICK APPROACH Start by expressing the dimensional formulas of force, velocity, and time, then assume density as a product of powers of F, V, and T and equate dimensions on both sides.

Step 1: Dimensional formula for density is $M^1L^{-3}T^0$.

Step 2: Write the dimensional formula for force F . It is $M^1L^1T^{-2}$.

Step 3: Write the dimensional formula for velocity V . It is L^1T^{-1} .

Step 4: Assume the dimensional formula of density in terms of F , V , and T as $F^aV^bT^c$.

Step 5: Equate the dimensions on both sides: $M^1L^{-3}T^0 = (M^1L^1T^{-2})^a(L^1T^{-1})^bT^c$.

Step 6: Solving gives: $a = 1, b = -4, c = -2$, so the dimensional formula is $F^1V^{-4}T^{-2}$.

57 Answer: B

Ref 7740

Easy ~1 min Example Topic

QUICK APPROACH Start from a defining formula for each quantity: $E = h\nu$, $V = W/q$, and $p = mv$. Remember that charge has dimensions $[AT]$.

Write the dimensions of each quantity from a formula that defines it.

Step 1. Planck's constant: $E = h\nu$, so $[h] = \frac{[E]}{[\nu]} = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$. So A matches III.

Step 2. Stopping potential is a potential difference: $V = \frac{W}{q} = \frac{[ML^2T^{-2}]}{[AT]} = [ML^2T^{-3}A^{-1}]$. So B matches IV.

Step 3. Work function is an energy, $[ML^2T^{-2}]$. So C matches I.

Step 4. Momentum $p = mv$ has dimensions $[MLT^{-1}]$. So D matches II.

Step 5. The matching A - III, B - IV, C - I, D - II is option (B).

Answer: (B) A - III, B - IV, C - I, D - II

COMMON TRAPS

- **Confusing h with energy.** Planck's constant is energy divided by frequency, so it carries one more power of T than energy: $[ML^2T^{-1}]$, not $[ML^2T^{-2}]$. *Avoid it:* Always divide by the dimensions of frequency, $[T^{-1}]$, when you get h from $E = h\nu$.
- **Treating stopping potential as an energy.** Stopping potential is measured in volts, which is energy per unit charge. Its dimensions include A^{-1} and T^{-3} . *Avoid it:* Write charge as current times time, $[AT]$, before dividing energy by it.

REVISE Make a table of dimensions for energy, power, charge, potential and momentum, and derive each from a formula. Practise match-the-list questions on dimensions of photoelectric quantities.

58 Answer: 2

Ref 8364

Medium ~4 min Dimensional analysis

QUICK APPROACH Angular momentum and torque differ by one power of time; stress and pressure gradient differ by one power of length.

Build each dimension from its defining formula and match.

Step 1. Angular momentum is $L = mvr$, so its dimensions are $M \cdot LT^{-1} \cdot L = ML^2T^{-1}$, which is III.

Step 2. Torque is force times distance: $MLT^{-2} \times L = ML^2T^{-2}$, which is I.

Step 3. Stress is force per area: $MLT^{-2}/L^2 = ML^{-1}T^{-2}$, which is IV.

Step 4. Pressure gradient is pressure per length: $ML^{-1}T^{-2}/L = ML^{-2}T^{-2}$, which is II.

Step 5. The match is A-III, B-I, C-IV, D-II.

Answer: (2) A-III, B-I, C-IV, D-II

COMMON TRAPS

- **Giving pressure gradient the dimensions of stress.** Dividing pressure by a length adds a factor L^{-1} , so pressure gradient is $ML^{-2}T^{-2}$, not $ML^{-1}T^{-2}$. *Avoid it:* Write gradient as change in pressure over change in distance before simplifying.
- **Confusing angular momentum with torque.** Torque is the rate of change of angular momentum, so torque has one extra T^{-1} . *Avoid it:* Use $\tau = dL/dt$ to check the time power.

REVISE Dimensions of rotational quantities. Practise matching quantities that differ by one power.

59 Answer: 2

Ref 8513

Medium ~2 min Dimensional analysis

QUICK APPROACH Surface tension is force per length and impulse is force times time; write the newton as $kg\,m\,s^{-2}$.

Write each quantity in base SI units using its defining formula.

Step 1. Surface tension is force per length: $N\,m^{-1} = kg\,m\,s^{-2}/m = kg\,s^{-2}$, which is IV.

Step 2. Pressure is force per area: $N\,m^{-2} = kg\,m^{-1}\,s^{-2}$, which is III.

Step 3. From $F = \eta A \frac{dv}{dx}$, viscosity has units $Pa\,s =$

$\text{kg m}^{-1} \text{s}^{-1}$, which is I.

Step 4. Impulse is force times time: $\text{N s} = \text{kg m s}^{-1}$, which is II.

Step 5. The match is A-IV, B-III, C-I, D-II.

Answer: (2) A-IV, B-III, C-I, D-II

COMMON TRAPS

- **Confusing surface tension with pressure.** Surface tension divides force by a length, pressure divides it by an area, so their units differ by one metre. *Avoid it:* Write the denominator explicitly before converting to base units.
- **Giving impulse the units of force.** Impulse is force multiplied by time, so one power of seconds cancels: kg m s^{-1} . *Avoid it:* Check impulse against momentum, which has the same units.

REVIEW SI base units of mechanics quantities. · Practise converting newton-based units to kg, m, s.

60 Answer: 4

Ref 8580

Medium ~3 min Measurement errors

The density of the cylindrical wire is given by $\rho = \frac{m}{\pi r^2 l}$. The maximum percentage error in density is

$$\frac{\Delta \rho}{\rho} \times 100\% = \left(\frac{\Delta m}{m} + 2 \frac{\Delta r}{r} + \frac{\Delta l}{l} \right) \times 100\%.$$

Given $\frac{\Delta m}{m} = \frac{0.01}{0.4} = 0.025$ or 2.5%, $\frac{\Delta l}{l} = \frac{0.04}{8} = 0.005$ or 0.5%, and $\frac{\Delta r}{r} = \frac{0.03}{6} = 0.005$ or 0.5% (unit conversion does not affect relative error). Thus,

$$(2.5 + 2 \times 0.5 + 0.5)\% = 4\%.$$

Option of 5% encodes the mistake of confusing the radius with diameter (halving r to 3 mm while using $\Delta r = 0.03$ mm, doubling relative error in r to 1%, yielding $2.5 + 2 \times 1 + 0.5 = 5\%$). This is a common error in measurement problems. The correct option is [4] 4%.

COMMON TRAPS

- **Forgetting to double the radius error.** Since $\rho \propto r^{-2}$, the 0.5% radius error counts as 1%. *Avoid it:* Multiply each fractional error by the power in the formula.
- **Subtracting errors for quantities in the denominator.** Maximum errors always add: $2.5 + 1 + 0.5 = 4\%$. *Avoid it:* Add all contributions for a maximum error.

REVIEW Maximum error in density measurements.

61 Answer: 4

Ref 8748

Medium ~2 min Dimensional analysis

Use dimensional analysis: both sides of $v = \lambda^a g^b \rho^c$ must have the dimensions of speed.

Step 1. The dimensions are $[v] = LT^{-1}$, $[\lambda] = L$, $[g] = LT^{-2}$ and $[\rho] = ML^{-3}$.

Step 2. So $LT^{-1} = L^a (LT^{-2})^b (ML^{-3})^c = M^c L^{a+b-3c} T^{-2b}$.

Step 3. Mass gives $c = 0$. Time gives $-2b = -1$, so $b = \frac{1}{2}$. Length gives $a + b - 3c = 1$, so $a = \frac{1}{2}$.

Step 4. Hence $v \propto \sqrt{\lambda g}$, the known result for deep water waves. The density does not enter, because no other quantity

carries mass to cancel it.

Answer: (4) $\frac{1}{2}, \frac{1}{2}, 0$

62 Answer: 5

Ref 8808

Medium ~3 min Measurement errors

The least count of a vernier is one main scale division minus one vernier division.

Step 1. There are 40 main scale divisions in 1 cm, so

$$1 \text{ MSD} = \frac{1}{40} \text{ cm} = 0.25 \text{ mm}.$$

Step 2. Fifty vernier divisions equal 49 main scale divisions,

$$\text{so } 1 \text{ VSD} = \frac{49}{50} \text{ MSD}.$$

Step 3. Least count = $1 \text{ MSD} - 1 \text{ VSD} = \frac{1}{50} \text{ MSD} = \frac{0.25}{50} \text{ mm} = 0.005 \text{ mm}.$

Step 4. Convert to metres: $0.005 \text{ mm} = 5 \times 10^{-6} \text{ m}.$

Answer: 5

63 Answer: 2

Ref 8882

Medium ~3 min Dimensional analysis, Applications

QUICK APPROACH Apply the principle of dimensional homogeneity by equating the dimensions of each term inside the parentheses with the dimension of length [L].

In the equation $(x - At)^2 + (y - \frac{t}{B})^2 = a^2$, dimensional homogeneity requires that the subtracted terms match the dimensions of x and y , both [L] since a is radius with [L].

Given $[t] = [T^{-1}]$, equate dimensions for the first correction: $[At] = [L]$. This yields $[A] \times [T^{-1}] = [L]$, so $[A] = [L] \times [T] = [LT]$.

For the second: $[\frac{t}{B}] = [L]$, so $[T^{-1}] / [B] = [L]$. Solving gives $[B] = [T^{-1}] / [L] = [L^{-1}T^{-1}]$.

These are exactly the dimensions in option [2]. Option [3] encodes the specific mistake of interchanging the dimensional contributions from the x - and y -correction terms (swapping inverse factors between $[A]$ and $[B]$), perhaps from misidentifying which shift pairs with the inverse-time variable. Correct analysis of homogeneity, without such swap, confirms option [2]: $A = [LT]$, $B = [L^{-1}T^{-1}]$.

COMMON TRAPS

- **Ignoring the given dimension of t .** Here $[t] = T^{-1}$, so At must be a length and $A = LT$. *Avoid it:* Use the dimension the question gives for t .
- **Inverting the term with B .** Since t/B is a length, $B = t/L = L^{-1}T^{-1}$. *Avoid it:* Solve $[t]/[B] = L$ for $[B]$ step by step.

REVIEW The principle of homogeneity of dimensions.

64 Answer: 2

Ref 7567

Medium ~4 min Dimensional analysis

QUICK APPROACH Use stress over strain, $F = \eta A dv/dx$, $E = h\nu$, and the fact that work function is an energy.

Write each quantity in terms of a formula whose dimensions are easy to find.

Step 1. Young's modulus is stress over strain, and strain has no dimensions, so $[Y] = \frac{[MLT^{-2}]}{[L^2]} = [ML^{-1}T^{-2}]$: III.

Step 2. Viscosity from $F = \eta A \frac{dv}{dx}$: $[\eta] = \frac{[MLT^{-2}]}{[L^2][T^{-1}]} = [ML^{-1}T^{-1}]$: I.

Step 3. Planck's constant from $E = h\nu$: $[h] = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$: II.

Step 4. Work function is an energy: $[\phi] = [ML^2T^{-2}]$: IV.

Step 5. The match is A-III, B-I, C-II, D-IV.

Answer: (2) A-III, B-I, C-II, D-IV

COMMON TRAPS

- **Mixing up viscosity and Young's modulus.** Both have ML^{-1} , but viscosity has T^{-1} and Young's modulus has T^{-2} . *Avoid it:* Check the power of time last.
- **Giving Planck's constant the dimensions of energy.** h is energy times time, so it has T^{-1} , not T^{-2} . *Avoid it:* Start from $E = h\nu$ and divide by frequency.

REVISE Dimensional formulae of common physical quantities.

65 Answer: 3

Ref 7881

Medium ~3 min Dimensional analysis

QUICK APPROACH Write each quantity as a ratio: pressure per length, energy per volume, force per charge and heat per mass.

Build each dimensional formula from a defining relation.

Step 1. Pressure gradient is pressure per unit length: $\frac{[ML^{-1}T^{-2}]}{[L]} = [ML^{-2}T^{-2}]$: III.

Step 2. Energy density is energy per unit volume: $\frac{[ML^2T^{-2}]}{[L^3]} = [ML^{-1}T^{-2}]$: II.

Step 3. Electric field is force per unit charge, with charge $[AT]$: $\frac{[MLT^{-2}]}{[AT]} = [MLT^{-3}A^{-1}]$: IV.

Step 4. Latent heat is heat per unit mass: $\frac{[ML^2T^{-2}]}{[M]} = [ML^2T^{-2}]$: I.

Step 5. The match is A-III, B-II, C-IV, D-I. Each item in List II is used once, which checks the matching.

Answer: (3) A-III, B-II, C-IV, D-I

COMMON TRAPS

- **Swapping pressure gradient and energy density.** Energy density has the dimensions of pressure, and the gradient divides that by one more length. *Avoid it:* Compare the power of L: -1 for energy density, -2 for the gradient.
- **Writing charge without time.** Charge is current times time, so electric field picks up T^{-3} . *Avoid it:* Use $[q] = [AT]$ for charge.

REVISE Dimensional formulae of derived quantities.

66 Answer: D

Ref 9049

Medium ~2 min SI Units

QUICK APPROACH Energy density has the same units as pressure; a gradient divides by one more metre.

Convert each quantity to base SI units through its defining formula.

Step 1. Torque is force times distance: $N\,m = kg\,m^2\,s^{-2}$, which is IV.

Step 2. Energy density is energy per volume: $J\,m^{-3} = kg\,m^2\,s^{-2}/m^3 = kg\,m^{-1}\,s^{-2}$, which is I.

Step 3. Pressure gradient is pressure per length: $kg\,m^{-1}\,s^{-2}/m = kg\,m^{-2}\,s^{-2}$, which is III.

Step 4. Impulse is force times time: $N\,s = kg\,m\,s^{-1}$, which is II.

Step 5. The match is A-IV, B-I, C-III, D-II.

Answer: (D) A-IV, B-I, C-III, D-II

COMMON TRAPS

- **Treating energy density like energy.** Energy density divides energy by volume, which leaves the units of pressure, $kg\,m^{-1}\,s^{-2}$. *Avoid it:* Divide by m^3 explicitly before matching.
- **Giving pressure gradient the units of pressure.** A gradient is per unit length, so pressure gradient has m^{-2} , not m^{-1} . *Avoid it:* Write the gradient as a ratio to a distance first.

REVISE Units of torque, energy density and impulse. · Practise SI base-unit conversions for derived quantities.

67 Answer: 2

Ref 8860

Medium ~2 min AC Fundamentals

QUICK APPROACH All three quantities are measured in ohms; count the net power of the ohm in each option.

Resistance, inductive reactance and capacitive reactance are all measured in ohms, so each has the same dimension.

Step 1. Call that common dimension $[\Omega]$. Then $[R] = [X_L] = [X_C] = [\Omega]$.

Step 2. Option (1): RX_LX_C has dimension $[\Omega]^3$.

Step 3. Option (2): $\sqrt{X_LX_C}$ has dimension $[\Omega]$, so $\frac{R}{\sqrt{X_LX_C}}$ has dimension $[\Omega]^0$, a pure number.

Step 4. Option (3): $\frac{R}{X_LX_C}$ has dimension $[\Omega]^{-1}$.

Step 5. Option (4): $R \frac{X_L}{X_C}$ has dimension $[\Omega]$.

Only option (2) is dimensionless.

Answer: (2) $\frac{R}{\sqrt{X_LX_C}}$

COMMON TRAPS

- **Thinking reactance has different dimensions from resistance.** $X_L = \omega L$ and $X_C = 1/(\omega C)$ are both ratios of voltage to current, so they carry ohms like R . *Avoid it:* Check units of ωL and $1/(\omega C)$ once before comparing.
- **Ignoring the square root.** $\sqrt{X_LX_C}$ has the dimension of one ohm, not two. *Avoid it:* Halve the power of a quantity under a square root.

REVISE Units of reactance and impedance. · Practise net-power counting in dimensional analysis.

68 Answer: 3

Ref 8218

Medium ~2 min Dimensional Analysis

QUICK APPROACH Express each quantity through force, area and length, then substitute MLT^{-2} for force.

Write each quantity in terms of force, length and time, then read off its dimensions.

Step 1. Torque is force times distance: $MLT^{-2} \times L = ML^2T^{-2}$, which is II.

Step 2. Stress is force per area: $MLT^{-2}/L^2 = ML^{-1}T^{-2}$, which is IV.

Step 3. Pressure gradient is pressure per length: $ML^{-1}T^{-2}/L = ML^{-2}T^{-2}$, which is I.

Step 4. From $F = \eta A \frac{dv}{dx}$, the coefficient of viscosity is $\eta = \frac{F}{A} \cdot \frac{dx}{dv}$, so its dimensions are $ML^{-1}T^{-2} \times T = ML^{-1}T^{-1}$, which is III.

Step 5. The match is A-II, B-IV, C-I, D-III.

Answer: (3) A-II, B-IV, C-I, D-III

COMMON TRAPS

- **Treating pressure gradient like pressure.** A gradient is a change per unit length, so pressure gradient has one more power of L^{-1} than pressure. *Avoid it:* Write the defining ratio, pressure divided by distance, before writing dimensions.
- **Mixing up torque with stress.** Torque multiplies force by a length while stress divides force by an area, so their powers of L differ by three. *Avoid it:* Check whether the defining formula multiplies or divides by a length.

REVISE Dimensions of torque, stress and viscosity. · Practise derived quantities such as gradients and densities.

69 Answer: 2

Ref 7368

Medium ~3 min

The vernier caliper has least count $LC = 0.1 \text{ mm} = 0.01 \text{ cm}$. When jaws are closed, the vernier zero lies to the right of the main-scale zero and the 6th vernier division coincides with a main-scale division. This is a positive zero error given by

$$+6 \times 0.01 = +0.06 \text{ cm}.$$

(Option 3 corresponds to the common mistake of adding this zero error instead of subtracting it.)

For the spherical bob, the vernier zero lies between the 3.2 cm and 3.3 cm marks of the main scale, so the main-scale reading (MSR) is 3.2 cm. The 4th vernier division coincides with a main-scale division, giving the vernier-scale reading (VSR)

$$4 \times 0.01 = 0.04 \text{ cm}.$$

Observed diameter = MSR + VSR = 3.20 + 0.04 = 3.24 cm.

True diameter = observed diameter – zero error = 3.24 cm – 0.06 cm = 3.18 cm.

Thus the measured diameter is 3.18 cm, which is option [2].

70 Answer: 2

Ref 8830

Easy ~1 min

Step 1: Analyze Statement I. Astronomical unit (Au), Parsec (Pc), and Light year (ly) are indeed units used for measuring astronomical distances, so this statement is true.

Step 2: Analyze Statement II. We know that 1 parsec is greater than 1 light year (1 parsec $\approx$ 3.26 light years), and 1 astronomical unit is less than 1 light year. This means the correct order is $Au < ly < Pc$.

Statement II asserts that $Au < Parsec < ly$, which is incorrect as compared to the true order.

Conclusion: Statement I is correct whereas Statement II is incorrect. Therefore, the most appropriate answer is option (2).

COMMON TRAPS

- **Thinking a light year is longer than a parsec.** One parsec is about 3.26 light years, so the right order is $AU < ly < pc$. *Avoid it:* Recall the sizes of the three units in metres.

REVISE Sizes of AU, light year and parsec.

71 Answer: 2

Ref 6921

Medium ~3 min Measurement errors

QUICK APPROACH Write $Y = 4mgL/(\pi d^2 \Delta l)$ and add the fractional errors, remembering the diameter is squared.

Find Y from the data, then its fractional error from the measured extension and diameter.

Step 1. $Y = \frac{FL}{A \Delta l} = \frac{4mgL}{\pi d^2 \Delta l}$, with $F = 1 \times 10 = 10 \text{ N}$ and $L = 1 \text{ m}$ exact.

Step 2. $\pi d^2 = \pi \times (0.4 \times 10^{-3})^2 = 5.03 \times 10^{-7} \text{ m}^2$, so $Y = \frac{4 \times 10 \times 1}{5.03 \times 10^{-7} \times 0.4 \times 10^{-3}} \approx 1.99 \times 10^{11} \text{ N m}^{-2}$.

Step 3. Fractional error: $\frac{\Delta Y}{Y} = \frac{\Delta(\Delta l)}{\Delta l} + 2 \frac{\Delta d}{d} = \frac{0.02}{0.4} + 2 \times \frac{0.01}{0.4} = 0.05 + 0.05 = 0.1$.

Step 4. $\Delta Y = 0.1 \times 1.99 \times 10^{11} \approx 2 \times 10^{10} \text{ N m}^{-2}$, so $x = 2$.

Answer: 2

COMMON TRAPS

- **Counting the diameter error once.** d appears squared, so its fractional error is doubled. *Avoid it:* Multiply each fractional error by the power of its quantity.
- **Giving the fractional error as the answer.** The question asks for ΔY in N m^{-2} , which needs the value of Y too. *Avoid it:* Multiply $\frac{\Delta Y}{Y}$ by Y at the end.

REVISE Propagation of errors in products and powers.

72 Answer: 2

Ref 6770

Medium ~2 min Measurement errors

Torque has dimensions ML^2T^{-2} , so its fractional error adds the errors in mass, length and time, each multiplied by its power.

Step 1. Write $\tau \propto ML^2T^{-2}$.

Step 2. The maximum fractional error is $\frac{\Delta \tau}{\tau} = \frac{\Delta M}{M} + 2 \frac{\Delta L}{L} + 2 \frac{\Delta T}{T}$. The negative power of T still adds, because maximum errors add.

Step 3. Each standard is accurate to 5%. So $\frac{\Delta \tau}{\tau} = 5 + 2 \times 5 +$

$$2 \times 5 = 25\%.$$

Step 4. The net accuracy of the measured torque is therefore 25%, not just the 15% obtained by adding the three errors without their powers.

Answer: (2) 25%

73 Answer: 3

Ref 6214

Medium ~2 min Dimensional analysis, Applications

Step 1: Perform a dimensional analysis for the expression for T:

$$T = K \sqrt{\frac{\rho r^3}{S}}$$

Step 2: Dimensional formula for T is [T].

Step 3: Dimensional formula for ρ (density) is $[M L^{-3}]$.

Step 4: Dimensional formula for r (radius) is [L].

Step 5: Therefore, r^3 has dimensions $[L^3]$.

Step 6: Dimensional formula for S (surface tension) is $[M T^{-2}]$.

Step 7: The right-hand side expression becomes $\sqrt{\frac{[ML^{-3}][L^3]}{[MT^{-2}]}} = \sqrt{\frac{[M][L^3]}{[MT^{-2}]}} = [T]$, which is dimensionally correct.

Step 8: Assertion (A) is true.

Step 9: Comment on Reason (R): The reason states the R.H.S has a different dimension than time period which is incorrect, so (R) is false.

Step 10: Therefore, the correct answer is (3) (A) is true but (R) is false.

74 Answer: 1

Ref 6154

Medium ~3 min Dimensional analysis, Applications

The coefficient of viscosity η satisfies $F = \eta A \frac{dv}{dx}$, so $[\eta] = \frac{[F]}{[A] \times [\text{velocity gradient}]}$. Standard MLT form is $[\eta] = M L^{-1} T^{-1}$. With P, A, T as base: $[P] = M L T^{-1}$, $[A] = L^2$, $[T] = T$.

Assume $[\eta] = [P]^a [A]^b [T]^c$. Then

$$M L^{-1} T^{-1} = (M L T^{-1})^a (L^2)^b (T)^c = M^a L^{a+2b} T^{-a+c}.$$

Equating exponents: $a = 1, a + 2b = -1 \Rightarrow b = -1, -a + c = -1 \Rightarrow c = 0$. Thus $[\eta] = P A^{-1} T^0$.

Option 3 equals stress in these units (force = momentum/time gives stress = $P A^{-1} T^{-1}$), omitting the extra time factor from velocity gradient ($\sim 1/T$). Correct option is [1].

COMMON TRAPS

- **Leaving a time factor in viscosity.** Force is P/T and the velocity gradient is T^{-1} , so the time powers cancel. *Avoid it:* Write $\eta = F/(A dv/dx)$ and substitute each part.
- **Writing the velocity gradient as a velocity.** dv/dx is velocity per length, so its dimension is T^{-1} . *Avoid it:* Check the dimension of each part of the formula.

REVIEW The defining formula of viscosity.

75 Answer: 3

Ref 6405

Medium ~2 min Applications

QUICK APPROACH Get the least count from the 10-to-9 match, then work out the negative zero error from the closed-jaw reading.

NTA's final answer key gives (3) 3.10 cm. The standard zero-error rule gives 3.12 cm, which is not among the options, so both workings are shown.

Step 1. 10 vernier divisions equal 9 main scale divisions, so 1 VSD = 0.9 mm and the least count is $1 - 0.9 = 0.1$ mm.

Step 2. Reading for the body: main scale 30 mm and the 6th division in line, so $30 + 6 \times 0.1 = 30.6$ mm.

Step 3. Standard rule: with the jaws closed the vernier zero is left of the main zero and the 4th division is in line, so the zero error is $-(10 - 4) \times 0.1 = -0.6$ mm. Corrected diameter = $30.6 + 0.6 = 31.2$ mm = 3.12 cm, which matches no option.

Step 4. The key's working reads the zero error as $-4 \times 0.1 = -0.4$ mm, so the diameter is $30.6 + 0.4 = 31.0$ mm = 3.10 cm, option (3).

Answer: (3) 3.10 cm, as in NTA's key (the standard rule gives 3.12 cm)

COMMON TRAPS

- **Adding a negative zero error with the wrong sign.** A negative zero error is subtracted, which adds its size to the reading. *Avoid it:* Write corrected reading = observed - (zero error) with the sign kept.
- **Reading the zero error straight from the coinciding division.** For a vernier zero left of the main zero, the error is $-(10 - n)$ times the least count when division n coincides. *Avoid it:* Picture where the vernier zero sits before counting divisions.

REVIEW Vernier calliper zero error and correction.

76 Answer: A

Ref 6410

Medium ~2 min SI Units

QUICK APPROACH Write time as v/a and length as v^2/a , then substitute the two given relations.

Build time and length from velocity and acceleration, then apply the given relations.

Step 1. Time has the form $\frac{v}{a}$ and length has the form $\frac{v^2}{a}$, since $\frac{LT^{-1}}{LT^{-2}} = T$ and $\frac{L^2 T^{-2}}{LT^{-2}} = L$.

Step 2. Time: $T_2 = \frac{v_2}{a_2} = \frac{(n/m^2)v_1}{a_1/(mn)} = \frac{n}{m^2} \times mn \times \frac{v_1}{a_1} = \frac{n^2}{m} T_1$.

Step 3. Length: $L_2 = \frac{v_2^2}{a_2} = \frac{(n^2/m^4)v_1^2}{a_1/(mn)} = \frac{n^2}{m^4} \times mn \times \frac{v_1^2}{a_1} = \frac{n^3}{m^3} L_1$.

Step 4. So $\frac{n^3}{m^3} L_1 = L_2$ and $\frac{n^2}{m} T_1 = T_2$, which is option A.

Answer: (A) $\frac{n^3}{m^3}L_1 = L_2$ and $\frac{n^2}{m}T_1 = T_2$

COMMON TRAPS

- **Squaring only part of the velocity factor.** In v_2^2 the whole factor $\frac{n}{m^2}$ is squared, giving $\frac{n^2}{m^4}$. *Avoid it:* Square the factor before dividing by the acceleration factor.
- **Swapping which system is on which side.** The options differ in whether L_1 or L_2 carries the factor. *Avoid it:* Keep each relation in the form system 2 equals factor times system 1.

REVISE Conversion of quantities between systems of units.

77 Answer: C

Ref 6706

Medium ~2 min SI Units

Step 1: Understand that Pascal is the SI unit of pressure, which is force per unit area.

Step 2: The dimensional formula for pressure is Pressure = $\frac{\text{Force}}{\text{Area}}$.

Step 3: The dimensional formula for force is $[MLT^{-2}]$, and for area is $[L^2]$.

Step 4: Combining these, the dimensional formula for pressure becomes $[ML^{-1}T^{-2}]$.

Step 5: The given unit is Pascal-sec, so multiply this formula by time (T):

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

Step 6: Thus, the dimensional formula for the physical quantity with unit Pascal-sec is $ML^{-1}T^{-1}$.

COMMON TRAPS

- **Ignoring the “-sec” part and giving only pressure dimension.** Pascal-sec means Pa $\times$ s, so the pressure dimension must be multiplied by time: $[ML^{-1}T^{-2}] \times [T] = [ML^{-1}T^{-1}]$. *Avoid it:* Underline compound units and explicitly write them as products before dimensional conversion: Pa-sec = Pa $\times$ s.
- **Treating “Pascal-sec” as Pascal per second.** A hyphen in unit names like “newton-metre” or “pascal-second” normally denotes multiplication, not division. Division is written as “per” or with “/”. *Avoid it:* Replace the hyphen by multiplication unless the question says “per” or uses “/”.

REVISE Named SI units by expanding them into base units, especially Pa = N/m². Practice exponent rules during dimensional division and multiplication.

78 Answer: 180

Ref 6743

Medium ~2 min Measurement errors

Find the observed reading and then remove the zero error.

Step 1. The vernier constant is 0.1 mm = 0.01 cm.

Step 2. The main scale reading is 1.7 cm and the 5th vernier division coincides. The observed reading is $1.7 + 5 \times 0.01 = 1.75$ cm.

Step 3. The zero error is -0.05 cm. The corrected reading is the observed reading minus the zero error: $1.75 - (-0.05) = 1.80$ cm.

Step 4. Write this in the asked form: 1.80 cm = 180×10^{-2} cm. A negative zero error means the instrument reads too little, so the correction adds to the reading.

Answer: 180

79 Answer: C

Ref 6865

Medium ~3 min Applications

QUICK APPROACH Start by converting the angular diameter from arcseconds to radians using the small-angle approximation to relate angular diameter, distance, and actual diameter.

The diameter d of the Sun is found using the small-angle approximation $d = \theta r$, where $r = 1.5 \times 10^{11}$ m is the Earth-Sun distance and θ is the angular diameter in radians.

Convert 2000" to radians: $1'' = \frac{\pi}{180 \times 3600}$ rad $\approx \frac{1}{206265}$ rad, so

$$\theta = \frac{2000}{206265} \approx 9.696 \times 10^{-3}$$

rad.

Then

$$d = (9.696 \times 10^{-3}) \times (1.5 \times 10^{11}) = 1.454 \times 10^9 \text{ m} \approx 1.45 \times 10^9 \text{ m}.$$

This matches option [C]. Option [B] (1.45×10^{10} m) encodes the specific mistake of using an erroneous conversion factor of $\approx 2.06 \times 10^4$ arcsec/rad (off by a factor of 10) instead of 206265, leading to a tenfold overestimate of θ and thus d .

80 Answer: 2

Ref 7028

Medium ~3 min Measurement errors

The pitch of the screw gauge is 0.5 mm with 50 divisions on the circular scale. Thus,

$$LC = \frac{0.5 \text{ mm}}{50} = 0.01 \text{ mm}.$$

Diameter of the wire is

$$d = \text{MSR} + (\text{CSR} \times LC) = 1.5 \text{ mm} + 7 \times 0.01 \text{ mm} = 1.57 \text{ mm} = 0.157 \text{ cm}.$$

Wire length $l = 6.8$ cm. Curved surface area (lateral surface of cylinder) is

$$A = \pi dl = 3.14 \times 0.157 \times 6.8 \approx 3.35 \text{ cm}^2.$$

For appropriate significant figures: $l = 6.8$ cm has two significant figures (precision to 0.1 cm), while $d = 1.57$ mm has three. In multiplication, the result takes the least number of significant figures (two), so 3.35 rounds to 3.4.

Option [3] (3.9 cm²) encodes the specific mistake of erroneous least count (e.g., wrongly taking LC = 0.05 mm), yielding $d = 1.85$ mm and $A \approx 3.95$ cm² (rounded to 3.9 cm²).

Thus, the correct option is [2] 3.4 cm².

COMMON TRAPS

- **Using the radius in the place of the diameter.** The curved area of a wire is πdl , which uses the diameter. *Avoid it:* Write $2\pi rl = \pi dl$ before substituting.
 - **Keeping too many significant figures.** The length 6.8 cm has two significant figures, so the area is 3.4 cm^2 . *Avoid it:* Round the final answer to the fewest significant figures.
- REVISE** Screw gauge readings and significant figures.

81 Answer: 1

Ref 7198

Medium ~3 min Measurement errors

QUICK APPROACH Start by applying the concept of propagation of relative errors for quantities raised to powers, using logarithmic differentiation of the given formula.

Step 1: The formula for relative error in a quantity Z that is dependent on multiple variables with powers is derived from the natural logarithm. Given $Z = \frac{A^2 B^3}{C^4}$, take the natural logarithm:

$$\ln Z = \ln A^2 + \ln B^3 - \ln C^4$$

Step 2: Use the properties of logarithms to further simplify:

$$\ln Z = 2 \ln A + 3 \ln B - 4 \ln C$$

Step 3: Differentiate both sides to find the differential (absolute error):

$$\frac{dZ}{Z} = 2 \frac{dA}{A} + 3 \frac{dB}{B} - 4 \frac{dC}{C}$$

Step 4: The relative error in Z translates to:

$$\frac{\Delta Z}{Z} = 2 \frac{\Delta A}{A} + 3 \frac{\Delta B}{B} + 4 \frac{\Delta C}{C}$$

Step 5: According to the options provided, option 1 corresponds to this derived expression.

Hence, the correct option is (1) $\frac{2\Delta A}{A} + \frac{3\Delta B}{B} + \frac{4\Delta C}{C}$.

82 Answer: 2

Ref 5599

Medium ~2 min Measurement errors

From $T = 2\pi\sqrt{L/g}$ we get $g = \frac{4\pi^2 L}{T^2}$, so the fractional error in g is the error in L plus twice the error in T .

Step 1. Length: $L = 10 \text{ cm}$ with $\Delta L = 1 \text{ mm} = 0.1 \text{ cm}$. So $\frac{\Delta L}{L} = \frac{0.1}{10} = 1\%$.

Step 2. Time: 200 oscillations take 100 s on a clock of 1 s resolution. The fractional error in the total time is $\frac{1}{100} = 1\%$, and the period has the same fractional error.

Step 3. Combine: $\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2 \frac{\Delta T}{T} = 1 + 2 \times 1 = 3\%$.

Step 4. So the percentage accuracy in g is about 3%.

Answer: (2) 3%

83 Answer: 3

Ref 4799

Medium ~3 min

The pitch of the screw gauge is 0.5 mm and there are 50 divisions on the circular scale. Thus, the least count is $LC = \frac{0.5}{50} = 0.01 \text{ mm}$.

When the ratchet is closed, the 5th division of the circular scale coincides with the reference line instead of the zero, giving a positive zero error of $+5 \times 0.01 = +0.05 \text{ mm}$. (Option 4 encodes the common mistake of adding this zero error instead of subtracting it.)

For the given observation, main scale reading (MSR) is 5 mm and the 20th circular scale division coincides with the reference line. The observed reading is therefore

$$5 + 20 \times 0.01 = 5.20$$

mm.

The true reading is observed reading minus zero error:

$$5.20 - 0.05 = 5.15$$

mm.

Hence the correct option is [3] 5.15 mm.

COMMON TRAPS

- **Adding the zero error instead of subtracting it.** A circular zero below the line is a positive zero error, so it is subtracted from the reading. *Avoid it:* Write true reading = observed reading – zero error, with the sign.
- **Using the pitch as the least count.** The least count is $0.5/50 = 0.01 \text{ mm}$, so 20 divisions give 0.20 mm. *Avoid it:* Find the least count before reading the circular scale.

REVISE Zero error and zero correction of a screw gauge.

84 Answer: 4

Ref 4810

Medium ~2 min Dimensional analysis

QUICK APPROACH Start by writing the dimensional formulas for energy, angular momentum, mass, and gravitational constant, then substitute these into the expression for P and simplify using the laws of exponents for dimensions.

To determine the dimensions of P in $P = EL^2 M^{-5} G^{-2}$, start with the standard dimensional formulas derived from fundamental relations. Energy E from $\frac{1}{2}mv^2$ is $[E] = [M^1 L^2 T^{-2}]$. Angular momentum $L = mvr$ (or $I\omega$) gives $[L] = [M^1 L^2 T^{-1}]$. Mass $[M] = [M^1]$. For G , from $F = G \frac{m_1 m_2}{r^2}$, rearrange to $[G] = [M^{-1} L^3 T^{-2}]$.

Now substitute: $[P] = [E]^1 [L]^2 [M]^{-5} [G]^{-2}$.

Expand: $[L]^2 = (M^1 L^2 T^{-1})^2 = M^2 L^4 T^{-2}$;
 $[G]^{-2} = (M^{-1} L^3 T^{-2})^{-2} = M^2 L^{-6} T^4$.

Combine exponents:

Mass (M): $1 + 2 - 5 + 2 = 0$;

Length (L): $2 + 4 + 0 - 6 = 0$;

Time (T): $-2 - 2 + 0 + 4 = 0$.

Thus $[P] = [M^0 L^0 T^0]$. Option 1 encodes the dimensions of force (a common error from mishandling the power of L or G

in multiplication). This confirms the expression is dimensionless.

The correct option is 4 ($[M^0 L^0 T^0]$).

COMMON TRAPS

- **Slipping on a power of G.** G has dimensions $M^{-1} L^3 T^{-2}$, so G^{-2} gives $M^2 L^{-6} T^4$. *Avoid it:* Write each factor with its power before multiplying.
- **Using the dimensions of linear momentum for L.** Angular momentum is $ML^2 T^{-1}$, not MLT^{-1} . *Avoid it:* Check which momentum the symbol stands for.

REVISE Dimensions of G and angular momentum.

85 Answer: 4

Ref 4885

Medium ~4 min

QUICK APPROACH Use the formula for the period of a pendulum and apply the rule for propagation of errors to relate the percentage errors in length and time to the percentage error in gravitational acceleration g .

Rearrange the formula for g and add the fractional errors, doubling the one for T because it is squared.

Step 1. From $T = 2\pi\sqrt{\frac{L}{g}}$, we get $g = \frac{4\pi^2 L}{T^2}$.

Step 2. So $\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T}$.

Step 3. Here $\frac{\Delta L}{L} = \frac{0.001}{1.0} = 0.1\%$ and $\frac{\Delta T}{T} = \frac{0.01}{1.95} \approx 0.513\%$.

Step 4. Then $\frac{\Delta g}{g} = 0.1\% + 2 \times 0.513\% \approx 1.13\%$.

Answer: (4) 1.13%

COMMON TRAPS

- **Forgetting the factor 2 on the time error.** Since $g \propto L/T^2$, the error in T counts twice. *Avoid it:* Multiply each fractional error by the power in the formula.
- **Leaving out the length error.** The length error adds 0.1% to the 1.03% from time. *Avoid it:* Add a term for every measured quantity.

REVISE Percentage error in g from a simple pendulum.

86 Answer: 3

Ref 5057

Easy ~1 min Dimensional analysis, Applications

QUICK APPROACH Start by recalling the definition of a dimensionless quantity and consider the physical dimensions of permeability of free space compared to ratios like power factor and quality factor.

Step 1: A dimensionless quantity is a quantity without any physical units, which means its dimensions are represented by $[M^0 L^0 T^0]$.

Step 2: Analyze each option:

- Power factor is a dimensionless quantity as it is the ratio of real power to apparent power.
- Quality factor is a dimensionless quantity as it is the ratio of resonant frequency to bandwidth.
- μ_0 , the permeability of free space, has dimensions $[MLT^{-2} A^{-2}]$, thus it is not dimensionless.
- μ_r , relative magnetic permeability, is dimensionless as it is the ratio of the permeability of a medium to the permeability of free space.

Step 3: Conclude that the only option that is not dimensionless is option 3, μ_0 .

COMMON TRAPS

- **Missing the word “not” in the stem.** The required answer is the single quantity with non-zero dimensions, not any dimensionless one. *Avoid it:* Circle or underline “not” before checking options; convert the stem into “Find the dimensional quantity.”
- **Treating μ_0 as dimensionless because it is a physical constant.** The explanation states “ μ_0 , the permeability of free space, has dimensions $[MLT^{-2} A^{-2}]$, thus it is not dimensionless.” *Avoid it:* Whenever a constant appears, recall or derive its unit from a defining formula; do not infer dimensionlessness from constancy.

REVISE Memorize and derive the dimensions of μ_0 : $N A^{-2} = [MLT^{-2} A^{-2}]$. • Common dimensionless ratios: power factor, quality factor, relative permeability, relative permittivity, refractive index, strain.

87 Answer: 4

Ref 5337

Medium ~2 min Dimensional analysis

Step 1: Understand the given information.

The main scale division (MSD) is a cm, and n^{th} division of the vernier scale coincides with $(n-1)^{\text{th}}$ division of the main scale.

Step 2: Apply the formula for the least count (LC) of a vernier callipers.

The least count is given by:

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

where VSD is Vernier Scale Division.

Step 3: Use the coinciding division information.

Since n^{th} division of the vernier coincides with $(n-1)^{\text{th}}$ division of the main scale:

$$n \times \text{VSD} = (n-1) \times \text{MSD}$$

Step 4: Solve for VSD.

$$\text{VSD} = \frac{(n-1)\text{MSD}}{n} = \frac{(n-1)a}{n} \text{ cm}$$

Step 5: Substitute VSD back into the LC formula:

$$LC = a - \frac{(n-1)a}{n} = \frac{a}{n} \text{ cm}$$

Step 6: Convert LC to mm.

$$LC = \frac{10a}{n} \text{ mm}$$

Thus, option 4 is correct.

COMMON TRAPS

- **Dividing by $n - 1$ instead of n .** Since n vernier divisions equal $n - 1$ main divisions, the least count is a/n cm. *Avoid it:* Write least count = 1 MSD – 1 VSD and simplify.
- **Forgetting the change from cm to mm.** a/n cm is $10a/n$ mm. *Avoid it:* Check the unit the question asks for.

REVIEW Least count of vernier callipers.

88 Answer: 2

Ref 5375

Medium ~1.5 min Measurement errors

For a vernier caliper, the measurement is given by:

$$\text{Observed reading} = \text{MSR} + (\text{vernier coincidence} \times \text{LC})$$

Here, the zero of the vernier scale lies between 8.5 cm and 8.6 cm on the main scale, so MSR = 8.5 cm. The vernier coincidence is 6 and LC = 0.01 cm. Thus,

$$\text{VSR} = 6 \times 0.01 = 0.06 \text{ cm}$$

$$\text{Observed reading} = 8.5 + 0.06 = 8.56 \text{ cm.}$$

The instrument has a positive zero error of 0.2 mm = +0.02 cm. Positive zero error arises when the vernier zero lies to the right of the main scale zero with jaws closed, so the device reads higher than the true value; correction requires subtracting it. Correct measurement = 8.56 – 0.02 = 8.54 cm.

Option [3] 8.58 cm encodes the specific mistake of adding (instead of subtracting) the positive zero error: 8.56 + 0.02 = 8.58 cm. This is a common sign-convention error. Therefore, the correct value is 8.54 cm, option [2].

COMMON TRAPS

- **Adding a positive zero error.** A positive zero error makes the reading too large, so it is subtracted: 8.56 – 0.02 = 8.54 cm. *Avoid it:* Subtract the zero error with its sign.
- **Leaving the zero error in mm.** 0.2 mm is 0.02 cm, which must match the units of the reading. *Avoid it:* Convert the zero error to cm before subtracting.

REVIEW Zero error correction in vernier callipers.

89 Answer: 3

Ref 5532

Medium ~3 min SI Units

Step 1: Identify the physical quantities and their units from List-(I) and List-(II).

- R_H , the Rydberg constant, has units of m^{-1} (option iii).
- h (Planck's constant) is known to have units of $\text{kg m}^2 \text{s}^{-1}$ (option ii).
- The magnetic field energy density μ_B has units of $\text{kg m}^{-1} \text{s}^{-2}$ (option iv).
- The coefficient of viscosity η has units of $\text{kg m}^{-1} \text{s}^{-1}$ (option i).

Step 2: Match these units with the list:

- (a) R_H : iii (m^{-1})
- (b) h : ii ($\text{kg m}^2 \text{s}^{-1}$)
- (c) μ_B : iv ($\text{kg m}^{-1} \text{s}^{-2}$)
- (d) η : i ($\text{kg m}^{-1} \text{s}^{-1}$)

Step 3: The correct matching is found in option 3: (a) - (iii), (b) - (ii), (c) - (iv), (d) - (i).

COMMON TRAPS

- **Confusing energy density with viscosity.** Energy density is energy per volume, $\text{kg m}^{-1} \text{s}^{-2}$, while viscosity is $\text{kg m}^{-1} \text{s}^{-1}$. *Avoid it:* Compare the power of seconds to tell them apart.
- **Giving the Rydberg constant energy units.** The Rydberg constant here is a wave number, so its unit is m^{-1} . *Avoid it:* Recall $\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$.

REVIEW SI units of h , η and energy density.

90 Answer: 1

Ref 5583

Medium ~4 min Dimensional analysis

Write each quantity from a defining formula and reduce it to M, L, T, A .

Step 1. Capacitance $C = \frac{Q}{V}$. With $[Q] = [AT]$ and $[V] = [ML^2T^{-3}A^{-1}]$, $[C] = [M^{-1}L^{-2}T^4A^2]$, which is (iii).

Step 2. From $F = \frac{q^2}{4\pi\epsilon_0 r^2}$, $[\epsilon_0] = \frac{[A^2T^2]}{[MLT^{-2}][L^2]} = [M^{-1}L^{-3}T^4A^2]$, which is (ii).

Step 3. From $\frac{F}{l} = \frac{\mu_0 I^2}{2\pi d}$, $[\mu_0] = \frac{[MLT^{-2}]}{[A^2]} = [MLT^{-2}A^{-2}]$, which is (iv).

Step 4. Electric field $E = \frac{F}{q}$, so $[E] = \frac{[MLT^{-2}]}{[AT]} = [MLT^{-3}A^{-1}]$, which is (i).

Answer: (1) (a)-(iii), (b)-(ii), (c)-(iv), (d)-(i)

COMMON TRAPS

- **Swapping capacitance and permittivity.** Permittivity is capacitance per length, so it has one more L^{-1} than capacitance. *Avoid it:* Use $C = \epsilon_0 A/d$ to link the two.
- **Mixing up ϵ_0 and μ_0 .** μ_0 has $MLT^{-2}A^{-2}$ from force between currents, quite unlike ϵ_0 . *Avoid it:* Derive μ_0 from $F/l = \mu_0 I_1 I_2 / (2\pi r)$.

REVIEW Dimensions of ϵ_0 , μ_0 and capacitance.

91 Answer: 1

Ref 5606

Medium ~2 min Dimensional analysis

Density is mass per unit volume, so its dimensional formula is $[\rho] = [M][L]^{-3}$.

The fundamental quantities here are force F , length L , and time T . Start from the definition of force: $F = ma = m \left(\frac{L}{T^2} \right)$. Thus, $[F] = [M][L][T]^{-2}$, which rearranges to $[M] = [F][L]^{-1}[T]^2$.

Substitute into the expression for density: $[\rho] = ([F][L]^{-1}[T]^2) \times [L]^{-3} = [FL^{-4}T^2]$.

This matches option [1]. Option [3] $[FL^{-3}T^2]$ encodes a specific mistake: deriving $[M] = [FT^2]$ by omitting the length dimension in acceleration (treating a as $[T]^{-2}$ only). This is a common error when students recall $F = ma$ but neglect $[a] = [LT^{-2}]$. The derivation above confirms option [1] as correct.

COMMON TRAPS

- **Taking mass as F times T.** From $F = Ma$, mass is FT^2L^{-1} , not FT . *Avoid it:* Write $M = F/a$ with $a = LT^{-2}$.
- **Dropping the extra power of L.** Density is M/L^3 , so the L^{-1} in mass makes it $FL^{-4}T^2$. *Avoid it:* Collect all powers of L at the end.

REVIEW Changing the base quantities in dimensional analysis.

92 Answer: 1

Ref 5773

Medium ~3 min Dimensional analysis, Applications

Write each quantity from a simple defining formula and reduce it to base dimensions.

Step 1. Planck's constant: $h = \frac{E}{\nu}$, so $[h] = [ML^2T^{-2}][T] = [ML^2T^{-1}]$, which is (ii).

Step 2. Kinetic energy: $E = \frac{1}{2}mv^2$, so $[E] = [ML^2T^{-2}]$, which is (iii).

Step 3. Electric potential: $V = \frac{W}{q}$, so $[V] = \frac{[ML^2T^{-2}]}{[IT]} = [ML^2I^{-1}T^{-3}]$, which is (iv).

Step 4. Linear momentum: $p = mv$, so $[p] = [MLT^{-1}]$, which is (i).

Answer: (1) (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)

93 Answer: A

Ref 5838

Medium ~3 min Uncertainty and Errors

According to Heisenberg's uncertainty principle,

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

where Δx is uncertainty in position and Δp in momentum. Mass of ball $m = 10 \text{ g} = 0.01 \text{ kg}$. Given velocity $v = 90 \text{ ms}^{-1}$, uncertainty $\Delta v = 5\%$ of $90 = 4.5 \text{ ms}^{-1}$. Thus $\Delta p = m\Delta v = 0.01 \times 4.5 = 0.045 \text{ kg ms}^{-1}$.

Minimum $\Delta x = \frac{h}{4\pi\Delta p}$. With $h = 6.63 \times 10^{-34} \text{ Js}$ and $4\pi \approx 12.566$,

$$\frac{h}{4\pi} \approx \frac{6.63 \times 10^{-34}}{12.566} \approx 5.276 \times 10^{-35}.$$

Then $\Delta x \approx \frac{5.276 \times 10^{-35}}{0.045} \approx 1.172 \times 10^{-33} \text{ m}$. Rounded to nearest integer, $x = 1$.

Option B (2) encodes the specific mistake of using $\frac{h}{2\pi}$ (instead of $\frac{h}{4\pi}$) for the uncertainty principle, which yields $\approx 2.34 \times 10^{-33} \text{ m}$ rounding to 2. The correct option is A.

94 Answer: 4

Ref 5848

Medium ~2 min Dimensional analysis

QUICK APPROACH Use dimensional homogeneity by expressing mass in terms of powers of the fundamental units t , v , and l ; start by writing the dimensions of angular momentum, velocity, and time in terms of M, L, and T.

Express mass using the new base quantities by first writing length in terms of them.

Step 1. The dimensions are $[t] = T$, $[v] = LT^{-1}$ and $[l] = ML^2T^{-1}$ for angular momentum.

Step 2. Length is velocity times time, so $L = vt$.

Step 3. From $l = ML^2T^{-1}$ we get $M = \frac{lT}{L^2}$. Substitute $L = vt$ and $T = t$: $M = \frac{lt}{v^2t^2} = l v^{-2} t^{-1}$.

Step 4. Check: $(ML^2T^{-1})(L^{-2}T^2)(T^{-1}) = M$. The powers of L and T cancel, leaving mass alone. A common slip is to forget that length must first be rewritten as vt .

Answer: (4) $[t^{-1}v^{-2}l^1]$

95 Answer: 4

Ref 3895

Easy ~1 min Dimensional analysis

QUICK APPROACH Start by expressing solar constant as energy per unit area per unit time and use dimensional analysis of energy, area, and time to find the overall dimension.

Step 1: The solar constant is defined as the amount of solar energy received per unit area per unit time.

Step 2: Energy has the dimension of ML^2T^{-2} .

Step 3: Since this energy is distributed per unit area, we divide by the area which has the dimension L^2 , resulting in $ML^2T^{-2}/L^2 = MT^{-3}$. Therefore, the dimension for the solar constant is ML^0T^{-3} .

96 Answer: 1

Ref 3974

Medium ~3 min Dimensional analysis

Step 1: Begin with the dimensional formula of Young's modulus: $Y = \text{Force} / \text{Area}$.

Step 2: In terms of fundamental units M, L, and T: Force has dimensions $[MLT^{-2}]$, and Area has dimensions $[L^2]$.

Step 3: Hence, Young's modulus has dimensions: $Y = [MLT^{-2}] / [L^2] = [ML^{-1}T^{-2}]$.

Step 4: Assume Young's modulus Y is expressed as a combination of given basic units: $Y = F^x A^y V^z$.

Step 5: Replace with dimensions of V, A, F: $V = LT^{-1}$, $A = L^2$, $F = MLT^{-2}$.

Step 6: Equate dimensions on both sides: $M^1 L^{-1} T^{-2} = [MLT^{-2}]^x [L^2]^y [LT^{-1}]^z$.

Step 7: Comparing the powers of M, L, and T: For M: $x = 1$, For L: $x + 2y + z = -1$, For T: $-2x - z = -2$.

Step 8: Solving the equations: $x = 1$, $y = -1$, $z = 0$.

Step 9: Substitute these values in $Y = F^x A^y V^z$: $Y = F^1 A^{-1} V^0 = FA^{-1} V^0$.

COMMON TRAPS

- **Not using that Young's modulus is force per area because strain is dimensionless.** Young's modulus has the same dimension as stress: $[Y] = [F]/[A]$. Therefore in the new fundamental units, $Y = FA^{-1}V^0$. *Avoid it:* Before solving exponents, write the base physical formula: $Y = \text{stress/strain} = (\text{Force/Area})/(\text{dimensionless})$.
- **Treating area A as length L instead of L^2 .** Area always carries dimension $[L^2]$, not $[L]$. *Avoid it:* Circle the word "area A" in the stem and write $A \rightarrow L^2$ immediately.

REVISE Dimensions of stress, strain, Young's modulus, force, speed, and area. Practice expanding expressions like $F^x A^y V^z$ into M, L, T powers before solving.

97 Answer: 4

Ref 4083

Medium ~3 min Measurement errors

Find the least count, the zero error and the observed reading, then subtract the zero error.

Step 1. Ten vernier divisions equal nine main scale divisions, so 1 VSD = 0.9 mm. The least count is $1 - 0.9 = 0.1 \text{ mm} = 0.01 \text{ cm}$.

Step 2. With the jaws closed, the vernier zero lies to the right of the main scale zero, so the zero error is positive. The 7th division coincides, so the zero error is $+7 \times 0.01 = +0.07 \text{ cm}$.

Step 3. For the cylinder, the main scale reading is 3.1 cm and the 4th division coincides. The observed reading is $3.1 + 4 \times 0.01 = 3.14 \text{ cm}$.

Step 4. Corrected length = observed reading minus zero error = $3.14 - 0.07 = 3.07 \text{ cm}$.

Answer: (4) 3.07 cm

98 Answer: B

Ref 4225

Medium ~2 min

QUICK APPROACH Start by calculating the least count using the relationship between pitch and the number of divisions on the circular scale; then analyze the zero error based on the initial position of the circular scale relative to the pitch scale.

Step 1: Calculate the least count of the screw gauge using the formula: Least Count = Pitch / Number of divisions on the circular scale. Here, pitch = 0.5 mm and the number of divisions = 50.

Step 2: Least Count = $0.5 \text{ mm} / 50 = 0.01 \text{ mm} = 10 \mu\text{m}$.

Step 3: Knowing the circular scale is 4 units ahead of the pitch scale indicates a positive zero error.

Step 4: Hence, the least count is $10 \mu\text{m}$ and the zero error is positive.

99 Answer: 2

Ref 4530

Medium ~2 min Dimensional analysis

Write energy as a product of powers of momentum, area and time, and match the dimensions.

Step 1. The dimensions are $[E] = ML^2T^{-2}$, $[P] = MLT^{-1}$, $[A] = L^2$ and $[T] = T$.

Step 2. Put $E = P^x A^y T^z$. Then $ML^2T^{-2} = M^x L^{x+2y} T^{-x+z}$.

Step 3. Mass gives $x = 1$. Length gives $1 + 2y = 2$, so $y = \frac{1}{2}$.

Time gives $-1 + z = -2$, so $z = -1$.

Step 4. So $[E] = PA^{1/2}T^{-1}$. This makes sense: energy is momentum times speed, and speed is a length $A^{1/2}$ divided by a time.

Answer: (2) $PA^{1/2}T^{-1}$

100 Answer: 3

Ref 4626

Medium ~3 min Dimensional analysis, Applications

Step 1: Write the dimensional formula of each parameter:

- Moment of inertia (I): $[ML^2]$
- Force (F): $[MLT^{-2}]$
- Velocity (v): $[LT^{-1}]$
- Work (W): $[ML^2T^{-2}]$
- Length (L): $[L]$

Step 2: Substitute these into the expression for x :

$$x = \frac{IFv^2}{WL^4}$$

Substitute the dimensional formulas:

$$[x] = \frac{[ML^2][MLT^{-2}][LT^{-1}]^2}{[ML^2T^{-2}][L]^4}$$

Step 3: Simplify the expression:

$$[x] = \frac{[M][L^2][M][L][T^{-2}][L^2][T^{-2}]}{[M][L^2][T^{-2}][L^4]}$$

$$[x] = \frac{[M^2][L^5][T^{-4}]}{[M][L^6][T^{-2}]}$$

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

Step 4: Compare with standard dimensional formulas:

- The dimensional formula for energy density (energy per unit volume) is $[M][L^{-1}][T^{-2}]$, which matches the derived formula for x .

Thus, the dimensional formula for x is the same as that of energy density.

COMMON TRAPS

- **Taking W as watt/power instead of work.** Here W is a physical quantity named work, not watt. Work/energy has dimension $[ML^2T^{-2}]$. *Avoid it:* Circle the defined quantities in the stem: "moment of inertia I, force F, velocity v, work W and Length L". Then write dimensions only from those names, not from symbols.
- **Forgetting to square velocity in v^2 .** Every power on a physical quantity applies to all its dimensions: $v^2 = [L^2T^{-2}]$. *Avoid it:* Before simplification, rewrite every exponent explicitly: $I^1 F^1 v^2 W^{-1} L^{-4}$. Then expand v^2 as $L^2 T^{-2}$.

REVISE Dimensions of work, power, moment of inertia, force constant, energy density, and viscosity as a contrast set. Use an M-L-T exponent table for every dimensional-analysis fraction.

101 Answer: 3

Ref 4633

Medium ~2 min

QUICK APPROACH Use the concept of significant figures and proper rounding rules when reporting measurements with uncertainty.

Step 1: Calculate the mean value of the measurements given: 5.50 mm, 5.55 mm, 5.45 mm, 5.65 mm. The average is provided as 5.5375 mm.

Step 2: The standard deviation is given as 0.07395 mm.

Step 3: When expressing measurements with uncertainty, the value must not exceed the least count of accuracy based on significant figures.

Step 4: For both mean and standard deviation, we consider three significant figures. Therefore, express the mean as 5.54 mm and standard deviation as 0.07 mm.

Step 5: Therefore, the appropriate expression with correct significant figures is (5.54 ± 0.07) mm.

102 Answer: 2

Ref 4644

Medium ~2 min

QUICK APPROACH Start by calculating the pitch, which is the distance moved by the screw in one complete rotation, then use the formula for least count as pitch divided by number of divisions on the circular scale.

Step 1: Calculate the pitch of the screw gauge. Pitch is the distance moved by the screw for one complete rotation. Given that the screw advances 3 mm in 6 rotations, the pitch = $3 \text{ mm} / 6 = 0.5 \text{ mm}$. Step 2: Determine the least count of the screw gauge. The least count (L.C.) is given by $\text{L.C.} = \text{Pitch} / \text{Number of divisions on the circular scale}$. Here, $\text{L.C.} = 0.5 \text{ mm} / 50 = 0.01 \text{ mm}$. Step 3: Convert the least count to cm. Since $1 \text{ mm} = 0.1 \text{ cm}$, we get $\text{L.C.} = 0.01 \text{ mm} = 0.001 \text{ cm}$. Therefore, the least count of the screw gauge is 0.001 cm .

103 Answer: (2)

Ref 4653

Medium ~2 min Dimensional analysis

Step 1: Identify the dimensional formulas for the constants:

- Planck's constant h has the dimensional formula $[ML^2T^{-1}]$.
- Speed of light c has the dimensional formula $[LT^{-1}]$.
- Gravitational constant G has the dimensional formula $[M^{-1}L^3T^{-2}]$.

Step 2: Calculate the dimensional formula of hc^5 :

- h is $[ML^2T^{-1}]$.
- c^5 is $[L^5T^{-5}]$.
- Therefore, $hc^5 = [ML^2T^{-1} \times L^5T^{-5}] = [ML^7T^{-6}]$.

Step 3: Combine with G :

$$\frac{hc^5}{G} = \frac{[ML^7T^{-6}]}{[M^{-1}L^3T^{-2}]} = [M^{1+1}L^{7-3}T^{-6+2}] = [M^2L^4T^{-4}]$$

Step 4: Find the dimensional formula of $\sqrt{\frac{hc^5}{G}}$:

- Take the square root to get $[M^2L^4T^{-4}]^{1/2} = [M^1L^2T^{-2}]$.

Thus, the answer is $[ML^2T^{-2}]$.

104 Answer: A

Ref 2254

Medium ~4 min Dimensional analysis

Write each new base quantity in M, L, T and match the powers of linear momentum.

Step 1. The dimensions are $[S] = MT^{-2}$, $[I] = ML^2$, $[h] = ML^2T^{-1}$, and momentum is $[p] = MLT^{-1}$.

Step 2. Put $p = S^a I^b h^c$. Then $MLT^{-1} =$

$$M^{a+b+c} L^{2b+2c} T^{-2a-c}.$$

Step 3. Compare powers. Mass gives $a + b + c = 1$. Length gives $2b + 2c = 1$, so $b + c = \frac{1}{2}$ and therefore $a = \frac{1}{2}$. Time gives $-2a - c = -1$, so $c = 1 - 2a = 0$. Then $b = \frac{1}{2}$.

Step 4. Check: $S^{1/2} I^{1/2} = (MT^{-2})^{1/2} (ML^2)^{1/2} = MLT^{-1}$, which is momentum. Planck's constant is not needed at all.

Answer: (A) $S^{1/2} I^{1/2} h^0$

105 Answer: 2

Ref 2309

Medium ~3 min Dimensional analysis

QUICK APPROACH Start by using dimensional analysis to make the exponent dimensionless, then relate the dimensions of force to those of α and β .

The argument of an exponential has no dimensions; use that to find α , then β .

Step 1. kT is an energy, so $[kT] = ML^2T^{-2}$, and $[x^2] = L^2$.

Step 2. $\frac{x^2}{\alpha kT}$ is dimensionless, so $[\alpha] = \frac{L^2}{ML^2T^{-2}} = M^{-1}T^2$.

Step 3. The exponential is dimensionless, so $[F] = [\alpha][\beta]$, with $[F] = MLT^{-2}$.

Step 4.

$$[\beta] = \frac{MLT^{-2}}{M^{-1}T^2} = M^2LT^{-4}$$

Answer: (2) M^2LT^{-4}

106 Answer: 3

Ref 2409

Medium ~3 min

A numerical value changes inversely with the size of the unit, so find how big the new unit of density is in SI units.

Step 1. The new unit of mass is $50 \text{ g} = 0.05 \text{ kg}$ and the new unit of length is $25 \text{ cm} = 0.25 \text{ m}$.

Step 2. The new unit of density is $\frac{0.05 \text{ kg}}{(0.25 \text{ m})^3} = \frac{0.05}{0.015625} \text{ kg m}^{-3} = 3.2 \text{ kg m}^{-3}$.

Step 3. The density is 128 kg m^{-3} . Divide by the size of the new unit: $n = \frac{128}{3.2} = 40$.

Step 4. Check with $n_2 = n_1 \left(\frac{M_1}{M_2}\right) \left(\frac{L_1}{L_2}\right)^{-3}$: $n_2 = 128 \times \frac{1000}{50} \times \left(\frac{100}{25}\right)^{-3} = 128 \times 20 \times \frac{1}{64} = 40$.

Answer: (3) 40

107 Answer: 3

Ref 2499

Medium ~4 min Measurement errors

QUICK APPROACH Start by calculating the radius from the diameter and then use the formula for the volume of a cylinder, applying error propagation for multiplication and powers.

Step 1: The formula for the volume of a cylinder is $V = \pi r^2 h$. To find the radius, divide the diameter by 2. For $d = 12.6 \pm 0.1 \text{ cm}$, the radius $r = \frac{12.6}{2} = 6.3 \text{ cm}$.

Step 2: The volume is $V = \pi(6.3)^2(34.2) \approx 4260 \text{ cm}^3$.

Step 3: Error in V can be calculated using propagation of error:

$$\begin{aligned}\frac{\Delta V}{V} &= 2\frac{\Delta r}{r} + \frac{\Delta h}{h} \\ &= 2\frac{0.05}{6.3} + \frac{0.1}{34.2} \\ &= 0.01587 + 0.00292 \approx 0.01879 \\ \Delta V &\approx 0.01879 \times 4260 \approx 80\end{aligned}$$

Step 4: Therefore, the answer is $4260 \pm 80 \text{ cm}^3$.

108 Answer: D

Ref 2572

Medium ~2 min Measurement errors

QUICK APPROACH Apply the concept of least count in a screw gauge, where least count = pitch divided by the number of divisions on the circular scale.

The least count of a screw gauge is the pitch divided by the number of circular scale divisions.

Step 1. One turn moves the screw by one main scale division, so the pitch is 1 mm.

Step 2. To measure $5 \mu\text{m}$ the least count must be at most $5 \mu\text{m} = 5 \times 10^{-3} \text{ mm}$.

Step 3. From $\text{LC} = \frac{\text{pitch}}{N}$ we get $N = \frac{1 \text{ mm}}{5 \times 10^{-3} \text{ mm}} = 200$.

Step 4. Fewer divisions would give a larger least count, so 200 is the minimum.

Answer: (D) 200

COMMON TRAPS

- **Using a least count of 1 mm directly.** The 1 mm is the pitch, and the least count is the pitch shared out over the circular divisions. *Avoid it:* Write $\text{LC} = \text{pitch}/N$ before putting in numbers.
- **Mixing micrometres and millimetres.** $5 \mu\text{m}$ is 0.005 mm, not 0.05 mm. *Avoid it:* Convert every length to millimetres before dividing.

REVIEW Least count of a screw gauge. · Conversions between mm and micrometres.

109 Answer: 4

Ref 2612

Medium ~2 min Dimensional analysis

QUICK APPROACH Start by expressing Young's modulus in terms of stress and then rewrite stress dimensions using the given fundamental units of speed, acceleration, and force.

Young's modulus is defined as $Y = \frac{\text{stress}}{\text{strain}}$. Since strain is dimensionless, $[Y] = [\text{stress}] = [F/A] = \text{M L}^{-1} \text{T}^{-2}$.

Express $[Y]$ in terms of the new fundamentals: $[V] = \text{L T}^{-1}$, $[A] = \text{L T}^{-2}$, $[F] = \text{M L T}^{-2}$.

Assume $[Y] = V^x A^y F^z$. Equating dimensions:

Mass: $z = 1$

Length: $x + y + z = -1$

Time: $-x - 2y - 2z = -2$

Substitute $z = 1$: $x + y = -2$ and $-x - 2y = 0$ so $x = -2y$.

Solving yields $y = 2$, $x = -4$, $z = 1$. Thus $[Y] = V^{-4} A^2 F$.

Option 3 encodes a sign error on the acceleration exponent (likely from mishandling the time equation when substituting $z = 1$).

The correct option is [4] $V^{-4} A^2 F$.

110 Answer: 1

Ref 2879

Medium ~3 min Measurement errors

Density of the cube is $\rho = \frac{m}{a^3}$, where m is mass and a is edge length. For maximum permissible error (relative),

$$\frac{\Delta \rho}{\rho} = \frac{\Delta m}{m} + 3 \frac{\Delta a}{a}.$$

Substitute $\Delta m = 0.10 \text{ kg}$, $m = 10.00 \text{ kg}$ so $\frac{\Delta m}{m} = 0.01$; $\Delta a = 0.01 \text{ m}$, $a = 0.10 \text{ m}$ so $\frac{\Delta a}{a} = 0.1$.

Thus, $\frac{\Delta \rho}{\rho} = 0.01 + 3(0.1) = 0.31$.

The error in density measurement is therefore 0.31 (relative). Option [4] (0.01) encodes the specific mistake of using only the relative error in mass and neglecting the length contribution entirely (the dominant term here). This question tests error propagation for powers, where the coefficient 3 arises from volume $V = a^3$.

111 Answer: C

Ref 2902

Medium ~3 min Dimensional analysis

QUICK APPROACH Apply dimensional analysis by expressing time as a product of powers of G , h , and c , and then equate the dimensions of mass, length, and time on both sides.

To derive the expression for time t proportional to powers of G , h , and c , assume $t \propto G^a h^b c^d$. Use dimensional analysis with the fundamental dimensions M , L , T .

The dimensions are: $[G] = \text{M}^{-1} \text{L}^3 \text{T}^{-2}$ (from $F = Gm_1 m_2 / r^2$), $[h] = \text{ML}^2 \text{T}^{-1}$ (from $E = hf$), and $[c] = \text{LT}^{-1}$. The left side has $[t] = \text{T}$ (so $\text{M}^0 \text{L}^0 \text{T}^1$).

Equating exponents yields the system:

- Mass: $-a + b = 0 \implies b = a$
- Length: $3a + 2b + d = 0$
- Time: $-2a - b - d = 1$

Substitute $b = a$ into the others: $5a + d = 0$ so $d = -5a$; then $-3a - (-5a) = 1 \implies 2a = 1$ so $a = 1/2$, $b = 1/2$, $d = -5/2$.

Thus $t \propto G^{1/2} h^{1/2} c^{-5/2} = \sqrt{\frac{Gh}{c^5}}$, which is option [C]. This matches the Planck time $t_p = \sqrt{\frac{\hbar G}{c^5}}$ (up to factors of 2π).

Option [A] $\sqrt{\frac{Gh}{c^3}}$ encodes the common mistake of deriving Planck length l_p instead (set L^1 on left side, yielding $a = b = 1/2$, $d = -3/2$). Students may have been taught the length formula but overlooked switching the target dimension from L to T . This error is frequent in JEE problems on Planck units.

The correct option is [C] $\sqrt{\frac{Gh}{c^5}}$.

COMMON TRAPS

- **Using c^3 instead of c^5 .** Matching the time powers of G , h and c needs $c^{-5/2}$, which gives the Planck time $\sqrt{Gh/c^5}$. *Avoid it:* Solve the three power equations for M , L and T fully.
- **Choosing the Planck length by memory.** $\sqrt{Gh/c^3}$ has dimensions of length, not time. *Avoid it:* Check the final answer has dimension T alone.

REVISE Building quantities from G , h and c .

112 Answer: C

Ref 3210

Easy ~1 min Significant Figures

Step 1: Identify the given information. The area of one square is 5.29 cm^2 .

Step 2: Determine the area of 7 such squares. Since each square has an area of 5.29 cm^2 , the total area is $5.29 \times 7 = 37.03 \text{ cm}^2$.

Step 3: Consider significant figures. The number 5.29 has 3 significant figures (5, 2, and 9).

Step 4: Apply significant figures. When multiplying, the result should have the same number of significant figures as the factor with the fewest significant figures. Therefore, the answer should have 3 significant figures, so the result is expressed as 37.0 cm^2 .

113 Answer: 3

Ref 3438

Medium ~2 min Measurement errors

QUICK APPROACH Work out the least count, decide the sign of the zero error from where the circular zero sits, and subtract it from the reading.

Find the least count, read the gauge, then correct for the zero error.

Step 1. Least count = $\frac{\text{pitch}}{\text{divisions}} = \frac{0.5}{100} = 0.005 \text{ mm}$.

Step 2. With the jaws closed, the zero of the circular scale lies

3 divisions below the mean line. The circular scale has already turned past zero, so the gauge reads 3 divisions too much:

zero error = $+3 \times 0.005 = +0.015 \text{ mm}$.

Step 3. Observed reading for the sheet: $5.5 + 48 \times 0.005 = 5.5 + 0.240 = 5.740 \text{ mm}$.

Step 4. Corrected thickness = observed reading – zero error = $5.740 - 0.015 = 5.725 \text{ mm}$.

Answer: (3) 5.725 mm

COMMON TRAPS

- **Ignoring the zero error.** The uncorrected reading 5.740 mm still contains the instrument's offset. *Avoid it:* Always subtract the zero error from the observed reading.
- **Getting the sign of the zero error wrong.** A circular zero below the mean line means a positive zero error. *Avoid it:* Decide whether the gauge reads too much or too little when closed.

REVISE Screw gauge least count and zero error.

114 Answer: 2

Ref 3494

Medium ~2 min Dimensional analysis

Step 1: Determine the dimensional formula for each variable:

- Inductance L : $[ML^2T^{-2}A^{-2}]$
- Resistance R : $[ML^2T^{-3}A^{-2}]$
- Capacitance C : $[M^{-1}L^{-2}T^4A^2]$
- Voltage V : $[ML^2T^{-3}A^{-1}]$

Step 2: Calculate the dimensional formula for $\frac{L}{RCV}$:

- First, find RC : $R \times C = [ML^2T^{-3}A^{-2}] \times [M^{-1}L^{-2}T^4A^2] = [T^1]$
- Next, compute RCV : $(RC) \times V = [T^1] \times [ML^2T^{-3}A^{-1}] = [ML^2T^{-2}A^{-1}]$
- Finally, divide L by RCV : $\frac{L}{RCV} = \frac{[ML^2T^{-2}A^{-2}]}{[ML^2T^{-2}A^{-1}]} = [A^{-1}]$

Step 3: Identify the correct option:

- The correct dimensional formula is $[A^{-1}]$, so option (2) is correct.

COMMON TRAPS

- **Missing that L/R and RC are times.** L/R is a time, so $\frac{L}{RCV} = \frac{T}{CV} = \frac{T}{Q}$. *Avoid it:* Group the expression into known time constants first.
- **Writing charge as just A .** Charge is current times time, so $[Q] = AT$ and $T/Q = A^{-1}$. *Avoid it:* Write $[Q] = AT$ whenever charge appears.

REVISE Time constants of RL and RC circuits.



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