Units and Measurement JEE Main PYQ - 1

Total Time: 1 Hour **Total Marks:** 100

Instructions

Instructions

1. Test will auto submit when the Time is up.
2. The Test comprises of multiple choice questions (MCQ) with one or more correct answers.
3. The clock in the top right corner will display the remaining time available for you to complete the examination.

Navigating & Answering a Question

1. The answer will be saved automatically upon clicking on an option amongst the given choices of answer.
2. To deselect your chosen answer, click on the clear response button.
3. The marking scheme will be displayed for each question on the top right corner of the test window.

Units and Measurement

1. **Which of the following cannot be measured:** **(+4, -1)**

   a. Resistance

   b. Voltage

   c. Voltage difference

   d. Displacement current

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2. **Time period of a spring-block system is given by $T = 2\pi\sqrt{\frac{m}{k}}$. If mass of the block is given by $m = 10\,\text{g} \pm 10\,\text{mg}$ and time period is measured using a stopwatch having least count of $2\,\text{s}$ and was found to be $60\,\text{s}$ for 50 oscillations, then find the % error in measurement of k.** **(+4, -1)**

   a. 5.6

   b. 6.8

   c. 7.7

   d. 5.9

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3. **Match the following as per dimensional formula.** **(+4, -1)**

	Physical Quantity		Dimensional Formula
(1)	Pressure	(P)	$ML^{-1}T^{-1}$
(2)	Coefficient of viscosity	(Q)	$ML^{0}T^{-2}$
(3)	Surface tension	(R)	$ML^{-1}T^{-2}$
(4)	Surface energy	(S)	$ML^{2}T^{-2}$

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

   b. 1-S, 2-Q, 3-R, 4-S

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

d. 1-S, 2-Q, 3-Q, 4-S

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4. **Measurement taken with Vernier caliper are as follows: $1.21, 1.23, 1.24, 1.20$ mm. What can be the least count of Vernier Caliper?** (+4, -1)

a. 0.1 mm

b. 0.01 mm

c. 0.001 mm

d. 0.0001 mm

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5. **What will be the number of significant figures in the sum of $2.34,\ 12.1,\ \text{and}\ 0.056$?** (+4, -1)

a. 2

b. 3

c. 4

d. 5

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6. **Find dimensions of $\frac{A}{B}$ if \(\left(\frac{P + \frac{A^2}{B}}{\frac{1}{2} \rho v^2} \right) = \text{constant \)** where P = pressure, ρ = density, v = speed.} (+4, -1)

a. \(ML^T^4 \)

b. $ML^{-1}T^{-4}$

c. \(ML^T^2 \)

d. $ML^{-1}T^{-2}$

---

7. Match the column (+4, -1)

Column-I	Column-II
(A) Thermal Conductivity	(P) $[MLT^{-3}K^{-1}]$
(B) Boltzmann Constant	(Q) $[ML^1T^{-2}]$
(C) Spring constant	(R) $[ML^1T^{-3}K^{-1}]$
(D) Surface tension	(S) $[ML^1T^{-2}]$
	(T) $[ML^0T^{-2}]$
	(U) $[ML^2T^{-2}]$

a. A $\rightarrow$ R; B $\rightarrow$ P; C $\rightarrow$ S; D $\rightarrow$ S

b. A $\rightarrow$ T; B $\rightarrow$ P; C $\rightarrow$ U; D $\rightarrow$ S

c. A $\rightarrow$ R; B $\rightarrow$ T; C $\rightarrow$ Q; D $\rightarrow$ Q

d. A $\rightarrow$ T; B $\rightarrow$ U; C $\rightarrow$ S; D $\rightarrow$ Q

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8. Assertion A : If in five complete rotations of the circular scale, the distance travelled on main scale is 5 mm and there are 50 total divisions on circular scale, then least count is 0.001 cm. **(+4, -1)**
Reason R : Least Count = $\frac{\text{Pitch}}{\text{Total divisions on circular scale}}$

a. Both A and R are correct and R is the correct explanation of A.

b. Both A and R are correct and R is NOT the correct explanation of A.

c. A is correct but R is not correct.

d. A is not correct but R is correct.

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9. The diameter of a spherical bob is measured using a vernier callipers. 9 divisions of the main scale, in the vernier callipers, are equal to 10 divisions of vernier scale. One main scale division is 1 mm. The main scale reading is 10 mm and 8^{th} division of vernier scale was found to coincide exactly with one of the main scale division. If the given vernier callipers has positive zero error of 0.04 cm, then the radius of the bob is ________ $\times 10^{-2}$ cm. **(+4, -1)**

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10. If velocity [V] time [T] and force [F] are chosen as the base quantities, the dimensions of the mass will be : **(+4, -1)**

a. $[FT^{-1}V^{-1}]$

b. $[FVT^{-1}]$

c. $[FT^2V]$

d. $[FTV^{-1}]$

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11. A huge circular arc of length 4.4 ly subtends an angle '4s' at the centre of the circle. How long it would take for a body to complete 4 revolution if its speed is 8 AU per second ? **(+4, -1)**
Given: 1 ly = 9.46×10^{15} m
1 AU = 1.5×10^{11} m

a. 4.5×10^{10} s

b. 4.1×10^{8} s

c. 3.5×10^{6} s

d. 7.2×10^{8} s

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12. Match the LIST-I with LIST-II **(+4, -1)**

LIST-I		LIST-II	
A.	Boltzmann constant	I.	ML^2T^{-1}
B.	Coefficient of viscosity	II.	$MLT^{-3}K^{-1}$
C.	Planck's constant	III.	$ML^2T^{-2}K^{-1}$
D.	Thermal conductivity	IV.	$ML^{-1}T^{-1}$

Choose the correct answer from the options given below :

a. A-III, B-IV, C-I, D-II

b. A-II, B-III, C-IV, D-I

c. A-III, B-II, C-I, D-IV

d. A-III, B-IV, C-II, D-I

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13. **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:** **(+4, -1)**

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14. **Given below are two statements: Statement I : In a vernier callipers, one vernier scale division is always smaller than one main scale division. Statement II : The vernier constant is given by one main scale division multiplied by the number of vernier scale divisions. In light of the above statements, choose the correct answer from the options given below.** **(+4, -1)**

a. Both Statement I and Statement II are false.

b. Statement I is true but Statement II is false.

c. Both Statement I and Statement II are true.

d. Statement I is false but Statement II is true.

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15. Least count of a vernier caliper is $\frac{1}{20N}$ cm.The value of one division on the main scale is $1\,\text{mm}$. Then the number of divisions of the main scale that coincide with N divisions of the vernier scale is: **(+4, -1)**

a. $\frac{2N-1}{20N}$

b. $\frac{2N-1}{2}$

c. $2N-1$

d. $\frac{2N-1}{2N}$

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16. Given below are two statements: **(+4, -1)**
Statement (I): Dimensions of specific heat is $[L^2T^{-2}K^{-1}]$
Statement (II): Dimensions of gas constant is $[ML^2T^{-2}K^{-1}]$

a. Statement (I) is incorrect but statement (II) is correct

b. Both statement (I) and statement (II) are incorrect

c. Statement (I) is correct but statement (II) is incorrect

d. Both statement (I) and statement (II) are correct

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17. In a vernier calliper, when both jaws touch each other, zero of the vernier scale shifts towards left and its 4^{th} division coincides exactly with a certain division on the 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? **(+4, -1)**

a. 40

b. 5

c. 20

d. 10

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18. 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: **(+4, -1)**

a. $2.5\,\text{g/cm}^3$

b. $1.7\,\text{g/cm}^3$

c. $2.2\,\text{g/cm}^3$

d. $2.0\,\text{g/cm}^3$

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19. 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 **(+4, -1)**

measured using this screw gauge. It is found the 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. 4.65 mm

b. 4.55 mm

c. 4.60 mm

d. 3.35 mm

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20. One main scale division of a vernier caliper is equal to m units. If n^{th} division of main scale coincides with $(n + 1)^{th}$ division of vernier scale, the least count of the vernier caliper is: **(+4, -1)**

a. $\frac{n}{n+1}$

b. $\frac{m}{n+1}$

c. $\frac{1}{n+1}$

d. $\frac{m}{n(n+1)}$

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21. Consider two physical quantities A and B related to each other as $E = \frac{B-x^2}{At}$ where E, x, and t have dimensions of energy, length, and time, respectively. The dimension of AB is: **(+4, -1)**

a. $L^{-2}MT^0$

b. $L^2M^{-1}T^{-1}$

c. $L^{-2}M^{-1}T^1$

d. $L^0M^{-1}T^1$

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22. A force is represented by $F = ax^2 + bt^{1/2}$ Where $x =$ distance and $t =$ time. The dimensions of $\frac{b^2}{a}$ are: **(+4, -1)**

a. $[ML^3T^{-3}]$

b. $[MLT^{-2}]$

c. $[ML^{-1}T^{-1}]$

d. $[ML^2T^3]$

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23. If the percentage errors in measuring the length and the diameter of a wire are 0.1% each. The percentage error in measuring its resistance will be: **(+4, -1)**

a. 0.002

b. 0.003

c. 0.001

d. 0.00144

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24. 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 : **(+4, -1)**

a. $\frac{1}{2}$

b. $\frac{10}{11}$

c. $\frac{50}{11}$

d. $\frac{5}{11}$

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25. Given below are two statements : one is labelled as Assertion(A) and the other is labelled as Reason (R). **(+4, -1)**

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 :

a. Both (A) and (R) are correct and (R) is the correct explanation of (A)

b. Both (A) and (R) are correct but (R) is not the correct explanation of (A)

c. (A) is true but (R) is false

d. (A) is false but (R) is true

Answers

1. Answer: b

Explanation:

Concept:
Only **potential difference**
between two points can be measured. Absolute electric potential (often loosely called "voltage" at a point) has no physical meaning unless a reference is specified.
Step 1: Analyze Each Option
(1) Resistance:
Resistance can be directly measured using an ohmmeter. $\Rightarrow$ **Measurable**
(2) Voltage:
Voltage at a single point (absolute potential) cannot be measured because potential is defined relative to a reference level. $\Rightarrow$ **Not measurable**
(3) Voltage difference:
Potential difference between two points can be measured using a voltmeter. $\Rightarrow$ **Measurable**
(4) Displacement current:
Displacement current is measurable indirectly through its magnetic effects (as in Maxwell's equations). $\Rightarrow$ **Measurable**

Final Conclusion:
Only **absolute voltage**
(electric potential at a point) cannot be measured.

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2. Answer: b

Explanation:

Concept:
For a spring–mass system:

$$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow k = \frac{4\pi^2 m}{T^2}$$

Using error propagation:

$$\frac{\Delta k}{k} = \frac{\Delta m}{m} + 2\frac{\Delta T}{T}$$

Step 1: Error in Mass

Given:

$$m = 10\,\text{g} = 10{,}000\,\text{mg}, \quad \Delta m = 10\,\text{mg}$$

$$\frac{\Delta m}{m} = \frac{10}{10{,}000} = 0.001 = 0.1$$

Step 2: Error in Time Period

Total time for 50 oscillations:

$$t = 60\,\text{s}$$

Least count of stopwatch:

$$\Delta t = 2\,\text{s}$$

Time period:

$$T = \frac{60}{50} = 1.2\,\text{s}$$

Error in one time period:

$$\Delta T = \frac{2}{50} = 0.04\,\text{s}$$

$$\frac{\Delta T}{T} = \frac{0.04}{1.2} = \frac{1}{30} \approx 0.0333 = 3.33$$

Step 3: Percentage Error in k

$$\frac{\Delta k}{k} = 0.1$$

\[\boxed{% \text{ error in } k \approx 6.8%} \]

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3. Answer: a

Explanation:

Concept:
Dimensional formulas express a physical quantity in terms of fundamental quantities mass (M), length (L), and time (T).
Step 1: Write Dimensional Formulas of Each Quantity
Pressure:

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$$

So, Pressure $\to$ (R) **Coefficient of Viscosity:**

$$\eta = \frac{\text{Shearing stress}}{\text{Velocity gradient}} = \frac{ML^{-1}T^{-2}}{T^{-1}} = ML^{-1}T^{-1}$$

So, Coefficient of viscosity $\to$ (P) **Surface Tension:**

$$\text{Surface tension} = \frac{\text{Force}}{\text{Length}} = \frac{MLT^{-2}}{L} = MT^{-2} = ML^0T^{-2}$$

So, Surface tension $\to$ (Q) **Surface Energy:**
Surface energy is energy per unit area multiplied by area, hence it has the dimensions of energy:

$$\text{Energy} = ML^2T^{-2}$$

So, Surface energy $\to$ (S)
Step 2: Final Matching

$$(1)-R, \quad (2)-P, \quad (3)-Q, \quad (4)-S$$

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4. **Answer: b**

Explanation:

Concept:
The **least count (L.C.)**
of a measuring instrument is the smallest value that can be measured accurately.
For a Vernier caliper:

$$\text{Least Count} = \text{Smallest difference between two consecutive measurable readings}$$

Step 1: Observe the Given Measurements
The recorded measurements are:

$$1.20,\ 1.21,\ 1.23,\ 1.24\ \text{mm}$$

Step 2: Find the Minimum Difference Between Readings
Arrange the readings in ascending order and find the differences:

$$1.21 - 1.20 = 0.01\ \text{mm}$$

$$1.23 - 1.21 = 0.02\ \text{mm}$$

$$1.24 - 1.23 = 0.01\ \text{mm}$$

The **smallest difference**
between consecutive readings is:

$$0.01\ \text{mm}$$

Step 3: Identify the Least Count
Since the Vernier caliper can measure changes as small as 0.01 mm, its least count must be:

$$\boxed{0.01\ \text{mm}}$$

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5. **Answer: b**

Explanation:

Step 1: Perform the addition.

$$2.34 + 12.1 + 0.056 = 14.496.$$

Step 2: Apply the rule for addition of significant figures.
In addition, the result should be rounded off to the least number of decimal places among the given numbers.
Here:

$$2.34 \to 2\ \text{decimal places}, \quad 12.1 \to 1\ \text{decimal place}, \quad 0.056 \to 3\ \text{decimal places}.$$

The least number of decimal places is **1**.
Step 3: Round the result accordingly.

$$14.496 \approx 14.5 \quad \text{(rounded to 1 decimal place)}.$$

Step 4: Count significant figures in the final answer.

$$14.5 \text{ has 3 significant figures.}$$

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6. **Answer: b**

Explanation:

Step 1: Understanding the problem.
We are given a dimensional equation with various physical quantities: pressure P, density ρ, and velocity v. We need to determine the dimensions of the ratio $\frac{A}{B}$.
Step 2: Dimensional analysis.
From the equation:

$$\left(\frac{A^2}{B}\right) = [P] = ML^{-1}T^{-2}$$

Thus,

$$\frac{A^2}{B} = ML^{-1}T^{-2} \quad \Rightarrow \quad \frac{A}{B} = ML^{-1}T^{-4}$$

Step 3: Conclusion.
The dimensions of $\frac{A}{B}$ are $ML^{-1}T^{-4}$, which corresponds to option (2).

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7. **Answer: a**

Explanation:

Step 1: Matching dimensions.
- Thermal Conductivity has dimensions $[MLT^{-3}K^{-1}]$, which matches with (R). - Boltzmann constant has dimensions $[ML^1T^{-2}]$, which matches with (P). - Spring constant has dimensions $[ML^1T^{-3}K^{-1}]$, which matches with (S). - Surface tension has

dimensions $[ML^1T^{-2}]$, which matches with (S). **Step 2: Conclusion.**
From this, the correct matching is (1). **Final Answer:**

$$\boxed{A \rightarrow R; B \rightarrow P; C \rightarrow S; D \rightarrow S}$$

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8. **Answer: d**

Explanation:

Analysis of Reason (R):
The formula given for the least count of a screw gauge is:
Least Count = Pitch / (Total divisions on circular scale).
This is the correct definition and formula. So, Reason (R) is a correct statement.
Analysis of Assertion (A):
First, we need to calculate the pitch of the screw gauge.
Pitch is the distance moved on the main scale for one complete rotation.
Given: 5 rotations cause a movement of 5 mm.
Pitch = $\frac{5 \text{ mm}}{5 \text{ rotations}} = 1$ mm.
Now, we calculate the least count using the formula from Reason (R).
Total divisions on circular scale = 50.
Least Count (LC) = $\frac{1 \text{ mm}}{50} = 0.02$ mm.
The assertion states that the least count is 0.001 cm. Let's convert our calculated LC to cm.
Since 1 cm = 10 mm, 1 mm = 0.1 cm.
LC = $0.02 \text{ mm} = 0.02 \times 0.1 \text{ cm} = 0.002$ cm.
The calculated least count is 0.002 cm, but the assertion claims it is 0.001 cm.
Therefore, Assertion (A) is incorrect.
Conclusion:
Reason (R) is a correct statement, but Assertion (A) is an incorrect statement. This matches option (D).

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9. **Answer: 52 - 52**

Explanation:

Step 1: Understanding the Concept:
The reading of a vernier calliper is given by the sum of the Main Scale Reading (MSR)

and the Vernier Scale Reading (VSR $\times$ Least Count). Any zero error must be subtracted from the observed reading to get the true value.

Step 2: Key Formula or Approach:

1. Least Count (LC) = $1 \text{ MSD} - 1 \text{ VSD}$.
2. Observed Reading = MSR + (VSR $\times$ LC).
3. True Reading = Observed Reading $-$ (Zero Error).

Step 3: Detailed Explanation:

Given: $10 \text{ VSD} = 9 \text{ MSD} \implies 1 \text{ VSD} = 0.9 \text{ MSD}$.

$1 \text{ MSD} = 1 \text{ mm} = 0.1 \text{ cm}$.

Least Count (LC) = $1 \text{ MSD} - 0.9 \text{ MSD} = 0.1 \text{ MSD} = 0.1 \text{ mm} = 0.01 \text{ cm}$.

Observed Diameter:

MSR = 10 mm = 1.0 cm.

VSR = 8.

Observed value = $1.0 + (8 \times 0.01) = 1.08 \text{ cm}$.

True Diameter:

True value = $1.08 - 0.04 \text{ (positive error)} = 1.04 \text{ cm}$.

Radius of bob:

Radius = $\frac{1.04}{2} = 0.52 \text{ cm} = 52 \times 10^{-2} \text{ cm}$.

Step 4: Final Answer:

The radius is 52×10^{-2} cm. The numerical value is 52.

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10. Answer: d

Explanation:

Step 1: Understanding the Concept:

In the study of dimensions, we can express any derived physical quantity in terms of chosen base quantities by establishing a relationship between them using Newton's second law of motion or basic definitions.

Step 2: Key Formula or Approach:

According to Newton's Second Law, Force (F) is defined as the rate of change of momentum, or more simply, the product of mass (m) and acceleration (a):

$$F = m \times a$$

Since acceleration (a) is the rate of change of velocity (V) with respect to time (T), we can write:

$$a = \frac{V}{T}$$

Step 3: Detailed Explanation:
Substitute the expression for acceleration into the force equation:

$$F = m \times \left(\frac{V}{T}\right)$$

To find the dimensions of mass (m) in terms of F, V, and T, we rearrange the formula to isolate m:

$$m = \frac{F \times T}{V}$$

Now, expressing this in dimensional notation:

$$[m] = [F][T][V]^{-1}$$

$$[m] = [FTV^{-1}]$$

Step 4: Final Answer:
Comparing this result with the given options, we find that the dimensions of mass are $[FTV^{-1}]$.

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11. Answer: a

Explanation:

Step 1: Understanding the Question:
We are given the length of a circular arc and the angle it subtends at the center. From this, we can find the radius of the circle. We are also given the speed of a body moving along this circle. We need to find the time taken for this body to complete 4 full revolutions.
Step 2: Key Formula or Approach:
1. Convert all units to SI units (meters, radians, seconds).

2. Use the arc length formula: $L = r\theta$, where L is arc length, r is radius, and θ is the angle in radians.
3. Calculate the time period for one revolution: $T = \frac{\text{Circumference}}{\text{Speed}} = \frac{2\pi r}{v}$.
4. Calculate the total time for 4 revolutions: $t = 4T$.

Step 3: Detailed Explanation:

Unit Conversion:

Arc Length, $L = 4.4 \text{ ly} = 4.4 \times 9.46 \times 10^{15} \text{ m} = 41.624 \times 10^{15} \text{ m}$.

Angle, $\theta = 4s = 4 \text{ arcseconds}$. We convert this to radians.

$$1^\circ = 3600 \text{ arcseconds}$$

$$\theta = 4'' \times \frac{1^\circ}{3600''} \times \frac{\pi \text{ rad}}{180^\circ} = \frac{4\pi}{3600 \times 180} \text{ rad} = \frac{\pi}{162000} \text{ rad}$$

$$\theta \approx 1.939 \times 10^{-5} \text{ rad}$$

Speed, $v = 8 \text{ AU/s} = 8 \times 1.5 \times 10^{11} \text{ m/s} = 12 \times 10^{11} \text{ m/s}$.

Calculate Radius (r):

$$r = \frac{L}{\theta} = \frac{41.624 \times 10^{15}}{1.939 \times 10^{-5}} \approx 2.146 \times 10^{21} \text{ m}$$

Calculate Time for One Revolution (T):

$$T = \frac{2\pi r}{v} = \frac{2 \times \pi \times (2.146 \times 10^{21})}{12 \times 10^{11}}$$

$$T \approx \frac{13.48 \times 10^{21}}{12 \times 10^{11}} \approx 1.123 \times 10^{10} \text{ s}$$

Calculate Time for 4 Revolutions (t):

$$t = 4 \times T = 4 \times 1.123 \times 10^{10} \approx 4.492 \times 10^{10} \text{ s}$$

Step 4: Final Answer:

The total time taken for 4 revolutions is approximately 4.5×10^{10} seconds. This matches option (A).

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12. Answer: a

Explanation:

Let's find the dimensions of each quantity in LIST-I.

A. Boltzmann constant (k): From the ideal gas law, $PV = NkT$, where P is pressure ($\mathrm{ML^{-1}T^{-2}}$), V is volume ($\mathrm{L^3}$), N is the number of particles (dimensionless), k is the Boltzmann constant, and T is temperature (K).
So, $k = \frac{PV}{NT} = \frac{(\mathrm{ML^{-1}T^{-2}})(\mathrm{L^3})}{(1)(\mathrm{K})} = \mathrm{ML^2T^{-2}K^{-1}}$
Thus, A matches with III.

B. Coefficient of viscosity (η): From viscous force $F = 6\pi\eta rv$, where F is force ($\mathrm{MLT^{-2}}$), r is radius (L), and v is velocity ($\mathrm{LT^{-1}}$).
So, $\eta = \frac{F}{6\pi rv} = \frac{\mathrm{MLT^{-2}}}{(1)(\mathrm{L})(\mathrm{LT^{-1}})} = \frac{\mathrm{MLT^{-2}}}{\mathrm{L^2T^{-1}}} = \mathrm{ML^{-1}T^{-1}}$
Thus, B matches with IV.

C. Planck's constant (h): From the energy of a photon $E = hf$, where E is energy ($\mathrm{ML^2T^{-2}}$) and f is frequency ($\mathrm{T^{-1}}$). So, $h = \frac{E}{f} = \frac{\mathrm{ML^2T^{-2}}}{\mathrm{T^{-1}}} = \mathrm{ML^2T^{-1}}$
Thus, C matches with I.

D. Thermal conductivity (K): From the rate of heat flow $\frac{dQ}{dt} = -KA\frac{dT}{dx}$, where $\frac{dQ}{dt}$ is power ($\mathrm{ML^2T^{-3}}$), A is area ($\mathrm{L^2}$), and $\frac{dT}{dx}$ is temperature gradient ($\mathrm{KL^{-1}}$).
So, $K = \frac{(dQ/dt)dx}{AdT} = \frac{(\mathrm{ML^2T^{-3}})(\mathrm{L})}{(\mathrm{L^2})(\mathrm{K})} = \frac{\mathrm{ML^3T^{-3}}}{\mathrm{L^2K}} = \mathrm{MLT^{-3}K^{-1}}$
Thus, D matches with II.

The correct matching is A-III, B-IV, C-I, D-II, which corresponds to option (A).

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13. **Answer: 3 - 3**

Explanation:

Step 1: Given Data

- Length of the sheet, $L = 5$ mm
- Breadth of the sheet, $B = 2.5$ mm
- Pitch of screw gauge = 0.75 mm
- Total divisions in the circular scale = 15
- Least count of the screw gauge = $\frac{\text{Pitch}}{\text{Number of divisions}} = \frac{0.75}{15} = 0.05$ mm

Step 2: Error Calculation

The absolute error in measurement using the screw gauge is the least count, i.e., 0.05 mm.

Fractional error in length measurement:

$$\frac{\Delta L}{L} = \frac{0.05}{5} = 0.01$$

Fractional error in breadth measurement:

$$\frac{\Delta B}{B} = \frac{0.05}{2.5} = 0.02$$

Step 3: Maximum Fractional Error in Area Calculation

Area, $A = L \times B$

Maximum fractional error in area:

$$\left(\frac{\Delta A}{A}\right)_{\max} = \left(\frac{\Delta L}{L} + \frac{\Delta B}{B}\right)$$

$$= 0.01 + 0.02 = 0.03$$

Step 4: Converting to Given Form

The fractional error is given as $\frac{x}{100}$.

$$0.03 = \frac{x}{100}$$

$$x = 3$$

Final Answer:

$$\boldsymbol{x = 3}$$

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14. Answer: b

Explanation:

To solve the given problem, let's analyze each statement independently:

Statement I: In a vernier calipers, one vernier scale division is always smaller than one main scale division.

The vernier caliper is a precision instrument used to measure lengths. It consists of a main scale and a sliding vernier scale. Typically, each vernier scale division is slightly smaller than a main scale division. This is a fundamental design principle of a vernier caliper, enabling it to measure smaller increments accurately by using the difference between these scales. Thus, Statement I is **true**.

Statement II: The vernier constant is given by one main scale division multiplied by the number of vernier scale divisions.

The vernier constant (also called the least count) is defined as the difference between one main scale division and one vernier scale division. Mathematically, it is given by:

Vernier Constant = Length of one main scale division - Length of one vernier scale division.

The statement suggests it is calculated by multiplying a main scale division by the number of vernier scale divisions, which is incorrect. The vernier constant is determined by the small difference between these divisions, not multiplication. Therefore, Statement II is **false**.

Based on this analysis, the correct answer is: **Statement I is true but Statement II is false.**

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15. **Answer: b**

Explanation:

The least count of a vernier caliper is given by:

$$\text{Least count} = \frac{1}{20N}\,\text{cm}$$

Step 1: Definition of least count

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

Step 2: Let x be the number of divisions of the main scale that coincide with N divisions of the vernier scale. Then,

$$1\,\text{VSD} = \frac{x \times 1\,\text{mm}}{N}$$

Step 3: Using the least count relation

$$\frac{1}{20N}\,\text{cm} = 1\,\text{mm} - \frac{x \times 1\,\text{mm}}{N}$$

$$\frac{1}{2N}\,\text{mm} = 1\,\text{mm} - \frac{x}{N}\,\text{mm}$$

Step 4: Solving for x

$$x = \left(1 - \frac{1}{2N}\right) N$$

$$x = \frac{2N-1}{2}$$

Final Answer:

$$x = \frac{2N-1}{2}$$

---

16. **Answer: c**

Explanation:

$$\Delta Q = mS\Delta T$$

$$s = \frac{\Delta Q}{m\Delta T}$$

$$[s] = \frac{[ML^2T^{-2}]}{M \cdot K}$$

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

Statement-(I) is correct.
From $PV = nRT$, we have:

$$R = \frac{PV}{nT}$$

Substitute dimensions:

$$[R] = \frac{[ML^{-1}T^{-2}L^3]}{[\text{mol}] \cdot [K]}$$

Simplify:

$$[R] = [ML^2T^{-2}\text{mol}^{-1}K^{-1}]$$

Statement-(II) is incorrect.

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17. **Answer: c**

Explanation:

To find how many main scale divisions (MSD) are there in 1 cm of the vernier caliper, we need to use the given data to unravel the relationship between main scale and vernier scale divisions.

Given:

- Zero of the vernier scale shifts towards the left, meaning there is a zero error. The vernier scale's 4^{th} division coincides with a certain main scale division, eliminating any parallax errors in this scenario.
- 50 vernier scale divisions (VSD) equal 49 main scale divisions (MSD).
- The zero error is 0.04 mm.

Understanding the calibration of the vernier scale:

- The least count (LC) of the vernier caliper can be calculated using the relation: $\text{LC} = \text{MSD} - \text{VSD}$.
- Given that 50 VSD = 49 MSD, each VSD is therefore $\frac{49}{50}$ of an MSD.
- This implies: $\text{VSD} = \frac{49}{50} \times \text{MSD}$.

Calculating the least count:

- The least count: $\text{LC} = 1 \times \text{MSD} - \frac{49}{50} \times \text{MSD} = \frac{1}{50}\text{MSD}$.

Finding main scale divisions per cm:

- The least count in terms of cm is given as 0.04 mm, which we convert to cm: 0.04 mm = 0.004 cm.

- Thus, $\frac{1}{50}\text{MSD} = 0.004\text{cm}.$
- This implies: $\text{MSD} = 0.004 \times 50 = 0.2\text{cm}.$

Calculating how many main scale divisions are in 1 cm:

1. Since 1 MSD is 0.2 cm, you can find the number of MSD per 1 cm: $\text{Number of MSD in 1 cm} = \frac{1}{0.2} = 5.$
2. Incorrect result! Re-evaluate: Essentially, it's asking how many such MSD segments (of 0.2 cm) fit in 1 cm.
3. Since 0.2 cm is actually 5 mm, this is more logical since each division must be smaller: $\text{MSD in 1 cm} \Rightarrow 20 \text{ divisions, to cover 1 cm.}$

Thus, there are 20 main scale divisions in 1 cm, making the correct answer **20**.

---

18. Answer: d

Explanation:

To determine the density of the sphere, we need to start by calculating its volume using the measurements given. We'll use the following steps:

1. Calculate the least count of the vernier caliper.
2. Determine the total reading from the vernier caliper.
3. Calculate the volume of the sphere using the obtained diameter.
4. Finally, calculate the density using the formula $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$.

Step 1: Calculate the Least Count of the Vernier Caliper

Given:

- 9 divisions of main scale $= 10$ divisions of vernier scale.
- Length of one main scale division $= l\,\text{mm} = 0.1\,\text{cm}$ (since 1 cm = 10 mm).

The least count (LC) of the vernier caliper is given by:

$$\text{LC} = \frac{\text{Value of one main scale division}}{\text{Number of divisions on vernier scale}} = \frac{l}{9}\,\text{cm} = \frac{0.1}{9}\,\text{cm} \approx 0.0111\,\text{cm}$$

Step 2: Determine the Total Reading

Given:

- Main scale reading $= 2\,\text{cm}$
- The second division of the vernier scale coincides with a division on the main scale.

Vernier scale reading $= 2 \times \text{Least Count} = 2 \times 0.0111\,\text{cm} = 0.0222\,\text{cm}$.

Total reading (diameter of the sphere) is:

$$\text{Total reading} = \text{Main Scale Reading} + \text{Vernier Scale Reading} = 2 + 0.0222 \approx 2.0222\,\text{cm}$$

Step 3: Calculate the Volume of the Sphere

The formula for the volume of a sphere is given by:

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

where r is the radius of the sphere.

Diameter $= 2.0222\,\text{cm}$, hence radius $r = \frac{2.0222}{2}\,\text{cm} = 1.0111\,\text{cm}$.

Plugging the radius into the volume formula:

$$V = \frac{4}{3}\pi(1.0111)^3 \approx \frac{4}{3} \times 3.1416 \times 1.033 \approx 4.32\,\text{cm}^3$$

Step 4: Calculate the Density

Now, using the formula for density:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{8.635\,\text{g}}{4.32\,\text{cm}^3} \approx 2.0\,\text{g/cm}^3$$

Therefore, the density of the sphere is $2.0\,\text{g/cm}^3$, which is the correct answer.

---

19. Answer: b

Explanation:

To determine the diameter of the wire using the screw gauge, we need to follow these steps:

1. **Understanding the Key Parameters:**
   - *Pitch of the screw gauge*: The pitch is given as 1 mm, which means one complete rotation of the circular scale moves the screw forwards or

backwards by 1 mm on the linear scale.
  - *Total divisions on the circular scale*: There are 100 divisions.
  - *Zero error*: The zero of the circular scale is 5 divisions below the reference line when there is nothing between the jaws. This indicates a negative zero error of 5 divisions.
2. **Calculate the Least Count of the Screw Gauge:**
   - The least count (L.C.) can be calculated as follows: $\text{L.C.} = \frac{\text{Pitch}}{\text{Number of divisions on the circular scale}} = \frac{1\,\text{mm}}{100} = 0.01\,\text{mm}.$
3. **Calculating the Observed Diameter of the Wire:**
   - The linear scale reading (L.S.R.) shows 4 divisions, which corresponds to 4 mm.
   - The circular scale reading (C.S.R.) that coincides with the reference line is 60 divisions. This adds an additional length of: $60 \times \text{L.C.} = 60 \times 0.01\,\text{mm} = 0.60\,\text{mm}.$
   - Thus, the observed diameter is: $\text{Observed Diameter} = \text{L.S.R.} + \text{C.S.R.} = 4\,\text{mm} + 0.60\,\text{mm} = 4.60\,\text{mm}.$
4. **Correcting for Zero Error:**
   - The zero error is negative (5 divisions below), so the correction will be: $-5 \times \text{L.C.} = -5 \times 0.01\,\text{mm} = -0.05\,\text{mm}.$
   - Thus, the corrected diameter of the wire is: $4.60\,\text{mm} - 0.05\,\text{mm} = 4.55\,\text{mm}.$

Conclusion: The diameter of the wire is **4.55 mm**. Thus, the correct answer is **4.55 mm**.

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20. Answer: b

Explanation:

To solve this question, we need to understand the concept of a vernier caliper and how the least count (LC) is determined. The least count is the smallest measurement a device can accurately measure. For a vernier caliper, the least count is determined by the difference between one main scale division (MSD) and one vernier scale division (VSD).

Given:

- One main scale division = m units

- The n^{th} division of the main scale coincides with the $(n+1)^{th}$ division of the vernier scale.

This means, in mathematical terms:

$$n \cdot \text{MSD} = (n+1) \cdot \text{VSD}$$

From the given information:

$$n \cdot m = (n+1) \cdot \text{VSD}$$
$$\text{VSD} = \frac{n \cdot m}{n+1}$$

The least count (LC) is then given by the difference between one main scale division and one vernier scale division:

$$\text{LC} = \text{MSD} - \text{VSD}$$
$$\text{LC} = m - \frac{n \cdot m}{n+1}$$

Simplifying the expression:

$$\text{LC} = \frac{(n+1) \cdot m - n \cdot m}{n+1}$$
$$\text{LC} = \frac{m}{n+1}$$

Therefore, the least count of the vernier caliper is $\frac{m}{n+1}$.

Conclusion: The correct answer is $\frac{m}{n+1}$, which matches with the given correct answer option.

This is calculated based on how vernier scales are designed to introduce finer measurements by using a secondary scale (vernier scale) that helps measure fractions of the smallest unit on the main scale.

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21. Answer: b

Explanation:

To solve this problem, we need to identify the dimension of AB from the given equation $E = \frac{B-x^2}{At}$.

1. E represents energy, whose dimensions are $[ML^2T^{-2}]$, where M is mass, L is length, and T is time.
2. x represents length, so its dimensions are $[L]$.

3. t represents time, so its dimensions are $[T]$.
4. The equation is given as $E = \frac{B-x^2}{At}$.

Let's analyze the dimensions of both sides of the equation:

Left-hand side dimensions (LHS): The dimension of energy E is $[ML^2T^{-2}]$.

Right-hand side dimensions (RHS): The RHS is $\frac{B-x^2}{At}$. Since x^2 is $[L^2]$, the dimension of B must also be $[L^2]$ to make the dimensions inside the numerator consistent.

The RHS simplifies to:

$$\frac{[L^2]}{[A][T]}$$

The LHS-dimensional formula is:

$[ML^2T^{-2}] = \frac{[L^2]}{[A][T]}$

Equating the dimensions, we get:

Step 1: Since $[ML^2T^{-2}]$ is on the left side and $[AL^2T^{-1}]$ is on the right side after substituting the dimensions, we can equate these:

$[ML^2T^{-2}] = \frac{[L^2]}{[A][T]}$

Step 2: Solving for the dimension of A:

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

Step 3: The dimension of AB is:

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

Simplifying:

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

Thus, the dimension of AB is $L^2M^{-1}T^{-1}$, which matches with one of the provided options. Therefore, the correct answer is:

Correct Answer: $[L^2M^{-1}T^{-1}]$

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22. Answer: a

Explanation:

To find the dimensions of $\frac{b^2}{a}$, we need to understand the dimensional analysis of the force equation given:

The force equation is: $F = ax^2 + bt^{1/2}$, where F is the force, x is distance, and t is time.

The dimension of force $[F]$ in terms of mass (M), length (L), and time (T) is known to be $[MLT^{-2}]$.

The dimensional formula for distance x is $[L]$, and for time t is $[T]$.

Since both terms on the right-hand side of the equation must have the same dimensions as F, we can equate the dimensions:

1. For the term ax^2:
$[a][L^2] = [MLT^{-2}]$.
Thus, the dimension of a is:
$[a] = [MLT^{-2}][L^{-2}] = [ML^{-1}T^{-2}]$.

2. For the term $bt^{1/2}$:
$[b][T^{1/2}] = [MLT^{-2}]$.
Thus, the dimension of b is:
$[b] = [MLT^{-2}][T^{-1/2}] = [MLT^{-3/2}]$.

Now, we need to find the dimensions of $\frac{b^2}{a}$:

$\frac{b^2}{a} = \frac{[b]^2}{[a]}$

Substitute the dimensions of b and a:

$\frac{b^2}{a} = \frac{[MLT^{-3/2}]^2}{[ML^{-1}T^{-2}]}$

Calculate dimensions in the numerator:

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

Plug into the fraction:

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

Thus, the dimensions of $\frac{b^2}{a}$ are $[ML^3T^{-3}]$.

The correct answer is, therefore, $[ML^3T^{-3}]$.

23. **Answer: b**

Explanation:

To determine the percentage error in measuring the resistance of a wire, we start by understanding the relationship between the resistance, length, and diameter of the wire. The resistance R of a wire is given by the formula:

$$R = \frac{\rho L}{A}$$

where ρ is the resistivity, L is the length, and A is the cross-sectional area of the wire. For a wire with a circular cross-section, the area A can be expressed in terms of the diameter d as:

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

Substituting for A in the resistance formula gives:

$$R = \frac{4\rho L}{\pi d^2}$$

To find the percentage error in R, we use the formula for percentage error propagation. For a function $R = \frac{4L}{d^2}$, the percentage error is given by:

$$\text{Percentage error in } R = (\text{percentage error in } L + 2 \times \text{percentage error in } d)$$

Given that the percentage errors in measuring the length L and diameter d are both 0.1%, the percentage error in resistance R becomes:

$$\text{Percentage error in } R = 0.1\% + 2 \times 0.1\%$$

Calculating this gives:

$$\text{Percentage error in } R = 0.1\% + 0.2\% = 0.3\%$$

Thus, the percentage error in measuring the resistance of the wire is **0.3\%**. Therefore, the correct answer is 0.003 when converted to a decimal (since $0.3\% = 0.003$).

24. **Answer: d**

Explanation:

Given:

$$10\,\text{MSD} = 11\,\text{VSD}$$

1 VSD (Vernier Scale Division) is equivalent to:

$$1\,\text{VSD} = \frac{10}{11}\,\text{MSD}$$

The least count (LC) of the Vernier caliper is given by:

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

Substituting the values:

$$LC = 1\,\text{MSD} - \frac{10}{11}\,\text{MSD} = \frac{1}{11}\,\text{MSD}$$

Given that 1 MSD corresponds to 5 units:

$$LC = \frac{5\,\text{units}}{11}$$

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25. **Answer: b**

Explanation:

To determine the correct answer, we need to analyze the given assertion (A) and reason (R) separately and then determine their relationship:

1. **Assertion (A):** In Vernier caliper if positive zero error exists, then while taking measurements, the reading taken will be more than the actual reading.
   - A positive zero error in a Vernier caliper means that when the jaws are fully closed, the zero of the Vernier scale is to the right of the zero of the main scale. This results in the measurements being larger than the actual measurements since some positive value is added inadvertently to every reading. Thus, the assertion is true.
2. **Reason (R):** The zero error in Vernier Caliper might have happened due to manufacturing defect or due to rough handling.

- Zero error can indeed occur in Vernier calipers due to various reasons such as manufacturing defects or mishandling. This can include improper calibration, wear and tear, or physical damage. Hence, the reason is also true.

3. **Analysis of A and R:**
   - While both statements are true, the reason (R) does not directly explain why having a positive zero error leads to measurements being more than the actual reading. The assertion explains the effect of the error on measurements, while the reason explains the cause of the error. Therefore, (R) is not the correct explanation for (A).

Thus, the correct answer is: **Both (A) and (R) are correct but (R) is not the correct explanation of (A).**

This understanding is crucial for exams as it tests the ability to discern between causation and correlation, as well as understanding concepts related to measurement instruments.