scale is 2.5 mm and that on the circular scale is 20 divisions. If the measured mass of the ball has a relative error of 2 %, the relative percentage error in the density is **[2011]**
(a) 0.9 % (b) 2.4 % (c) 3.1 % (d) 4.2 %

44. A vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the Vernier scale which match with 16 main scale divisions. For this Vernier calipers, the least count is **[2010]**
(a) 0.02 mm (b) 0.05 mm (c) 0.1 mm (d) 0.2 mm

45. Students I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and /or record time for different number of oscillations. The observations are shown in the table. **[Main 2008, July 22, 2021 (II)]**
Least count for length = 0.1 cm
Least count for time = 0.1 s

Student	Length of the pendulum (cm)	No. of oscillations (n)	Total time for (n) oscillations (s)	Time period (s)
I	64.0	8	128.0	16.0
II	64.0	4	64.0	16.0
III	20.0	4	36.0	9.0

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

46. A student performs an experiment to determine the Young's modulus of a wire, exactly 2 m long, by Searle's method. In a particular reading, the student measures the extension in the length of the wire to be 0.8 mm with an uncertainty of ± 0.05 mm at a load of exactly 1.0 kg. The student also measures the diameter of the wire to be 0.4 mm with an uncertainty of ± 0.01 mm. Take $g = 9.8$ m/s^2 (exact). The Young's modulus obtained from the reading is **[2007]**
(a) $(2.0 \pm 0.3) \times 10^{11}$ N/m^2 (b) $(2.0 \pm 0.2) \times 10^{11}$ N/m^2
(c) $(2.0 \pm 0.1) \times 10^{11}$ N/m^2 (d) $(2.0 \pm 0.05) \times 10^{11}$ N/m^2

47. A student performs an experiment for determination of $g\left(=\frac{4\pi^2\ell}{T^2}\right)$. The error in length ℓ is $\Delta\ell$ and in time T is ΔT and n is number of times the reading is taken. The measurement of g is most accurate for **[2006 - 3M, –1]**

	$\Delta\ell$	ΔT	n
(a)	5mm	0.2 sec	10
(b)	5mm	0.2 sec	20
(c)	5mm	0.1 sec.	10
(d)	1mm	0.1 sec	50

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

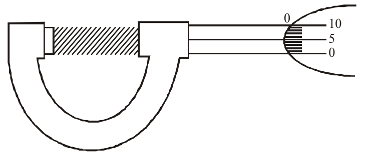


Figure (i)

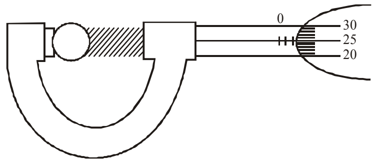


Figure (ii)

(a) 2.25 mm (b) 2.20 mm
(c) 1.20 mm (d) 1.25 mm

49. A wire of length $\ell = 6 \pm 0.06$ cm and radius $r = 0.5 \pm 0.005$ cm and mass $m = 0.3 \pm 0.003$ gm. Maximum percentage error in density is **[2004S]**
(a) 4 (b) 2 (c) 1 (d) 6.8

50. A cube has a side of length 1.2×10^{-2}m. Calculate its volume.
(a) 1.7×10^{-6} m^3 (b) 1.73×10^{-6} m^3 **[2003S]**
(c) 1.70×10^{-6} m^3 (d) 1.732×10^{-6} m^3

2 Integer Value Answer

51. In an experiment for determination of the focal length of a thin convex lens, the distance of the object from the lens is 10 ± 0.1 cm and the distance of its real image from the lens is 20 ± 0.2 cm. The error in the determination of focal length of the lens is n%. The value of n is _____. **[Adv. 2023]**

52. The energy of a system as a function of time t is given as $E(t) = A^2 \exp(-\alpha t,)$ where $\alpha = 0.2$ s^{-1}. The measurement of A has an error of 1.25%. If the error in the measurement of time is 1.50%, the percentage error in the value of $E(t)$ at $t = 5$ s is **[Adv. 2015]**

53. During Searle's experiment, zero of the Vernier scale lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale. The 20th division of the Vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale but now the 45th division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2 m and its cross-sectional area is 8×10^{-7} m^2. The least count of the Vernier scale is 1.0×10^{-5} m. The maximum percentage error in the Young's modulus of the wire is **[Adv. 2014]**

3 Numeric Answer

54. In a screw gauge, there are 100 divisions on the circular scale and the main scale moves by 0.5 mm on a complete rotation of the circular scale. The zero of circular scale lies 6 divisions below the line of graduation when two studs are brought in contact with each other. When a wire is placed between the studs, 4 linear scale divisions are clearly visible while 46th division the circular scale coincide with the reference line. The diameter of the wire is _____ $\times 10^{-2}$ mm. **[Main Jan. 30, 2023 (I)]**

55. In an experiment of measuring the refractive index of a glass slab using travelling microscope in physics lab, a student measures real thickness of the glass slab as 5.25 mm and apparent thickness of the glass slab at 5.00 mm. Travelling microscope has 20 divisions in one cm on main scale and 50 divisions on Vernier scale is equal to 49 divisions on main scale. The estimated uncertainty in the measurement of refractive index of the slab is $\frac{x}{10}\times10^{-3}$, where x is _________ **[Main Jan. 29, 2023 (II)]**

56. In an experiment to find acceleration due to gravity (g) using simple pendulum, time period of 0.5 s is measured from time of 100 oscillation with a watch of 1s resolution. If measured value of length is 10 cm known to 1 mm accuracy. The accuracy in the determination of g is found to be x%. The value of x is **[Main July 28, 2022 (II)]**

57. The one division of main scale of vernier callipers reads 1 mm and 10 divisions of Vernier scale is equal to the 9 divisions on main scale. When the two jaws of the instrument touch each other the zero of the Vernier lies to the right of zero of the main scale and its fourth division coincides with a main scale division. When a spherical bob is tightly placed between the two jaws, the zero of the Vernier scale lies in between 4.1 cm and 4.2 cm and 6th Vernier division coincides with a main scale division. The diameter of the bob will be__ 10^{-2} cm **[Main July 27, 2022 (I)]**

58. 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_____ $\times 10^{-2}$ cm. **[Main June 29, 2022 (II)]**

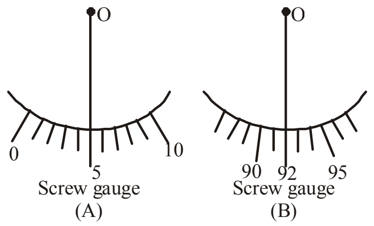
59. A student in the laboratory measures thickness of a wire using screw gauge. The readings are 1.22 mm, 1.23 mm, 1.19 mm and 1.20 mm. The percentage error is $\frac{x}{121}$%. The value of x is _________. **[Main June 28, 2022 (II)]**

60. In a vernier callipers, each cm on the main scale is divided into 20 equal parts. If tenth vernier scale division coincides with nineth main scale division. Then the value of vernier constant will be .... $\times 10^{-2}$ mm. **[Main June 26, 2022 (I)]**

61. For $z = a^2 x^3 y^{1/2}$, where 'a' is a constant. If percentage error in measurement of 'x' and 'y' are 4% and 12%, respectively, then the percentage error for 'z' will be %. **[Main June 25, 2022 (II)]**

62. 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 8th 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. **[Main Aug. 31, 2021 (II)]**

63. Student A and Student B used two screw gauges of equal pitch and 100 equal circular divisions to measure the radius of a given wire. The actual value of the radius of the wire is 0.322 cm. The absolute value of the difference between the final circular scale readings observed by the students A and B is ________.
[Figure shows position of reference 'O' when jaws of screw gauge are closed]
Given pitch = 0.1 cm. **[Main July 25, 2021 (I); June 25, 2022 (I)]**



64. The radius of a sphere is measured to be (7.50 + 0.85) cm. Suppose the percentage error in its volume is x. The value of x, to the nearest x, is _________. **[Main March 18, 2021 (II)]**

65. The resistance $R=\frac{V}{I}$, where V = (50 ± 2)V and $I=(20\pm0.2)$A. The percentage error in R is 'x'%. The value of 'x' to the nearest integer is _______. **[Main March 16, 2021 (I)]**

66. Two capacitors with capacitance values $C_1 = 2000 \pm 10$ pF and $C_2 = 3000 \pm 15$ pF are connected in series. The voltage applied across this combination is $V = 5.00 \pm 0.02$ V. The percentage error in the calculation of the energy stored in this combination of capacitors is _______. **[Adv. 2020]**

67. The density of a solid metal sphere is determined by measuring its mass and its diameter. The maximum error in the density of the sphere is $\left(\frac{x}{100}\right)$%. If the relative errors in measuring the mass and the diameter are 6.0% and 1.5% respectively, the value of x is ___. **[Main Sep. 06, 2020 (I)]**

68. An optical bench has 1.5 m long scale having four equal divisions in each cm. While measuring the focal length of a convex lens, the lens is kept at 75 cm mark of the scale and the object pin is kept at 45 cm mark. The image of the object pin on the other side of the lens overlaps with image pin that is kept at 135 cm mark. In this experiment, the percentage error in the measurement of the focal length of the lens is ___ **[Adv. 2019]**

69. A steel wire of diameter 0.5 *mm* and Young's modulus 2×10^{11} $N\,m^{-2}$ carries a load of mass M. The length of the wire with the load is 1.0 m. A vernier scale with 10 divisions is attached to the end of this wire. Next to the steel wire is a reference wire to which a main scale, of least count 1.0 *mm*, is attached. The 10 divisions of the vernier scale correspond to 9 divisions of the main scale. Initially, the zero of vernier scale coincides with the zero of main scale. If the load on the steel wire is increased by 1.2 *kg*, the vernier scale division which coincides with a main scale division is __________. Take g = 10 $m\,s^{-2}$ and $\pi = 3.2$. **[Adv. 2018]**

70. The side of a cube is measured by vernier callipers (10 divisions of a vernier scale coincide with 9 divisions of main scale, where 1 division of main scale is 1 mm). The main scale reads 10 mm and first division of vernier scale coincides with the main scale. Mass of the cube is 2.736 g. Find the density of the cube in appropriate significant figures. **[2005 - 2 Marks]**

71. In Searle's experiment, which is used to find Young's Modulus of elasticity, the diameter of experimental wire is $D = 0.05$ cm (measured by a scale of least count 0.001 cm) and length is $L = 110$ cm (measured by a scale of least count 0.1 cm). A weight of 50 N causes an extension of $X = 0.125$ cm (measured by a micrometer of least count 0.001cm). Find maximum possible error in the values of Young's modulus. Screw gauge and meter scale are free from error. **[2004 - 2 Marks]**

72. A screw gauge having 100 equal divisions and a pitch of length 1 mm is used to measure the diameter of a wire of length 5.6 cm. The main scale reading is 1 mm and 47^{th} circular division coincides with the main scale. Find the curved surface area of wire in cm^2 to appropriate significant figure. (use $\pi = \frac{22}{7}$). **[2004 - 2 Marks]**

6 MCQs with One or More than One Correct Answer

73. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52s, 0.56s, 0.57s, 0.54s and 0.59s. The least count of the watch used for the measurement of time period is 0.01s. Which of the following statement(s) is (are) true? **[Adv. 2016]**

(a) The error in the measurement of r is 10%
(b) The error in the measurement of T is 3.75%
(c) The error in the measurement of T is 2%
(d) The error in the determined value of g is 11%

74. Consider a Vernier callipers in which each 1 cm on the main scale is divided into 8 equal divisions and a screw gauge with 100 divisions on its circular scale. In the Vernier callipers, 5 divisions of the Vernier scale coincide with 4 divisions on the main scale and in the screw gauge, one complete rotation of the circular scale moves it by two divisions on the linear scale. Then : **[Adv. 2015]**

(a) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(b) If the pitch of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm
(c) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.01 mm
(d) If the least count of the linear scale of the screw gauge is twice the least count of the Vernier callipers, the least count of the screw gauge is 0.005 mm

75. Using the expression $2d \sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90°. The wavelength λ is exactly known and the error in θ is constant for all values of θ. As θ increases from 0° **[Adv. 2013]**

(a) The absolute error in d remains constant
(b) The absolute error in d increases
(c) The fractional error in d remains constant
(d) The fractional error in d decreases

76. A student uses a simple pendulum of exactly 1m length to determine g, the acceleration due to gravity. He uses a stop watch with the least count of 1 sec for this and records 40 seconds for 20 oscillations. For this observation, which of the following statement(s) is (are) true? **[2010]**

(a) Error ΔT in measuring T, the time period, is 0.05 seconds
(b) Error ΔT in measuring T, the time period, is 1 second
(c) Percentage error in the determination of g is 5%
(d) Percentage error in the determination of g is 2.5%

8 Comprehension/Passage Based Questions

Passage

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

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

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

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

The above derivation makes the assumption that $\Delta x/x \ll 1$, $\Delta y/y \ll 1$. Therefore, the higher powers of these quantities are neglected. **[Adv. 2018]**

77. Consider the ratio $r = \frac{(1-a)}{(1+a)}$ to be determined by measuring a dimensionless quantity a. If the error in the measurement of a is Δa ($\Delta a/a \ll 1$, then what is the error Δr in determining r?

(a) $\frac{\Delta a}{(1+a)^2}$ (b) $\frac{2\Delta a}{(1+a)^2}$ (c) $\frac{2\Delta a}{(1-a^2)}$ (d) $\frac{2a\Delta a}{(1-a^2)}$

78. In an experiment the initial number of radioactive nuclei is 3000. It is found that 1000 ± 40 nuclei decayed in the first 1.0 s. For $|x| \ll 1$, $\ln(1+x) = x$ up to first power in x. The error $\Delta\lambda$, in the determination of the decay constant λ, in s^{-1}, is

(a) 0.04 (b) 0.03 (c) 0.02 (d) 0.01

10 Subjective Problems

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

Topic-4: Miscellaneous (Mixed Concepts) Problems

8 Comprehension/Passage Based Questions

Passage

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

1. Taking the electronic charge as 'e' and the permittivity as 'ε_0'. Use dimensional analysis to determine the correct expression for ω_p.

(a) $\sqrt{\frac{Ne}{m\varepsilon_0}}$ (b) $\sqrt{\frac{m\varepsilon_0}{Ne}}$ (c) $\sqrt{\frac{Ne^2}{m\varepsilon_0}}$ (d) $\sqrt{\frac{Ne^2}{m\varepsilon_0}}$

2. Estimate the wavelength at which plasma reflection will occur for a metal having the density of electrons $N \approx 4 \times 10^{27}\ m^{-3}$. Taking $\varepsilon_0 = 10^{-11}$ and mass $m \approx 10^{-30}$, where these quantities are in proper SI units.

(a) 800 nm (b) 600 nm (c) 300 nm (d) 200 nm

Answer Key

Topic-1 : Unit of Physical Quantities

1. (b) 2. (b) 3. (a) 4. (c) 5. (a) 6. (a) 7. (b) 8. (a, b, c, d) 9. (b)
10. (b) 11. (A → p, q; B → r, s; C → r, s; D → r, s)

Topic-2 : Dimensions of Physical Quantities

1. (a) 2. (a) 3. (a) 4. (b) 5. (c) 6. (d) 7. (a) 8. (b) 9. (b) 10. (a)
11. (d) 12. (c) 13. (d) 14. (d) 15. (a) 16. (a) 17. (c) 18. (d) 19. (a) 20. (c)
21. (c) 22. (d) 23. (a) 24. (a) 25. (c) 26. (a) 27. (d) 28. (b) 29. (d) 30. (b)
31. (a) 32. (d) 33. (b) 34. (c) 35. (a) 36. (a) 37. (b) 38. (b) 39. (a) 40. (d)
41. (b) 42. (c) 43. (b) 44. (b) 45. (c) 46. (d) 47. (d) 48. (c) 49. (d) 50. (c)
51. (4) 52. (3) 53. $[M^{-1}L^{-3}T^3A^2]$ 54. $[ML^5T^{-2}]$ 55. $[M^{-3}L^{-2}T^4Q^4]$ 56. $[ML^2T^{-1}]$
57. (b, d) 58. (a, b) 59. (a, b, c) 60. (b, d) 61. (a, c) 62. (a, c, d) 63. (b, c) 64. (a, b, c) 65. (a, d) 66. (a)
67. (c) 68. (b) 69. (c) 70. (b) 71. (b) 72. (a) 73. (c) 75. (c) 76. (d)

Topic-3 : Errors in Measurements & Experimental Physics

1. (a) 2. (a) 3. (c) 4. (c) 5. (c) 6. (c) 7. (c) 8. (b) 9. (b) 10. (d)
11. (a) 12. (a) 13. (c) 14. (b) 15. (c) 16. (c) 17. (c) 18. (a) 19. (b) 20. (d)
21. (d) 22. (b) 23. (a) 24. (None) 25. (d) 26. (c) 27. (c) 28. (c) 29. (c) 30. (d)
31. (b) 32. (b) 33. (d) 34. (c) 35. (d) 36. (b) 37. (a) 38. (b) 39. (a) 40. (d)
41. (b) 42. (a) 43. (c) 44. (d) 45. (b) 46. (b) 47. (d) 48. (c) 49. (a) 50. (a)
51. (1) 52. (4) 53. (4) 54. (22) 55. (41) 56. (5) 57. (412) 58. (180) 59. (150) 60. (5)
61. (18) 62. (52) 63. (13) 64. (34) 65. (5) 66. (1.30) 67. (1050) 68. (1.39) 69. (3.00)
70. ($2.66\ g\ cm^{-3}$) 71. ($1.09 \times 10^{10}\ N/m^2$) 72. ($2.6\ cm^2$) 73. (a, b, d) 74. (b, c) 75. (d) 76. (a, c)
77. (b) 78. (c)

Topic-4 : Miscellaneous (Mixed Concepts) Problems

1. (c) 2. (b)