Exercise-1

✍ **Marked Questions can be used as Revision Questions.**

PART - I : SUBJECTIVE QUESTIONS

1. Using screw gauge, the observation of the diameter of a wire are 1.324, 1.326, 1.334, 1.336 cm respectively. Find the average diameter, the mean error, the relative error and % error.

2.✍ Find significant figures in the following observations -

(i) 0.007 gm (ii) 2.64×10^{24} kg (iii) 0.2370 gm/cm^3 (iv) 6.320 J/K

(v) 6.032 N/m^2 (vi) 0.0006032 K^{-1}

3. Round off the following numbers within three significant figures -

(i) 0.03927 kg (ii) 4.085×10^8 sec (iii) 5.2354 m (iv) 4.735×10^{-6} kg

4. If a tuning fork of frequency (f_0) 340 Hz and tolerance $\pm$1% is used in resonance column method [$v = 2f_0 (\ell_2 - \ell_1)$], the first and the second resonance are measured at ℓ_1 = 24.0 cm and ℓ_2 = 74.0 cm. Find max. permissible error in speed of sound.

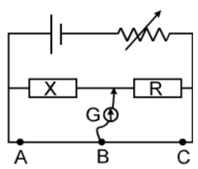
5. A screw gauge with a pitch of 1mm has 100 divisions on its circular scale. When the screw gauge is used to measure the diameter of a uniform wire of length 5.6 cm, the main scale reading is 1 mm and the circular scale reading is 47. Calculate the area of the curved surface of the wire in cm^2 to appropriate significant figures, using $\pi = \frac{22}{7}$. There is no zero error in the screw gauge.

[JEE Mains & Scr. 2004]

6. In the determination of Young's modulus Y by Searle's method, the diameter of the wire is measured by a screw gauge (least count = 0.001 cm) as 0.050 cm. The length of the wire is measured by a scale (least count = 0.1 cm) as 110.0 cm. When a weight of 50 N is applied on the wire, The micrometer (least count = 0.001 cm) reading gives the extension in its length as 0.125 cm. Determine the maximum possible error in Y, using $\pi = \frac{22}{7}$. **[JEE Mains & Scr. 2004]**

7. Side of a cube is measured with the help of vernier calliper. Main scale reading is 10 mm and vernier scale reading is 1. It is known that 9 M.S.D. = 10 V.S.D. Mass of the cube is 2.735 g. Find density of the cube upto appropriate significant figure. **[JEE Mains 2005]**

8. For the three values of resistances R namely R_1, R_2 and R_3 the balanced positions of jockey are at A, B and C respectively. Which position will show most accurate result for calculation of X. Give reason. B is near the mid point of the wire. **[JEE Mains_2005]**



PART - II : ONLY ONE OPTION CORRECT TYPE

1.✍ The length of a rectangular plate is measured by a meter scale and is found to be 10.0 cm. Its width is measured by vernier callipers as 1.00 cm. The least count of the meter scale and vernier callipers are 0.1 cm and 0.01 cm respectively (Obviously). Maximum permissible error in area measurement is -

(A) + 0.2 cm^2 (B) + 0.1 cm^2 (C) + 0.3 cm^2 (D) Zero

2. In the previous question, minimum possible error in area measurement can be -

(A) + 0.02 cm^2 (B) + 0.01 cm^2 (C) + 0.03 cm^2 (D) Zero

3. For a cubical block, error in measurement of sides is + 1% and error in measurement of mass is + 2%, then maximum possible error in density is -
(A) 1% (B) 5% (C) 3% (D) 7%

4. To estimate 'g' (from $g = 4\pi^2 \frac{L}{T^2}$), error in measurement of L is + 2% and error in measurement of T is + 3%. The error in estimated 'g' will be -
(A) + 8% (B) + 6% (C) + 3% (D) + 5%

5. The least count of a stop watch is 0.2 second. The time of 20 oscillations of a pendulum is measured to be 25 seconds. The percentage error in the time period is
(A) 16% (B) 0.8 % (C) 1.8 % (D) 8 %

6. The dimensions of a rectangular block measured with a vernier callipers having least count of 0.1 mm is 5 mm × 10 mm × 5 mm. The maximum percentage error in measurement of volume of the block is
(A) 5 % (B) 10 % (C) 15 % (D) 20 %

7. An experiment measures quantities x, y, z and then t is calculated from the data as $t = \frac{xy^2}{z^3}$. If percentage errors in x, y and z are respectively 1%, 3%, 2%, then percentage error in t is :
(A) 10 % (B) 4 % (C) 7 % (D) 13 %

8. The external and internal diameters of a hollow cylinder are measured to be (4.23 ± 0.01) cm and (3.89 ± 0.01) cm. The thickness of the wall of the cylinder is
(A) (0.34 ± 0.02) cm (B) (0.17 ± 0.02) cm (C) (0.17 ± 0.01) cm (D) (0.34 ± 0.01) cm

9. The mass of a ball is 1.76 kg. The mass of 25 such balls is
(A) 0.44×10^3 kg (B) 44.0 kg (C) 44 kg (D) 44.00 kg

10. Two resistors R_1 (24 ± 0.5) Ω and R_2 (8 ± 0.3) Ω are joined in series. The equivalent resistance is
(A)32 ± 0.33 Ω (B) 32 ± 0.8 Ω (C) 32 ± 0.2 Ω (D) 32 ± 0.5 Ω

11. The pitch of a screw gauge is 0.5 mm and there are 100 divisions on it circular scale. The instrument reads +2 circular scale divisions when nothing is put in-between its jaws. In measuring the diameter of a wire, there are 8 divisions on the main scale and 83rd circular scale division coincides with the reference line. Then the diameter of the wire is
(A) 4.05 mm (B) 4.405 mm (C) 3.05 mm (D) 1.25 mm

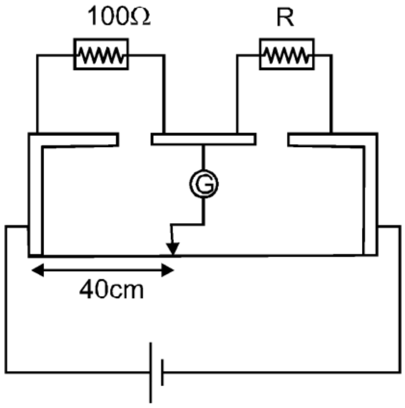
12. The pitch of a screw gauge is 1 mm and there are 50 divisions on its circular scale. When the two jaws of the screw gauge are in contact with each other, the zero of the circular scale lies 6 division above the line of graduation. When a wire is placed between the jaws, 3 main scale divisions are clearly visible while 31st division on the circular scale coincide with the reference line. The diameter of the wire is :
(A) 3.62 mm (B) 3.50 mm (C) 3.5 mm (D) 3.74 mm

13. The smallest division on the main scale of a vernier callipers is 1 mm, and 10 vernier divisions coincide with 9 main scale divisions. While measuring the diameter of a sphere, the zero mark of the vernier scale lies between 20 and 21 mm and the fifth division of the vernier scale coincide with a main scale division. Then diameter of the sphere is
(A) 20.5 mm (B) 21.5 mm (C) 21.50 mm (D) 20.50 mm

14. To measure the diameter of a wire, a screwgauge is used. In a complete rotation, spindle of the screw gauge advances by $\frac{1}{2}$ mm and its circular scale has 50 deviations. The main scale is graduated to $\frac{1}{2}$ mm. If the wire is put between the jaws, 4 main scale divisions are clearly visible and 10 devisions of circular scale co–inside with the reference line. The resistance of the wire is measured to be (10Ω ± 1%). Length of the wire is measured to be 10 cm using a scale of least count 1mm. Maximum permissible error in resistivity measurement is :

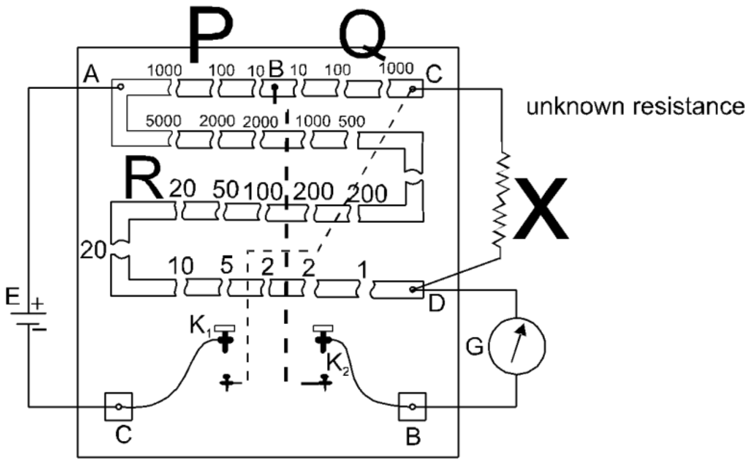
(A) 1.5% (B) 2% (C) 2.5% (D) 3%

15. In a meter bridge circuit, the known resistance used in resistance box is 100 Ω (without any error, and the unknown resistor is put in right arm). The null point is found to be 40 cm from left end. If mm scale is used in the meter bridge then resistance of the unknown resistor is :



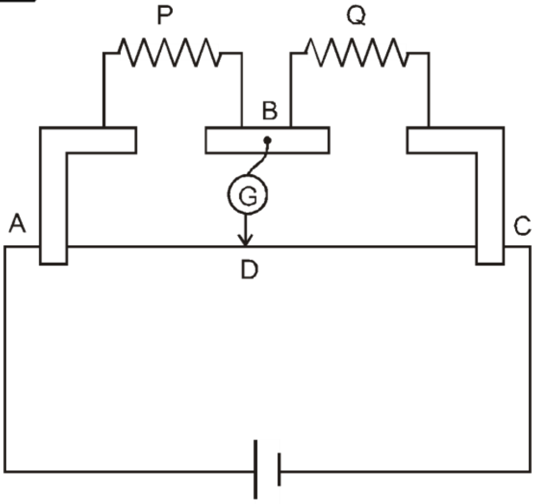
(A) $150\Omega \pm \frac{3}{8}\Omega$ (B) $150\Omega \pm \frac{3}{8}\Omega$ (C) $150\Omega \pm \frac{5}{8}\Omega$ (D) $150\Omega \pm \frac{7}{16}\Omega$

16. In the post office box circuit, 10 Ω plug is taken out in arm AB and 100 Ω plug is taken out in arm BC. If the unknown resistor is kept in melting ice chamber, 600 Ω resistance is required in arm AD for zero deflection in galvanometer. Now if the unknown resistor is kept at 100° C (steam chamber), 630 Ω resistance is required in arm AD for zero deflection. Temprature coefficient of resistance of the unknown wire is :



(A) 2.5×10^{-4} / C° (B) 5×10^{-4}/ C° (C) 7.5×10^{-4} / C° (D) 8×10^{-4} / C°

17.* In the meter bridge circuit, the point D is the balance point.

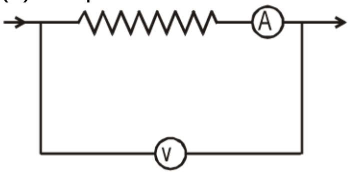


(A) If the jockey is shifted to the left of D, current will flow from the meter bridge wire to the point B.
(B) If jockey is shifted to the right of D, current will flow from point B to the meter bridge wire.
(C) If the jockey is at point D, but now the resistance P is heated, then the current will flow from point B to the meter bridge wire.
(D) If the jockey is at point D, but now the resistance P is heated, then the current will flow from the meter bridge wire to the point B.

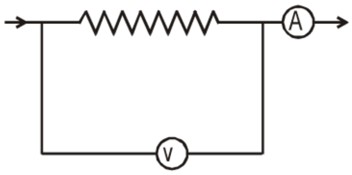
PART - III : COMPREHENSION

Comprehension - 1

In the Ohm's law experiment to find resistance of unknown resistor R, following two arrangements (a) and (b) are possible.



(a)



(b)

The resistance measured is given by

$$R_{measured} = \frac{V}{i}$$

V = voltage reading of voltmeter, i = current reading of ammeter.
But unfortunately the ammeters and voltmeter used are not ideal, but having resistance R_A and R_v respectively.

1. For arrangement (a), the measured resistance is

(A) $R + R_v$ (B) $R + R_A$ (C) $\frac{RR_v}{R+R_v}$ (D) $\frac{RR_v}{R+R_v}+R_A$

2. For arrangement (b), the measured resistance is

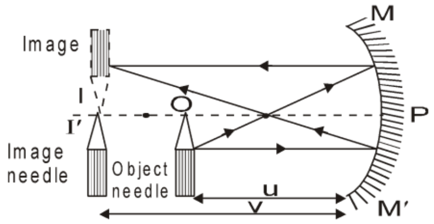
(A) $R + R_v$ (B) $R + R_A$ (C) $\frac{RR_v}{R+R_v}$ (D) $\frac{RR_v}{R+R_v}+R_A$

3. You are given two unknown resistors X and Y. These resistances are to be determined, using an ammeter of $R_A = 0.5\ \Omega$ and a voltmeter of $R_v = 20\ k\Omega$. It is known that X is in range of a few ohms and Y is in the range of several kilo ohm's. Which circuit is preferable to measure X and Y :

Resistor	Circuit
x	(a)
y	(b)

(A) x → (a), y → (b) (B) x → (b), y → (a) (C) x → (a), y → (a) (D) x → (b), y → (b)

Comprehension–2



To find focal length of a concave mirror using u-v method, for different u, we measure different v, and thus we find f using mirror's formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$.

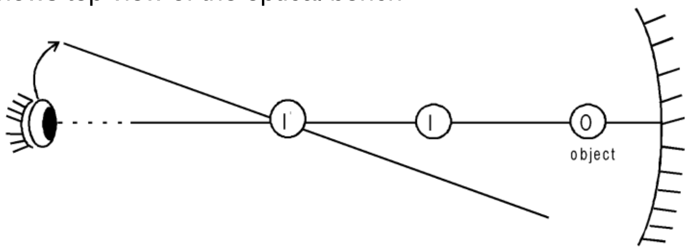
In this experiment, a concave mirror is fixed at position MM' and a knitting needle is used as an object, mounted in front of the concave mirror. This needle is called object needle (O in fig)

First of all we make a rough estimation of *f*. For estimating f roughly, make a sharp image of a far away object (like sun) on a filter paper. The image distance of the far object will be an approx estimation of focal length.

Now, the object needle is kept beyond f, so that its real and inverted image (I in fig) can be formed. You can see this inverted image in the mirror by closing your one eye and keeping the other eye along the pole of the mirror.

To locate the position of the image, use a second needle, and shift this needle such that its peak Coincide with the image. The second needle gives the distance of image (v), so it is called "image needle" (I' in figure). Note the object distance 'u' and image distance 'v' from the mm scale on optical bench.

Parallax: Figure shows top view of the optical bench

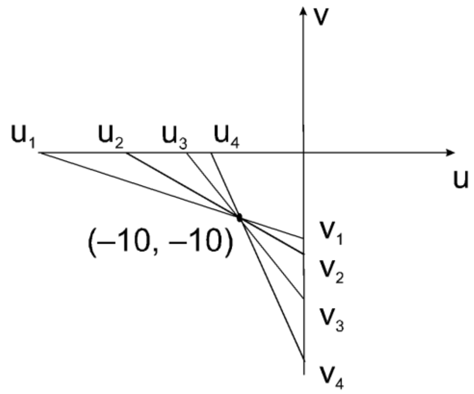


Suppose image needle (I') doesn't co-insisde with image (I), the image is farther from eyes as compared to the image needle (I') as shown. If we shift our eyes to the left, the image (I), which is more distant from us, will appear to move to the left of the line of sight and if we shift our eyes to right, the image (I) will appear to move to the right of the line of sight. This shifting is called parallax. To remove this, we shift the image needle (I') towards mirror, such that it exactly co–inside with the image (I).

4. Parallax aries due to :
(A) Defect in the observers eyes
(B) The object and the image needles are not parallel
(C) Our eyes are not in the line of object and image
(D) The image needle is not placed exactly co-insiding the image

5. In an obseravtion, if we shift our eyes to left, the image (I) appears to move to the right of the line of sight. To find the image distance (to remove prallax), we have to shift the image needle (I′) :
(A) Towards the mirror (B) Away from the mirror
(C) Perpendicular to the principle axis (D) No need to shift

6. To find the focus distance of the concave mirror, for the different values of object distances (u_1, u_2 ... u_n), the values of image distances (v_1, v_2 ..... v_n) are measured. We mark u_1, u_2 ..... u_n on x-axis and v_1, v_2 ..... u_n on y-axis. Now draw lines joining u_1 with v_1, u_2 with u_2 .... u_n with v_n as shown in figure. The focus distance of the mirror should be



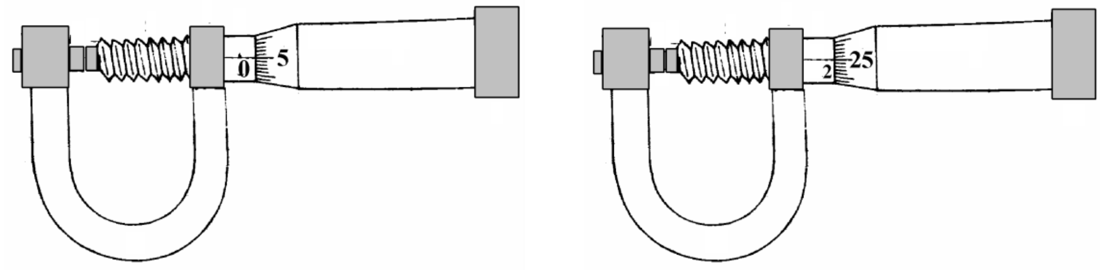
(A) 5 cm (B) 10 cm (C) 20 cm (D) 15 cm

Exercise-2

✍ **Marked Questions can be used as Revision Questions.**
*** Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1.✍ The number of circular divisions on the shown screw gauge is 50. It moves 0.5 mm on main scale for one complete rotation. Main scale reading is 2. The diameter of the ball is : **[JEE 2006; 3/181, –1]**



(A) 2.25 mm (B) 2.20 mm (C) 1.20 mm (D) 1.25 mm

2. A student performs an experiment for determination of $g\left(=\frac{4\pi^2\ell}{T^2}\right)$, $\ell \approx 1$m, and he commits an error of $\Delta\ell$. For T he takes the time of n oscillations with the stop watch of least count ΔT and he commits a human error of 0.1 sec. For which of the following data, the measurement of g will be most accurate ? **[JEE 2006; 3/181, –1]**
(A) $\Delta L = 0.5$, $\Delta T = 0.1$, n = 20 (B) $\Delta L = 0.5$, $\Delta T = 0.1$, n = 50
(C) $\Delta L = 0.5$, $\Delta T = 0.01$, n = 20 (D) $\Delta L = 0.1$, $\Delta T = 0.05$, n = 50

3._ In an experiment to determine the focal length (f) of a concave mirror by the u – v method, a student places the object pin A on the principal axis at a distance x from the pole P. The student looks at the pin and its inverted image from a distance keeping his/her eye in line with PA. When the student shifts his/her eye towards left, the image appears to the right of the object pin. Then, **[JEE 2007, 3/184, –1]**
(A) x < f (B) f < x < 2f (C) x = 2f (D) x > 2f

4. 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 0.80 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 **[JEE 2007, 3/184, –1]**
(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

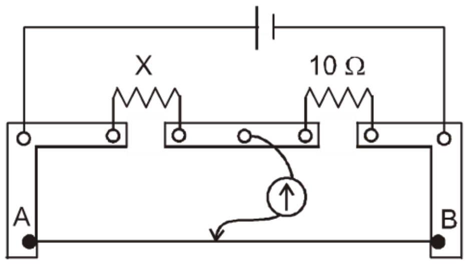
5. Student I, II and III perform an experiment for measuring the acceleration due to gravity (g) using a simple pendulum. They use different lengths of the pendulum and /or record time for different number of oscillations. The observations are shown in the table.
Least count for length = 0.1 cm
Least count for time = 0.1 s

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

If E_I, E_{II} and E_{III} are the percentage errors in g, i.e., $\left(\frac{\Delta g}{g}\times 100\right)$ for students I, II and III, respectively, **[JEE 2008, 3/163, –1]**
(A) $E_I = 0$ (B) E_I is minimum (C) $E_I = E_{II}$ (D) E_{II} is maximum

6. A vernier calliper has 1 mm marks on the main scale. It has 20 equal division on the Vernier scale which match with 16 main scale divisions. For this Vernier calliper, the least count is : **[JEE 2010, 5/163,–2]**
(A) 0.02 mm (B) 0.05 mm (C) 0.1 mm (D) 0.2 mm

7. A meter bridge is set-up as shown, to determine an unknown resistance 'X' using a standard 10 ohm resistor. The galvanometer shows null point when tapping-key is at 52 cm mark. The end-corrections are 1 cm and 2 cm respectively for the ends A and B. The determined value of 'X' is **[JEE 2011, 3/160,–1]**



(A) 10.2 ohm (B) 10.6 ohm
(C) 10.8 ohm (D) 11.1 ohm

8. The density of a solid ball is to be determined in an experiment. The diameter of the ball is measured with a screw gauge, whose pitch is 0.5 mm and there are 50 divisions on the circular scale. The reading on the main scale is 2.5 mm and that on the circular scale is 20 divisions. If the measured mass of the ball has a relative error of 2%, the relative percentage error in the density is **[JEE 2011, 3/160,–1]**
(A) 0.9% (B) 2.4% (C) 3.1% (D) 4.2%

9. In the determination of Young's modulus $\left(Y = \frac{4MLg}{\pi \ell d^2}\right)$ by using Searle's method, a wire of length L = 2 m and diameter d = 0.5 mm is used. For a load M = 2.5 kg, an extension ℓ = 0.25 mm in the length of the wire is observed. Quantities d and ℓ are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm. The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the Y measurement **[IIT-JEE-2012, Paper-1; 3/70, –1]**
(A) due to the errors in the measurements of d and ℓ are the same.
(B) due to the error in the measurement of d is twice that due to the error in the measurement of ℓ.
(C) due to the error in the measurement of ℓ is twice that due to the error in the measurement of d.
(D) due to the error in the measurement of d is four time that due to the error in the measurement of ℓ.

10. The diameter of a cylinder is measured using a vernier callipers with no zero error. It is found that the zero of the vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The vernier scale has 50 division equivalent to 2.45 cm. The 24^{th} division of the vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is : **[JEE(Advanced)-2013 ; P-1, 3/60, –1]**
(A) 5.112 cm (B) 5.124 cm (C) 5.136 cm (D) 5.148 cm

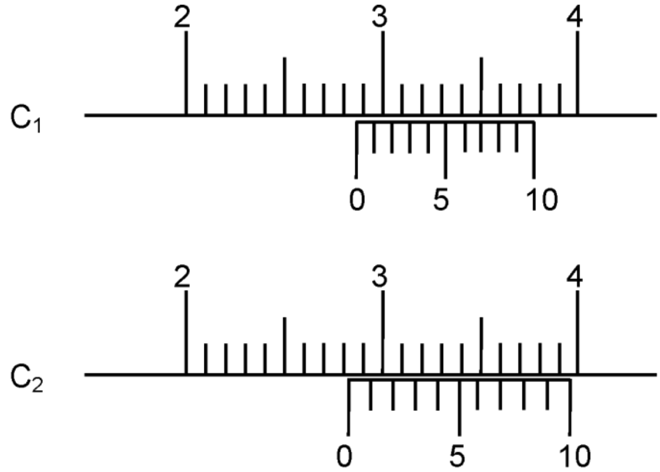
11.✍ Using the expression 2d sin θ = λ, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90º. The wavelength λ is exactly knowns and the error in θ is constant for all values of θ. As θ increases from 0º : **[JEE(Advanced)-2013 ; P-2, 3/60, –1]**
(A) the absolute 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.

12. Durring 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 20^{th} division of the Vernier scale exactly coincides with one of the main scale divisions. When an additional load of 2 kg is applied to the wire, the zero of the Vernier scale still lies between 3.20×10^{-2} m and 3.25×10^{-2} m of the main scale but now the 45^{th} division of Vernier scale coincides with one of the main scale divisions. The length of the thin metallic wire is 2m. and its cross-sectional area is 8×10^{-7} m². 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 **[JEE (Advanced)-2014 ; P-1, 3/60]**

13.* 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 division 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, **[JEE(Advanced) 2015 ; P-1,4/88, –2]**
(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 0.01mm.
(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 0.005mm.
(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.

14. 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 **[JEE (Advanced) 2015 ; P-2, 4/88]**

15. There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale divisions. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are **[JEE (Advanced) 2016; P-2, 3/62, –1]**



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

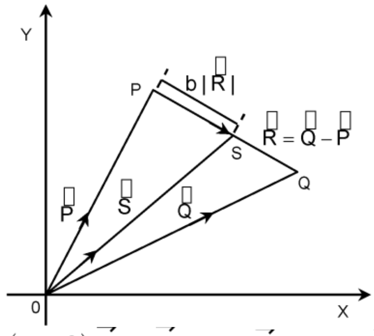
16.* In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and r are measured to be (60 ± 1) mm and (10 ± 1) mm respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56 s, 0.57 s, 0.54 s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is (are) true? **[JEE (Advanced) 2016; P-2, 4/62, –2]**

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

17. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T = 0.01$ seconds and he measures the depth of the well to be L = 20 meters. Take the acceleration due to gravity $g = 10 ms^{-2}$ and the velocity of sound is $300 ms^{-1}$. Then the fractional error in the measurement $\frac{\delta L}{L}$, is closest to : **[JEE (Advanced) 2017; P-2, 3/61, –1]**

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

18. Three vectors $\vec{P}$, $\vec{Q}$ and $\vec{R}$ are shown in the figure. Let S be any point on the vector $\vec{R}$. The distance between the point P and S is $b|\vec{R}|$. The general relation among vectors $\vec{P}$, $\vec{Q}$ and $\vec{S}$ is : **[JEE (Advanced) 2017; P-2, 3/61, –1]**



(A) $\vec{S} = (b-1)\vec{P} + b\vec{Q}$ (B) $\vec{S} = (1-b^2)\vec{P} + b\vec{Q}$ (C) $\vec{S} = (1-b)\vec{P} + b^2\vec{Q}$ (D) $\vec{S} = (1-b)\vec{P} + b\vec{Q}$

19. A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is

δT = 0.01 seconds and he measures the depth of the well to be L = 20 meters. Take the acceleration due to gravity g = $10ms^{-2}$ and the velocity of sound is 300 ms^{-1}. Then the fractional error in the measurement $\frac{\delta L}{L}$, is closest to : **[JEE (Advanced) 2017; P-2, 3/61, –1]**

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

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. Two full turns of the circular scale of a screw gauge cover a distance of 1mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw gauge has a zero error of –0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is : **[AIEEE-2008, 3/105]**

(1) 3.32 mm (2) 3.73 mm (3) 3.67 mm (4) 3.38 mm

2. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distance is measured by **[AIEEE-2008, 3/105]**

(1) a vernier scale provided on the microscope (2) a standard laboratory scale
(3) a metal scale provided on the microscope (4) a screw gauge provided on the microscope

3. In an experiment the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (0.5°), then the least count of the instrument is: **[AIEEE-2009, 4/144]**

(1) half minute (2) one degree (3) half degree (4) one minute

4. In an optics experiment, with the position of the object fixed, a student varies the position of the convex lens and for each position, the screen is adjusted to get a clear image of the object. A graph between the object distance u and the image distance v, from the lens, is plotted using the same scale for the two axes. A straight line passing through the origin and making an angle of 45° with the x-axis meets the experimental curve at P. The coordinates of P will be: **[AIEEE-2009, 4/144]**

(1) $\left(\frac{f}{2}, \frac{f}{2}\right)$ (2) (f, f) (3) (4f, 4f) (4) (2f, 2f)

5. The respective number of significant figures for the numbers 23.023, 0.0003 and 2.1×10^{-3} are **[AIEEE-2010, 4/144, –1]**

(1) 5, 1, 2 (2) 5, 1, 5 (3) 5, 5, 2 (4) 4, 4, 2

6. A screw gauge gives the following reading when used to measure the diameter of a wire.
Main scale reading : 0 mm
Circular scale reading : 52 division
Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.
The diameter of wire from the above data is : **[AIEEE - 2011, 4/120, –1]**

(1) 0.52 cm (2) 0.052 cm (3) 0.026 cm (4) 0.005 cm

7. If 400 Ω of resistance is made by adding four 100 Ω resistances of tolerance 5%, then the tolerance of the combination is : **[AIEEE 2011, 11 May; 4/120–1]**

(1) 5% (2) 10 % (3) 15 % (4) 20 %

8. The Current voltage relation of diode is given by I = ($e^{1000V/T}$–1) mA, where the applied voltage V is in volts and the temperature T is in degree Kelvin. If a student makes an error measuring ± 0.01V while measuring the current of 5 mA at 300K, what will be the error in the value of current in mA ?

[JEE (Main) 2014; 4/120, –1]

(1) 0.2 mA (2) 0.02 mA (3) 0.5 mA (4) 0.05 mA

9. A student measured the length of a rod and wrote it as 3.50 cm. Which instrument did he use to measure it? **[JEE (Main) 2014; 4/120, –1]**

(1) A meter scale.

(2) A vernier calliper where the 10 divisions in vernier scale matches with 9 division in main scale and main scale has 10 divisions in 1 cm.

(3) A screw gausge having 100 divisions in the circular scale and pitch as 1 mm.

(4) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm.

10. The period of oscillation of a simple pendulum is T = $2\pi\sqrt{\frac{L}{g}}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90s using a wrist watch of 1s resolution. The accuracy in the determination of g is : **[JEE (Main) 2015; 4/120, –1]**

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

11. A student measures the time period of 100 oscillations of a simple pendulum four times. That data set is 90 s, 91 s, 95 s and 92 s. If the minimum division in the measuring clock is 1 s, then the reported mean time should be : **[JEE (Main) 2016; 4/120, –1]**

(1) 92 ± 5.0 s (2) 92 ± 1.8 s (3) 92 ± 3 s (4) 92 ± 2 s

12. A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a thin sheet of Aluminium. Before starting the measurement, it is found that when the two jaws of the screw gauge are brought in contact, the 45^{th} division coincides with the main scale line and that the zero of the main scale is barely visible. What is the thickness of the sheet if the main scale reading is 0.5mm and the 25^{th} division coincides with the main scale line ?**[JEE(Main) 2016; 4/120, –1]**

(1) 0.80 mm (2) 0.70mm (3) 0.50mm (4) 0.75mm

13. The following observations were taken for determining surface tension T of water by capillary method :
diameter of capillary, D = 1.25×10^{-2} m rise of water , h = 1.45×10^{-2} m. Using g = 9.80 m/s^2 and the simplified relation T = $\frac{rhg}{2} \times 10^3$ N/m, the possible error in surface tension is closest to :

[JEE (Main) 2017, 4/120, –1]

(1) 10% (2) 0.15% (3) 1.5% (4) 2.4%

Answers

EXERCISE-1

PART - I

1. $\bar{D} = 1.330$ cm , $\overline{\Delta D} = 0.005$ cm ,

   Relative error = + 0.004 %, error = 0.4%

2. (i) 1 , (ii) 3 (iii) 4

   (iv) 4 (v) 4 (vi) 4

3. (i) 0.0393 kg (ii) 4.08 x 10^8 sec

   (iii) 5.24 m (iv) 4.74 x 10^{-6} kg

4. 1.4%

5. The area is 2.6 cm^2.

6. The maximum possible error is 1.1 × 10^{10} Nm^{-2}.

7. 0.00265

8. 50 cm.

PART - II

1.	(A)	**2.**	(D)	**3.**	(B)
4.	(A)	**5.**	(B)	**6.**	(A)
7.	(D)	**8.**	(C)	**9.**	(B)
10.	(B)	**11.**	(B)	**12.**	(D)
13.	(A)	**14.**	(C)	**15.**	(C)
16.	(B)	**17.**	(ABD)		

PART - III

1.	(B)	**2.**	(C)	**3.**	(B)
4.	(D)	**5.**	(B)	**6.**	(B)

EXERCISE-2

PART - I

1.	(C)	**2.**	(D)	**3.**	(B)
4.	(B)	**5.**	(B)	**6.**	(D)
7.	(B)	**8.**	(C)	**9.**	(A)
10.	(B)	**11.**	(D)	**12.**	4
13.	(BC)	**14.**	4	**15.**	(C)
16.	(ABD)	**17.**	(D)	**18.**	(D)
19.	(D)				

PART - II

1.	(4)	**2.**	(1)	**3.**	(4)
4.	(4)	**5.**	(1)	**6.**	(2)
7.	(1)	**8.**	(1)	**9.**	(2)
10.	(2)	**11.**	(4)	**12.**	(1)
13.	(3)				

Solutions

EXERCISE-1

PART - I

4. $v = 2f_0(\ell_2 - \ell_1)$,

$$\Rightarrow \left(\frac{\Delta v}{v}\right)_{max} = \frac{\Delta f_0}{f_0} + \frac{\Delta \ell_1 + \Delta \ell_2}{\ell_2 - \ell_1}$$

$$= \frac{1}{100} + \frac{0.1 + 0.1}{74 - 24} = 1.4\%.$$

PART - II

5. $\Delta t = 0.2$ s.

$t = 25$ s

$$T = \frac{t}{N} \Rightarrow \frac{\Delta T}{T} = \frac{\Delta t}{t} = \frac{0.2}{25} = 0.8\ \%$$

13. $D = 20 + 5 \times \frac{10 - 9}{10} = 20.5$ mm

15. $\frac{100}{R} = \frac{40}{60} \Rightarrow R = 150\ \Omega$

For % error :

$$\frac{100}{R} = \frac{\ell}{100 - \ell}$$

$$\Rightarrow R = 100\left(\frac{100 - \ell}{\ell}\right),$$

take log and differenciate

$$\frac{dR}{R} = \frac{d\ell}{100 - \ell} + \frac{d\ell}{\ell},$$

$\left(\frac{\Delta R}{R}\right)_{max} = \frac{\Delta \ell}{100-\ell} + \frac{\Delta \ell}{\ell}$

$= \frac{1\text{ mm}}{(100-40)} + \frac{1\text{ mm}}{40\text{cm}}$

$\frac{(\Delta R)_{max}}{150} = \frac{0.1}{60} + \frac{0.1}{40} \Rightarrow (\Delta R)_{max} = \frac{5}{8}$.

16. $\frac{P}{Q} = \frac{R}{X} \Rightarrow \frac{10}{100} = \frac{600}{X}$

X = 6000 Ω

For second case $\frac{P}{Q} = \frac{R}{X} \Rightarrow \frac{10}{100} = \frac{630}{X}$

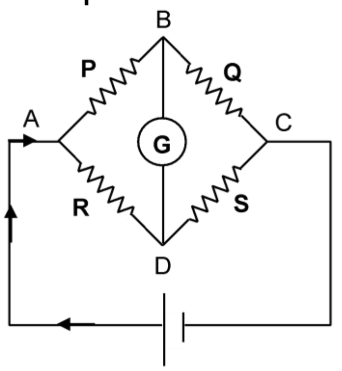
$\Rightarrow$ X = 6300 Ω

$R_f = R_0 (1 + \propto \Delta T)$

6300 = 6000 (1 + ∝ (100))

$\propto = 5 \times 10^{-4}$ / C°

17. **Concept :**



In the wheat stone bridge :

If $\frac{P}{Q} = \frac{R}{S}$ then $V_B = V_D$ But if $\frac{P}{Q} > \frac{R}{S}$ then potential drop across P will be more than that across R. So potential at B will be less than that at D. So current in the Galvanometer will flow from B to D. We can remember it like this :

If $\frac{P}{Q}\uparrow$ then potential at the point B between them will be less

If $\frac{R}{S}\uparrow$ then potential at the point D between them will be less.

(A) If jockey is shifted to the left of D,

$\frac{R}{S}\downarrow$ So $V_D\uparrow$ $\Rightarrow$ current in galvanometer will flow from meter bridge wire to B.

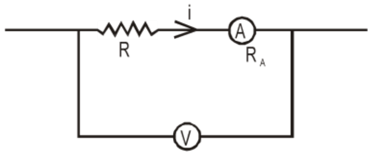
(B) If the jockey is shifted to right of D,

$\frac{R}{S}\uparrow \Rightarrow V_D\downarrow \Rightarrow$ Current in the galvanometer will flow from B to the meter bridge wire.

(D) If resistor P is heated, then its resistance will increase $\frac{P}{Q}\uparrow \Rightarrow V_B\downarrow \Rightarrow$ Current in galvanometer will flow from the meter bridge wire to B.

PART - III

1.



Reading of Ammeter = i

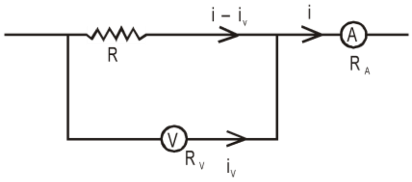
Reading of voltmeter = P.d. across voltmeter

= P.d. across $(R + R_A)$ system = $i (R + R_A)$

$\Rightarrow$ Measured resistance = $\frac{V}{i} = \frac{i(R+R_A)}{i}$

$= R + R_A$

2.



- Reading of Ammeter = i

and $i_v R_V = (i - i_v) R \Rightarrow i_V = \frac{i\ R}{R+R_v}$

- Reading of Voltmeter

$V = i R_{eq} = i \times \frac{RR_v}{(R+R_v)}$

measured resistance = $\frac{v}{i} = \frac{iRR_v/(R+R_v)}{i}$

$= \frac{RR_v}{R+R_v}$

3. If R is very large (~ K Ω)

Then measured resistance from arrangement (a) will be

$R_{measured} = R + R_A \approx R$

So (a) will be preferred

If R is very small (~ few Ohm)

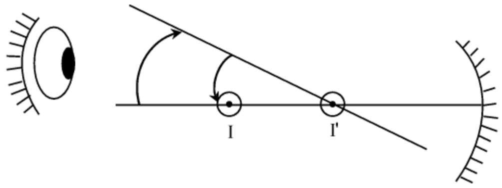
then measured resistance from (b) will be

$R_{measured}$ = where R/R_v is negligible

so, $R_{measured}$ R So (b) will be preferred

4. It is clear from the passage that the parallax arises if the image needle is not placed co–insiding the image.

5.



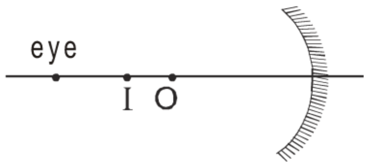
From these observations, we can say that image (I) is farther from mirror, as compared to the image needle (I'). So to remove the parallax, we have to shift the image needle (I') away from the mirror

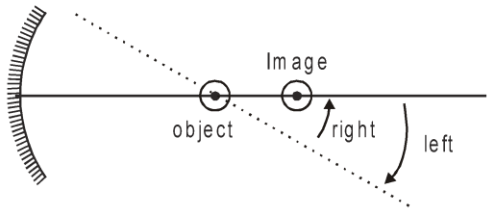
6. (f, f) = (–10, –10) ⇒ f = –10 cm.

EXERCISE-2
PART - I

1. Zero error = $5 \times \frac{0.5}{50}$ = 0.05 mm
Actual measurement
= 2 × 0.5 mm + 25 × $\frac{0.5}{50}$ – 0.05 mm
= 1 mm + 0.25 mm – 0.05 mm = 1.20 mm.

3. Since object and image move in opposite directions, the positioning should be as shown in figure. Object lies between focus and centre of curvature f < x < 2f





4. $\frac{mg}{\pi r^2} = (Y)\frac{x}{\ell_0}$

$Y = \frac{mg\ell_0}{\left(\pi\frac{d^2}{4}\right)x} = 2 \times 10^{11}$ N/m²

$\left(\frac{\Delta Y}{Y}\right)_{max} = 2\left(\frac{\Delta d}{d}\right) + \frac{\Delta x}{x}$

$= 2\left(\frac{0.01}{0.4}\right) + \frac{0.05}{0.8} = \frac{9}{80}$

$\Delta Y = \frac{9}{80} \times 2 \times 10^{11} = 0.225 \times 10^{11}$ N/m²
$= 0.2 \times 10^{11}$ N/m²

5. The least count of length $\Delta\ell$ = 0.1 cm
The least count of time Δt = 0.1 s

% error of g = $\frac{\Delta g}{g} \times 100$

$T = 2\pi\sqrt{\frac{\ell}{g}} \Rightarrow g = \frac{4\pi^2\ell}{T^2}$ where $T = \frac{t}{n}$

so $g = \frac{4\pi^2\ell}{t^2}.n^2$

$\frac{\Delta g}{g} = \frac{\Delta\ell}{\ell} + 2\frac{\Delta t}{t}$

For student I $\left(100 \times \frac{\Delta g}{g}\right)_I$

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

$E_I = \frac{0.2}{64.0} \times 100 = \frac{20}{64}$

For student II $\left(100 \times \frac{\Delta g}{g}\right)_{II}$

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

$E_{II} = \frac{0.3}{64.0} \times 100 = \frac{30}{64}$

For student III $\left(100 \times \frac{\Delta g}{g}\right)_{III}$

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

$E_{III} = \left(\frac{0.1}{20.0} + \frac{0.1}{18.0}\right) \times 100 = \frac{19}{18}$

E_I is least. **Ans. (B)**

9. $\Delta d = \Delta\ell = \frac{0.5}{100}$ mm

$y = \frac{4MLg}{\pi\ell d^2}$

$\left(\frac{\Delta y}{y}\right)_{max} = \frac{\Delta\ell}{\ell} + 2\frac{\Delta d}{d}$

error due to ℓ measurement

$\frac{\Delta\ell}{\ell} = \frac{0.5/100 \text{ mm}}{0.25 \text{ mm}}$

error due to d measurement

$2\frac{\Delta d}{d} = \frac{2 \times \frac{0.5}{100}}{0.5 \text{ mm}} = \frac{0.5/100}{0.25}$

So error in y due to ℓ measurement = error in y due to d measurement

10. 50 VSD = 2.45 cm

1 VSD = $\frac{2.45}{50}$ cm = 0.049 cm

Least count of vernier = 1MSD – 1 VSD
= 0.05 cm – 0.049 cm
= 0.001 cm

Thickness of the object = Main scale reading + vernier scale reading × least count
= 5.10 + (24) (0.001)
= 5.124 cm.

11. $2d \sin\theta = \lambda$ ......(1)

$d = \frac{\lambda}{2\sin\theta} = \frac{\lambda}{2}$ (cosecθ)

differntiate

$\Delta(d) = \frac{\lambda}{2}(-\operatorname{cosec}\theta \cot\theta)\Delta\theta$

$|\Delta(d)| = \frac{\lambda\cos\theta}{2\sin^2\theta}\Delta\theta$ .....(2)

as θ = increases , cosθ decreases and sinθ increases so $\frac{\lambda\cos\theta}{2\sin^2\theta}$ decreases

⇒ Absolute error in d (that is |Δ (d)|) decreases.

Deviding eqn 2 and 1

$\frac{|\Delta(d)|}{d} = \frac{\cos\theta}{\sin\theta}(\Delta\theta) = \cot\theta\,\Delta\theta$

as θ = increases, cotθ decreases so fractional error in d (that is $\frac{|\Delta(d)|}{d}$) will also decrease.

13. For Vernier calipers

1MSD = $\frac{1}{8}$cm

5 VSD = 4 MSD

1VSD = $\frac{4}{5}\text{MSD} = \frac{4}{5}\times\frac{1}{8} = \frac{1}{10}$cm

LC of vernier calliper

$= \frac{1}{8}\text{cm} - \frac{1}{10}\text{cm} = 0.025$ cm

pitch of screw gauge = 2 × (0.025) = 0.05 cm

Leastcount of screw gauge

$= \frac{0.05}{100}$cm = 0.005 mm

(C) & (D) Least count of linear scale of screw gauge = 0.05 cm

pitch = 0.05 × 2 cm = 0.1 cm

Leastcount of screw gauge

$= \frac{0.1}{100}$cm = 0.01 mm

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

$\alpha = 0.2\ s^{-1}$

$\frac{dA}{A}$ = 1.25%

$\frac{dt}{t}$ = 1.50 %

$\frac{dE}{E}$ = ?

log E = 2 log A – αt

$\frac{dE}{E} = \pm 2\frac{dA}{A} \pm \alpha dt$

= ±2 (1.25) ± 0.2(7.5) = ± 2.5 ± 1.5 = ± 4 %

15. For vernier C_1

10 VSD = 9 MSD = 9 mm

1 VSD = 0.9 mm

⇒ LC = 1MSD – 1VSD = 1mm – 0.9 mm = 0.1 mm

Reading of C_1 = MSR + (VSR)(L.C.) = 28mm + (7)(0.1)

Reaing of C_1 = 28.7 mm = 2.87 cm

For vernier C_2 : the vernier C_2 is abnormal, So we have to find the reading from basics.

The point where both of the marks are matching :

distance measured from main scale = distance measured from vernier scale

28mm + (1mm)(8) = (28 mm + x) + (1.1 mm) (7)

solving x = 0.3 mm

So reading of C_2 = 28 mm + 0.3 mm = 2.83 cm

16.

S. No.	T	absolute error = $\lvert T - T_{mean}\rvert$
(1)	0.52	0.04
(2)	0.56	0.00
(3)	0.57	0.01
(4)	0.54	0.02
(5)	0.59	0.03
	$T_{mean} = \frac{2.78}{5}$ T_{mean} = 0.56	$(\Delta T)_{mean}$ = 0.02

% error in T = $\frac{0.02}{0.56}$ ×100 = 3.57%

According to the question

$g \propto \frac{T^2}{R-r}$

$\frac{dg}{g} = 2\frac{dT}{t} + \frac{dR+dr}{R-r}$

$\frac{dg}{g}$ = 2(3.57%) + $\frac{1+1}{60-10}$ ×100%

$\frac{dg}{g}$ = 11% **Ans. (A,B,D)**

17. $t = \sqrt{\frac{L}{5}} + \frac{L}{300}$

$dt = \frac{1}{\sqrt{5}}\frac{1}{2}L^{-1/2}\,dL + \left(\frac{1}{300}dL\right)$

$dt = \frac{1}{2\sqrt{5}}\frac{1}{\sqrt{20}}\,dL + \frac{dL}{300} = 0.01$

$dL\left(\frac{1}{20}+\frac{1}{300}\right) = 0.01$

$dL\left[\frac{15}{300}\right] = 0.01$; $dL = \frac{3}{16}$

$\frac{dL}{L}\times 100 = \frac{3}{16}\times\frac{1}{20}\times 100 = \frac{15}{16} \simeq 1\%$

18. $\vec{S} = \vec{P} + b\vec{R} = \vec{P} + b\left(\vec{Q} - \vec{P}\right) = \vec{P}(1-b) + b\vec{Q}$

19. $t = \sqrt{\frac{L}{5}} + \frac{L}{300}$

$dt = \frac{1}{\sqrt{5}}\frac{1}{2}L^{-1/2}\,dL + \left(\frac{1}{300}dL\right)$

$dt = \frac{1}{2\sqrt{5}}\frac{1}{\sqrt{20}}\,dL + \frac{dL}{300} = 0.01$

$dL\left(\frac{1}{20}+\frac{1}{300}\right) = 0.01$

$dL\left[\frac{15}{300}\right] = 0.01$

$dL = \frac{3}{16}$

$\frac{dL}{L}\times 100 = \frac{3}{16}\times\frac{1}{20}\times 100 = \frac{15}{16} \simeq 1\%$

PART - II

3. 29 division of main scale coincides with 30 divisions of vernier scale

Hence one division of vernier scale = $\frac{29}{30}$ of main scale = $\frac{29}{30}\times 0.5°$

So least count = 1 MSD – 1 VSD

$= 0.5° - \frac{29}{30}\times 0.5° = \frac{1}{30}\times 0.5°$

$= \frac{1}{30}\times 0.5\times 60$ min = 1 min.

8. $I = e^{\frac{1000\,V}{T}} - 1$

$I + 1 = e^{\frac{1000\,V}{T}}$

$\log(I+1) = \frac{1000V}{T}$

$\frac{d(I+1)}{I+1} = \frac{1000}{T}dV \Rightarrow \frac{dI}{I+1} = \frac{1000}{T}dV$

$\frac{dI}{(5+1)mA} = \frac{1000}{300}(0.01)$; $dI = 0.2$ mA

11. $t_{mean} = \frac{90+91+95+92}{4} = 92$ sec.

absolute error in each reading = 2, 1, 3, 0

mean error = $\frac{2+1+3+0}{2} = 1.5\,\text{sec}.$

put the least count of the measuring clock is 1 sec.

so it cannot measure upto 0.5 second so we have to round it off.

so mean error will be 2 second

so t = 92 ± 2 sec.

12. When jaws are closed, the zero error will be

= main scale reading + (circularscale reading) (Least count)

= –0.5 mm + (45)(0.01)

zero error = –0.05 mm

when the sheet is placed between the jaws ; measured thickness

= 0.5 mm + (25)(0.01) = 0.75 mm

⇒ Actual thickness

= 0.75 mm –(–0.05) = 0.80 mm

13. Here the information of least count of D and h measurement are not given so we will use max. permissible error in D and h = place value of last digit.

$D = 1.25 \times 10^{-2}$m so $\Delta D = 0.01 \times 10^{-2}$ m

$h = 1.45 \times 10^{-2}$ m so $\Delta h = 0.01 \times 10^{-2}$m

$g = 9.80$ m/s^2

$T = \frac{rgh}{2}\times 10^{3}$

$\frac{\Delta T}{T} = \frac{\Delta r}{r} + \frac{\Delta h}{h} = \frac{\Delta D}{D} + \frac{\Delta h}{h}$

$\frac{\Delta T}{T} = \frac{0.01\times 10^{-2}}{1.25\times 10^{-2}} + \frac{0.01\times 10^{-2}}{1.45\times 10^{-2}}$

$\frac{\Delta T}{T} = \left(\frac{1}{125}+\frac{1}{145}\right)\times 100\%$

= (0.008 + 0.0069) × 100% = 1.49 ≈ 1.5%