CHAPTER

21 Experimental Skills

1. In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance of 5 Ω, a balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell.
(a) 1 Ω (b) 1.5 Ω (c) 2 Ω (d) 2.5 Ω
(2018)

2. In a circuit for finding the resistance of a galvanometer by half deflection method, a 6 V battery and a high resistance of 11 kΩ are used. The figure of merit of the galvanometer is 60 μA per division. In the absence of shunt resistance, the galvanometer produces a deflection of θ = 9 divisions when current flows in the circuit. The value of the shunt resistance that can cause the deflection of θ/2, is closest to
(a) 55 Ω (b) 110 Ω (c) 220 Ω (d) 550 Ω
(Online 2018)

3. The following observations were taken for determining surface tension T of water by capillary method:
Diameter of capillary, $D = 1.25 \times 10^{-2}$ m
rise of water, $h = 1.45 \times 10^{-2}$ m
Using $g = 9.80$ m s^{-2} and the simplified relation, $T = \frac{rhg}{2} \times 10^3$ N m^{-1}, the possible error in surface tension is closest to
(a) 0.15% (b) 1.5%
(c) 2.4% (d) 10% *(2017)*

4. In an experiment a sphere of aluminium of mass 0.20 kg is heated upto 150°C. Immediately, it is put into water of volume 150 cc at 27°C kept in a calorimeter of water equivalent to 0.025 kg. Final temperature of the system is 40°C. The specific heat of aluminium is
(take 4.2 joule = 1 calorie)
(a) 315 J/kg-°C (b) 378 J/kg-°C
(c) 476 J/kg-°C (d) 434 J/kg-°C
(Online 2017)

5. In an experiment to determine the period of a simple pendulum of length 1 m, it is attached to different spherical bobs of radii r_1 and r_2. The two spherical bobs have uniform mass distribution. If the relative difference in the periods, is found to be 5×10^{-4} s, the difference in radii, $|r_1 - r_2|$ is best given by
(a) 0.1 cm (b) 0.01 cm
(c) 0.5 cm (d) 1 cm
(Online 2017)

6. In an experiment a convex lens of focal length 15 cm is placed coaxially on an optical bench in front of a convex mirror at a distance of 5 cm from it. It is found that an object and its image coincide, if the object is placed at a distance of 20 cm from the lens. The focal length of the convex mirror is
(a) 27.5 cm (b) 20.0 cm
(c) 25.0 cm (d) 30.5 cm
(Online 2017)

7. 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 45th 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 0.5 mm and the 25th division coincides with the main scale line?
(a) 0.75 mm (b) 0.80 mm
(c) 0.70 mm (d) 0.50 mm *(2016)*

8. In an experiment for determination of refractive index of glass of a prism by $i - \delta$, plot, it was found that a ray incident at angle 35°, suffers a deviation of 40° and that it emerges at angle 79°. In that case which of the following is closest to the maximum possible value of the refractive index?
(a) 1.5 (b) 1.6 (c) 1.7 (d) 1.8
(2016)

9. To find the focal length of a convex mirror, a student records the following data.

Object Pin	Convex Lens	Convex Mirror	Image Pin
22.2 cm	32.2 cm	45.8 cm	71.2 cm

The focal length of the convex lens is f_1 and that of mirror is f_2. Then taking index correction to be negligibly small, f_1 and f_2 are close to
(a) $f_1 = 7.8$ cm $f_2 = 12.7$ cm
(b) $f_1 = 12.7$ cm $f_2 = 7.8$ cm
(c) $f_1 = 15.6$ cm $f_2 = 25.4$ cm
(d) $f_1 = 7.8$ cm $f_2 = 25.4$ cm *(Online 2016)*

10. A thin 1 m long rod has a radius of 5 mm. A force of 50π kN is applied at one end to determine its Young's modulus. Assume that the force is exactly known. If the least count in the measurement of all lengths is 0.01 mm, which of the following statements is false?

(a) The maximum value of Y that can be determined is 10^{14} N/m^2.

(b) $\frac{\Delta Y}{Y}$ gets minimum contribution from the uncertainty in the length.

(c) $\frac{\Delta Y}{Y}$ gets its maximum contribution from the uncertainty in strain.

(d) The figure of merit is the largest for the length of the rod.

(Online 2016)

11. The period of oscillation of a simple pendulum is $q = 7\pi\sqrt{\frac{i}{-}}$.

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 90 s using a wrist watch of 1 s resolution. The accuracy in the determination of g is

(a) 1% (b) 5% (c) 2% (d) 3%

(2015)

12. Diameter of a steel ball is measured using a Vernier callipers which has divisions of 0.1 cm on its main scale (MS) and 10 divisions of its vernier scale (VS) match 9 divisions on the main scale. Three such measurements for a ball are given as:

S.No.	MS (cm)	VS divisions
1.	0.5	8
2.	0.5	4
3.	0.5	6

If the zero error is –0.03 cm, then mean corrected diameter is

(a) 0.56 cm (b) 0.59 cm (c) 0.53 cm (d) 0.52 cm

(Online 2015)

13. The AC voltage across a resistance can be measured using a

(a) potentiometer

(b) moving coil galvanometer

(c) moving magnet galvanometer

(d) hot wire voltmeter *(Online 2015)*

14. A spectrometer gives the following reading when used to measure the angle of a prism.

Main scale reading : 58.5 degree

Vernier scale reading : 09 divisions

Given that 1 division on main scale corresponds to 0.5 degree. Total divisions on the vernier scale is 30 and match with 29 divisions of the main scale. The angle of the prism from the above data

(a) 58.77 degree (b) 58.65 degree

(c) 59 degree (d) 58.59 degree *(2012)*

15. 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 divisions

Given that 1 mm on main scale corresponds to 100 divisions of the circular scale.

The diameter of wire from the above data is :

(a) 0.52 cm (b) 0.052 cm

(c) 0.026 cm (d) 0.005 cm *(2011)*

16. 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

(a) one minute (b) half minute

(c) one degree (d) half degree *(2009)*

17. In an optics experiment, with the position of the object fixed, a student varies the position of a 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

(a) $(2f, 2f)$ (b) $(f/2, f/2)$

(c) (f, f) (d) $(4f, 4f)$ *(2009)*

18. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distances are measured by

(a) a screw gauge provided on the microscope

(b) a vernier scale provided on the microscope

(c) a standard laboratory scale

(d) a meter scale provided on the microscope. *(2008)*

19. While measuring the speed of sound by performing a resonance column experiment, a student gets the first resonance condition at a column length of 18 cm during winter. Repeating the same experiment during summer, she measures the column length to be x cm for the second resonance. Then

(a) $36 > x > 18$ (b) $18 > x$

(c) $x > 54$ (d) $54 > x > 36$. *(2008)*

20. Two full turns of the circular scale of a screw gauge cover a distance of 1 mm 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

(a) 3.38 mm (b) 3.32 mm

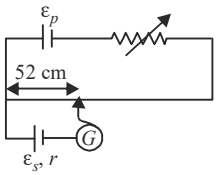
(c) 3.73 mm (d) 3.67 mm. *(2008)*

ANSWER KEY

1. (b) **2.** (b) **3.** (b) **4.** (d) **5.** (*) **6.** (a) **7.** (b) **8.** (a) **9.** (a) **10.** (a) **11.** (d) **12.** (b)
13. (d) **14.** (b) **15.** (b) **16.** (a) **17.** (a) **18.** (b) **19.** (c) **20.** (a)

Explanations

1. (b) : Without shunting condition :



On balancing

$\varepsilon_s = 52 \times k$ ...(i)

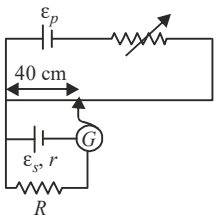
where k is potential gradient of wire.

With shunting condition :

On balancing

$$\varepsilon_s - \frac{\varepsilon_s}{(r+R)} r = 40 \times k \quad \text{...(ii)}$$

From eqns. (i) and (ii),

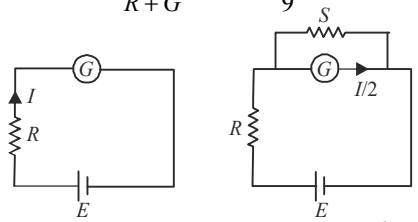


$$\frac{1}{1-\frac{r}{r+R}} = \frac{52}{40} \Rightarrow \frac{r+R}{R} = \frac{52}{40}$$

$$r = \left(\frac{52}{40} \times R\right) - R = \left(\frac{52}{40} \times 5\right) - 5$$

$\therefore \quad r = 1.5\ \Omega$

2. (b) : Initially $I = \frac{\varepsilon}{R+G} \quad \therefore \quad G = \frac{1}{9}\,\text{k}\Omega$



Finally, $\frac{I}{2} = \frac{\varepsilon}{R + \frac{GS}{G+S}} \times \frac{S}{S+G} \Rightarrow \frac{I}{2} = \frac{\varepsilon S}{R(S+G)+GS}$

$$S = \frac{RG \times \frac{I}{2}}{\varepsilon - \frac{(R+G)I}{2}} = \frac{11\times10^3 \times \frac{1}{9} \times 10^3 \times 270 \times 10^{-6}}{6 - \left(\frac{6}{2}\right)} \Rightarrow S = 110\ \Omega$$

3. (b) : Surface tension is given by

$$T = \frac{rhg}{2} \times 10^3\ \text{N m}^{-1} = \frac{Dhg}{4} \times 10^3\ \text{N m}^{-1}$$

Possible error in the surface tension is

$$\frac{\Delta T}{T} \times 100 = \frac{\Delta D}{D} \times 100 + \frac{\Delta h}{h} \times 100 + 0$$

$$= \left(\frac{0.01\times10^{-2}}{1.25\times10^{-2}} + \frac{0.01\times10^{-2}}{1.45\times10^{-2}}\right) \times 100$$

(Permissible error in D and h is the place value of the last digit.)

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

$$\frac{\Delta T}{T} \times 100 = 0.8 + 0.689 = 1.489 \approx 1.5\%$$

4. (d) : Let S be the specific heat of aluminium. By principle of calorimetry, $Q_{\text{Given}} = Q_{\text{used}}$

Heat capacity of water = 1 cal/g-° C

$$200 \times S \times (150 - 40) = 150 \times 1 \times 1 \times (40 - 27) + 25 \times 1 \times (40 - 27)$$

$$200 \times S \times 110 = 150 \times 13 + 25 \times 13$$

$$S = \frac{13\times175}{200\times110} = 0.1034\ \text{cal/g-°C} = 103.4 \times 4.2\ \text{J/kg-°C} = 434\ \text{J/kg-°C}$$

5. (*) : Time period of simple pendulum,

$$T = 2\pi\sqrt{\frac{l}{g}} \quad i.e. \quad T \propto \sqrt{l} \Rightarrow T = 6.28\sqrt{\frac{1}{9.8}} \simeq 2\ \text{s}$$

$T_1 - T_2 = \Delta T = 5 \times 10^{-4}$ s; $|r_1 - r_2| = \Delta l = ?$

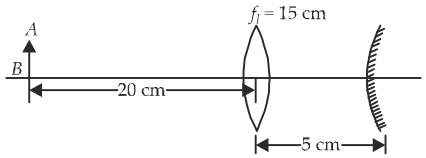
Use error analysis to find $|r_1 - r_2|$

$$\frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l} \Rightarrow \Delta l = 2 \times \frac{\Delta T}{T} \times l = 2 \times \frac{5\times10^{-4}}{2} \times 1\,\text{m}$$

$= 5 \times 10^{-2}$ cm = 0.05 cm

* None of the given options is correct.

6. (a) :



For lens, $u = -20$ cm, $f_l = 15$ cm, $v = ?$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f_l} \Rightarrow \frac{1}{v} - \frac{1}{-20} = \frac{1}{15} \Rightarrow \frac{1}{v} = \frac{1}{15} - \frac{1}{20} = \frac{1}{60};\ \therefore v = 60\ \text{cm}$$

To obtain its real image on object's place. The center of curvature of the convex mirror must be at the position of virtual image, *i.e.*, at 60 cm

According to given figure, $5 + 2f_R = 60 \Rightarrow 2f_R = 55 \Rightarrow f_R = 27.5$ cm

7. (b) : Screw gauge has negative zero error.

Least count of screw gauge

$$\text{LC} = \frac{\text{Pitch}}{\text{Number of divisions on circular scale}} = \frac{0.5\ \text{mm}}{50} = 0.01\ \text{mm}$$

Zero error = (45 – 50) × 0.01 mm = – 0.05 mm

Thickness of sheet = Main scale reading

+ (circular scale reading × LC) – zero error

= 0.5 + (25 × 0.01) – (–0.05) = 0.50 + 0.30 = 0.80 mm

8. (a) : Here, $i = 35°$, $e = 79°$, $\delta = 40°$

We know, $\delta = i + e - A \Rightarrow A = i + e - \delta$

$\therefore \quad A = 35° + 79° - 40° = 74°$

Refractive index of prism, $\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\left(\frac{A}{2}\right)}$

$$\mu = \frac{\sin\left(37° + \frac{\delta_m}{2}\right)}{\sin 37°} = \frac{5}{3}\sin\left(37° + \frac{\delta_m}{2}\right)$$

Maximum value of μ can be $\frac{5}{3}$, so required value of μ should be less than $\frac{5}{3}$.

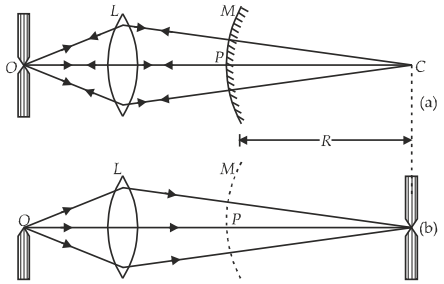
Also, δ_m will be less than 40°, so

$$\mu < \frac{5}{3}\sin\left(37° + \frac{40°}{2}\right) = \frac{5}{3}\sin 57°$$

$$\mu < \frac{5}{3}\sin 57° < \frac{5}{3}\sin 60° = 1.44 \ \therefore \ \mu < 1.44$$

So the nearest possible value of μ for the given arrangement should be 1.5.

9. (a) : The given figures shows the experimental set up to find the focal length of convex mirror using convex lens.



$\therefore$ For lens, $u_1 = -(32.2 - 22.2)$ cm $= -10$ cm

$v_1 = (71.2 - 32.2)$ cm $= 39$ cm $\therefore \quad \frac{1}{f_1} = \frac{1}{v_1} - \frac{1}{u_1} = \frac{1}{39} + \frac{1}{10} = \frac{49}{390}$

or $\quad f_1 = \frac{390}{49}$ cm ≈ 7.8 cm

$\therefore$ For mirror, $R = (71.2 - 45.8)$ cm $= 25.4$ cm

or $\quad f_2 = \frac{25.4}{2}$ cm $= 12.7$ cm.

10. (a) : Here, $L = 1$ m, $r = 5$ mm $= 5 \times 10^{-3}$ m

$F = 50\pi$ kN, L.C. of all lengths $= 0.01$ mm

$Y = ?$

$$Y = \frac{\text{Stress}}{\text{Stain}} = \frac{FL}{Al} = \frac{FL}{\pi r^2 l}$$

$$Y = \frac{50\pi \times 10^3}{\pi(5\times10^{-3})^2} \times \frac{L}{l} = 2\times10^9 \times \frac{L}{l} = \frac{2\times10^9}{l}$$

$$\frac{\Delta Y}{Y} = 2\frac{\Delta r}{r} + \frac{\Delta L}{L} + \frac{\Delta l}{l}$$

11. (d) : $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow g = \frac{4\pi^2 L}{T^2} = \frac{4\pi^2 L n^2}{t^2} \left(\because T = \frac{t}{n}\right)$

Maximum percentage error in g

$$\frac{\Delta g}{g}\times100 = \frac{\Delta L}{L}\times100 + 2\frac{\Delta t}{t}\times100$$

$$= \frac{0.1}{20.0}\times100 + 2\times\frac{1}{90}\times100 = 2.72\% \simeq 3\%$$

$\therefore$ Accuracy in the determination of g is approximately 3%

12. (b) : Least count $= 0.01$ cm

$d_1 = 0.5 + 8 \times 0.01 + 0.03 = 0.61$ cm

$d_2 = 0.5 + 4 \times 0.01 + 0.03 = 0.57$ cm

$d_3 = 0.5 + 6 \times 0.01 + 0.03 = 0.59$ cm

Mean diameter,

$$\bar{d} = \frac{d_1 + d_2 + d_3}{3} = \frac{0.61 + 0.57 + 0.59}{3} = 0.59 \text{ cm}$$

13. (d) : In a potentiometer, the null point will fluctuate due to varying current and voltage.

In the moving magnet/coil galvanometer, the dial will be unsteady due to varying current through it.

In hot wire voltmeter, the principle of heat due to current is used to measure the voltage.

$m_{\text{ms}} = \frac{s^7_{oj\ p}}{o}$ $\{\sim s^7_{oj\ p} = o m_{\text{ms}}$

$\therefore$ Hot wire voltmeter

14. (b) : 30 VSD $=$ 29 MSD

$$1 \text{ VSD} = \frac{29}{30} \text{ MSD}$$

Least count $=$ 1 MSD $-$ 1 VSD $= \left(1 - \frac{29}{30}\right)\text{MSD} = \frac{1}{30}\times0.5°$

Reading = Main scale reading + Vernier scale reading × least count

$$= 58.5° + 9 \times \frac{0.5°}{30} = 58.5° + 0.15° = 58.65°.$$

15. (b) : Least count of screw gauge

$$= \frac{\text{Pitch}}{\text{Number of divisions on circular scale}} = \frac{1}{100} \text{ mm} = 0.01 \text{ mm}$$

Diameter of wire = Main scale reading

+ circular scale reading × Least count

$= 0 + 52 \times 0.01 = 0.52$ mm $= 0.052$ cm

16. (a) : Least count $= \frac{\text{value of 1 main scale division}}{\text{The number of divisions on the vernier scale}}$

as shown below.

Here n vernier scale divisions $= (n - 1)$ M.S.D.

$$\therefore \quad 1 \text{ V.S.D.} = \frac{n-1}{n} \text{ M.S.D}$$

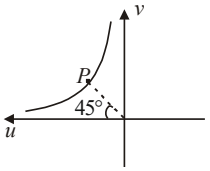
$$\text{L.C.} = 1 \text{ M.S.D.} - 1 \text{ V.S.D} = 1 \text{ M.S.D} - \frac{(n-1)}{n} \text{ M.S.D.}$$

$$\Rightarrow \quad \text{L.C.} = 0.5° - \frac{29}{30}\times0.5°$$

$$\Rightarrow \quad \text{L.C.} = \frac{0.5}{30} = \frac{1}{30}\times\frac{1}{2} = \frac{1}{60}° = 1 \text{ min.}$$

17. (a) : According to New Cartesian coordinate system used in our 12th classes, for a convex lens, as u is negative, the lens equation is

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}.$$



One has to take that u is negative again for calculation, it effectively comes to

$$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}.$$

If u = radius of curvature, $2f$, $v = 2f$ *i.e.*, $\frac{1}{2f} + \frac{1}{2f} = \frac{1}{f}$.

v and u are have the same value when the object is at the centre of curvature. The solution is (a).

According the real and virtual system, u is +ve and v is also +ve as both are real. If $u = v$, $u = 2f$ = radius of curvature.

$$\therefore \quad \frac{1}{v} + \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{2f} + \frac{1}{2f} = \frac{1}{f}.$$

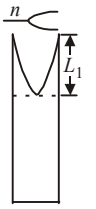
The answer is the same (a).

(The figure given is according to New Cartesian system).

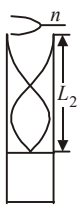
18. (b) : A travelling microscope moves horizontally on a main scale provided with a vernier scale, provided with the microscope.

19. (c) : $v_1 = \sqrt{\frac{\gamma RT}{M}}$ assuming M is the average molar mass of the air (*i.e.*, nitrogen) and γ is also for nitrogen.

$v_1 = \sqrt{\frac{\gamma RT_1}{M}}$; $v_2 = \sqrt{\frac{\gamma RT_2}{M}}$ where T_1 and T_2 stand for winter and summer temperatures.



1st resonance



2nd resonance

$$L_1 = \frac{v_1}{n} = \frac{\lambda}{4} = 18 \text{ cm at temperature } T_1.$$

At T_2, summer, $v_2 > v_1$.

$$L_2 = \frac{v_2}{n} = \frac{3\lambda}{4} > 3\times18. \quad \therefore \quad L_2 > 54 \text{ cm.}$$

20. (a) : Least count of the screw gauge $= \frac{0.5 \text{ mm}}{50} = 0.01$ mm

Main scale reading $= 3$ mm.

Vernier scale reading $= 35$

$\therefore$ Observed reading $= 3 + 0.35 = 3.35$

zero error $= -0.03$

$\therefore$ actual diameter of the wire $= 3.35 - (-0.03) = 3.38$ mm.