JEE MAIN · PAPER 1 · PHYSICS

20 Experimental Skills

Formula & concept sheet

What the practical part of JEE Main asks: reading a vernier calliper and a screw gauge (least count, zero error), estimating the error in a result, and knowing for each standard experiment what is measured, the working formula, the graph and the main source of error. Each idea is explained first, then the formulas, shortcuts and traps.

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READ ALONGSIDE NCERT Laboratory Manual · Physics XI and XII (the matching experiments)

HOW TO USE THIS SHEET

1. **Skim** — Read the Key ideas, then the formula cards.
2. **Memorise** — Learn the formulas and check every Trap box.
3. **Test** — Do the worked examples, then this chapter's PYQs.
4. **Revise** — Use the last-minute checklist before the exam.

Formula memorise · **Key idea** why it works · **Trap** marks lost here · **PYQ** how it is asked

Practise this chapter with real past-paper questions on Prep Vault. Written for revision, not as a first read.

CHAPTER 20

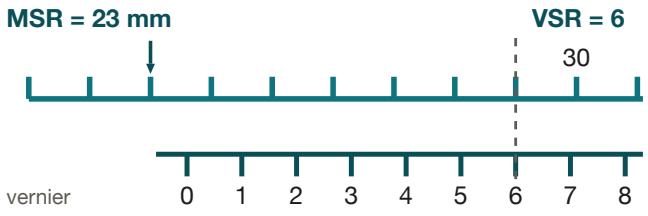
Experimental Skills

NCERT Laboratory Manual · Physics XI and XII (the matching experiments)

Covers: vernier callipers · screw gauge · least count and zero error · errors in an experiment · simple pendulum · Young's modulus · surface tension · viscosity · resonance tube · specific heat · metre bridge · half-deflection method · focal lengths · prism · refractive index by a travelling microscope · diode.

1 Vernier callipers

VERNIER PRINCIPLE A sliding scale (the vernier) whose divisions are a little shorter than those of the main scale lets you read a fraction of a main-scale division. The smallest reading it can give is the **least count**, $LC = 1\ \text{MSD} - 1\ \text{VSD}$. If N vernier divisions equal $N - 1$ main-scale divisions, $LC = \dfrac{1\ \text{MSD}}{N}$.



reading = 23 + 6 × 0.1 = 23.6 mm

least count $= 1\ \text{MSD} - 1\ \text{VSD} = 0.1$ mm, since 10 VSD $= 9$ MSD

READING IT

- **MSR**: the main-scale reading just to the left of the vernier zero.
- **VSR**: the number of the vernier division that lines up exactly with some main-scale division; only that division matters.
- Reading $= \text{MSR} + \text{VSR} \times LC$, then correct for zero error.

LEAST COUNT

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

n VSD $= m$ MSD: $LC = \left(1 - \dfrac{m}{n}\right)\text{MSD}$

THE n-TH MSD MEETS THE $(n+1)$-TH VSD

$LC = \dfrac{\text{MSD}}{n+1}$

n MSD $= (n+1)$ VSD, so 1 VSD $= \dfrac{n}{n+1}$ MSD

ZERO ERROR

$\text{true} = \text{observed} - e$

e = reading with the jaws closed: positive if the vernier zero is to the right of the main zero (subtract it), negative if to the left (add its size)

LEAST COUNTS TO RECOGNISE

SCALE	LEAST COUNT
10 VSD $=$ 9 MSD, MSD $= 1$ mm	0.1 mm $= 0.01$ cm
50 VSD $=$ 49 MSD, MSD $= 0.5$ mm (travelling microscope)	0.01 mm
50 VSD $=$ 48 MSD, MSD $= 0.05$ mm	0.002 mm
20 VSD $=$ 19 MSD, $LC = 0.1$ mm	MSD $= 2$ mm

TRAP

A **positive** zero error means the reading is too high, so subtract it; a **negative** one means too low, so add its size. Keep every quantity in the same unit (mm or cm) before applying the correction.

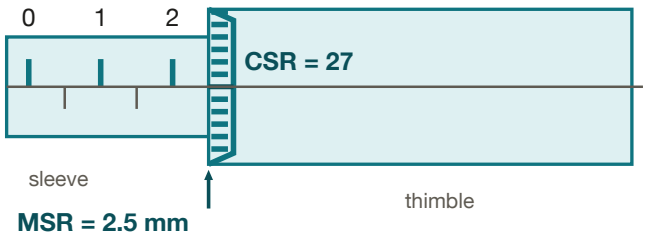
QUICK CHECK

A vernier has $LC = 0.1$ mm. It reads 15.5 mm and the zero error is $+0.4$ mm. Corrected length?

Answer: $15.5 - 0.4 = 15.1$ mm.

2 Screw gauge

reading = 2.5 + 27 × 0.01 = 2.77 mm



pitch 0.5 mm, 50 divisions: least count $= 0.5/50 = 0.01$ mm

SCREW GAUGE A screw of known **pitch** (the distance it advances in one full turn of the thimble) with a circular scale on the thimble. One circular division is $\dfrac{\text{pitch}}{\text{number of divisions}}$ of advance: that is the least count. It measures wire diameters and sheet thicknesses.

READING IT

- **MSR** (pitch-scale reading): the last mark on the linear scale uncovered by the thimble.
- **CSR**: the circular-scale division that lies on the reference line.
- Reading $= \text{MSR} + \text{CSR} \times LC$, then correct for zero error.

PITCH

$$\text{pitch} = \frac{\text{linear advance}}{\text{number of rotations}}$$

5 rotations moving 2.5 mm give a pitch of 0.5 mm

LEAST COUNT

$$LC = \frac{\text{pitch}}{\text{circular divisions}}$$

pitch 0.5 mm, 50 divisions: 0.01 mm; 100 divisions: 0.005 mm

CHANGE OF SCALE

$$LC \propto \frac{\text{pitch}}{N}$$

pitch up 75% and divisions down 50%: $LC \times \dfrac{1.75}{0.5} = 3.5$ ($0.01 \to 0.035$ mm)

ZERO ERROR FROM THE CLOSED READING

closed reading $+x$ divisions: $e = +x \times LC$

scale short of zero by x divisions: $e = -x \times LC$

true reading $=$ observed $- e$; a closed reading of, say, 95 on a 100-division scale is a **negative** error of 5 divisions

LEAST COUNT FROM RECORDED DATA

READINGS	LEAST COUNT
$1.24, 1.25, 1.23, 1.21$ mm	0.01 mm (the place value of the last digit)
3.14 cm with a vernier	0.01 cm

KEY IDEA

For the least count only **three things** matter: pitch (or the MSD), the number of divisions, and which division coincides. Everything else in a question is a twist on these.

QUICK CHECK

Pitch 0.5 mm, 50 divisions. MSR 3 mm, CSR 35, zero error -0.03 mm. Diameter?

Answer: observed $= 3 + 35 \times 0.01 = 3.35$ mm; true $= 3.35 - (-0.03) = 3.38$ mm.

3 Errors and graphs in an experiment

- The **least count** is the smallest reading an instrument can give and is taken as the absolute error of a single reading.
- For a result $Q = \dfrac{x^a y^b}{z^c}$ the **relative errors** combine, each multiplied by its power: $\dfrac{\Delta Q}{Q} = |a|\dfrac{\Delta x}{x} + |b|\dfrac{\Delta y}{y} + |c|\dfrac{\Delta z}{z}$. For sums and differences, absolute errors add.
- Many experiments are best analysed by a **graph** whose slope or intercept is the wanted quantity: choose the axes the question names.

ERROR IN g FROM A PENDULUM

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T}$$

$g = \frac{4\pi^2 L}{T^2}$; time many oscillations to make $\frac{\Delta T}{T}$ small

GRAPH METHODS

EXPERIMENT	PLOT	SLOPE OR INTERCEPT
Pendulum	T^2 against L	slope $= \frac{4\pi^2}{g}$
Lens or mirror	$\frac{1}{v}$ against $\frac{1}{u}$	intercepts $= \frac{1}{f}$
Prism	δ against i	minimum gives δ_m
Ohm's law	I against V	slope $= \frac{1}{R}$
Stokes	v_t against r^2	straight line through the origin

TRAP

Do not add errors of a product as absolute values: the **relative** errors add, and powers multiply them. In a pendulum the length is measured to the **centre of the bob** (thread plus bob radius).

QUICK CHECK

$L = 100.0$ cm with $\Delta L = 0.1$ cm; 20 oscillations take 40.0 s with $\Delta t = 0.1$ s. Percentage error in g?

Answer: $\frac{\Delta g}{g} = \frac{0.1}{100} + 2 \times \frac{0.1}{40} = 0.1\% + 0.5\% = 0.6\%$.

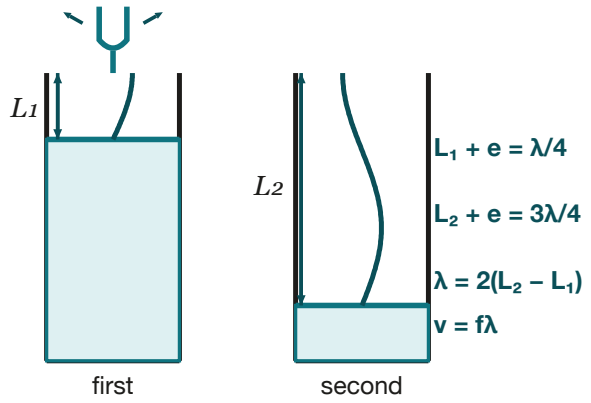
4 The experiments: what, formula, graph, error

SYLLABUS NOTE

The list of experiments below comes from a secondary source, not the NTA document. Learn the principle and working formula of each; JEE Main asks about the basic approach, observations and the main source of error.

MECHANICS, HEAT AND PROPERTIES OF MATTER

EXPERIMENT	PRINCIPLE AND FORMULA	MAIN CARE OR ERROR
Simple pendulum	$T = 2\pi\sqrt{L/g}$, small amplitude; damping: a plot of (amplitude)^2 against time is an exponential decay	length to the bob centre; time 20 oscillations
Mass by moments (metre scale)	$m\,x = M\,y$, so $m = M\frac{y}{x}$, where x and y are the measured distances of m and M from the pivot	pivot at the balance point of the empty scale
Young's modulus (Searle)	$Y = \frac{MgL}{\pi r^2\,\Delta l}$	radius from a screw gauge; stay within the elastic limit
Surface tension (capillary rise)	$h = \frac{2T\cos\theta}{r\rho g}$, $h \propto \frac{1}{r}$	clean tube; detergent lowers T
Viscosity (Stokes)	$v_t = \frac{2r^2(\rho - \sigma)g}{9\eta}$	use the radius; sphere must reach terminal speed
Specific heat (mixtures)	$m_1c_1(T_1 - T) = (m_2c_2 + m_cc_c)(T - T_2)$	include the calorimeter; stir; heat loss



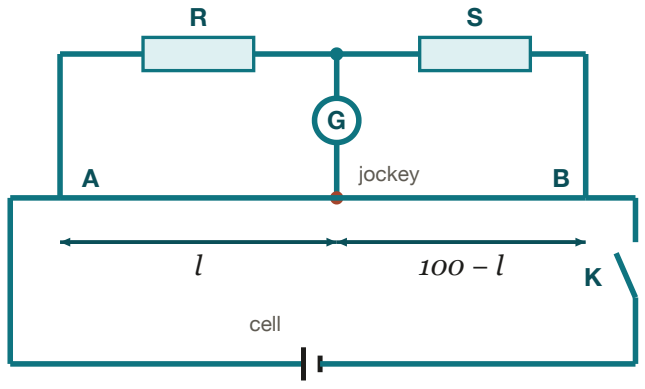
two resonance lengths cancel the end correction e: $\lambda = 2(L_2 - L_1)$

SPEED OF SOUND: RESONANCE TUBE

- A tuning fork of frequency f over an air column that is lengthened by raising the water level. Resonance (a loud note) first at $l_1 + e = \dfrac{\lambda}{4}$, again at $l_2 + e = \dfrac{3\lambda}{4}$.
- Subtract to remove the end correction e: $\lambda = 2(l_2 - l_1)$, $v = f\lambda$, and $e = \dfrac{l_2 - 3l_1}{2} \approx 0.3\,d$.

ELECTRICITY, OPTICS AND MODERN PHYSICS

EXPERIMENT	PRINCIPLE AND FORMULA	MAIN CARE OR ERROR
Resistivity (metre bridge)	$X = \dfrac{R(100 - l)}{l}$ (R in the left gap), $\rho = \dfrac{X\pi r^2}{L}$	interchange R and X to cancel end errors
Ohm's law	$R = V/I$; slope of the I-V line is $1/R$	wire heating changes R; small currents
Galvanometer by half deflection	$G = \dfrac{RS}{R - S} \approx S$ for $R \gg S$; figure of merit $k = \dfrac{E}{(R + G)\theta}$	keep R unchanged after the shunt is on
Focal length: concave mirror	$u = v = 2f$ (object at the centre of curvature)	parallax removed by moving the eye
Focal length: convex lens	$\dfrac{1}{f} = \dfrac{1}{v} - \dfrac{1}{u}$; $f = \dfrac{uv}{u + v}$ in magnitudes	graph of $\dfrac{1}{v}$ against $\dfrac{1}{u}$
Prism	$\mu = \dfrac{\sin\frac{A + \delta_m}{2}}{\sin\frac{A}{2}}$ from the least deviation	read δ_m at the flat of the i-δ curve
Refractive index (travelling microscope)	$\mu = \dfrac{\text{real depth}}{\text{apparent depth}} = \dfrac{R_3 - R_1}{R_3 - R_2}$	R_1 mark, R_2 mark through the slab, R_3 top surface
Diode characteristics	dynamic resistance $r = \dfrac{\Delta V}{\Delta I}$ on the forward curve	reverse current is very small
Identifying components (multimeter)	resistor: same both ways; diode: one way only; LED: one way and glows; capacitor: deflects then settles	check polarity before connecting



balance: $\dfrac{R}{S} = \dfrac{l}{100 - l}$, with l the jockey length from A and $100 - l$ the length from B

METRE BRIDGE: THE DETAILS THAT ARE ASKED

- Balance point l measured from the end where the **known** resistance R sits: $\dfrac{R}{X} = \dfrac{l}{100 - l}$.
- Interchanging R and X and averaging cancels the error from the copper strips at the ends; with end corrections α, β use $l + \alpha$ and $100 - l + \beta$.
- Aim for l near 50 cm: that is where the percentage error in X is smallest.

5 Worked examples

VERNIER READING

1 MSD $=$ 1 mm, 10 VSD $=$ 9 MSD. MSR 52 mm, the 6th VSD coincides, zero error $+0.02$ mm. Length?

$LC = 0.1$ mm; observed $52 + 6 \times 0.1 = 52.6$ mm; true $52.6 - 0.02 = 52.58$ mm

TRAVELLING MICROSCOPE

50 VSD $=$ 49 MSD and one MSD is 0.5 mm. The least count?

$$LC = \frac{0.5}{50} = 0.01 \text{ mm}$$

SCREW GAUGE: FIVE TURNS

The thimble moves 2.5 mm in 5 rotations and has 100 divisions. Least count?

pitch $= \dfrac{2.5}{5} = 0.5$ mm; $LC = \dfrac{0.5}{100} = 0.005$ mm

CHANGED PITCH

A screw gauge has $LC = 0.01$ mm. Pitch is raised by 75% and the divisions cut by 50%. New least count?

$$0.01 \times \frac{1.75}{0.5} = 0.035 \text{ mm} = 35 \times 10^{-3} \text{ mm}$$

RESONANCE TUBE

$f = 512$ Hz; resonances at $l_1 = 16.0$ cm and $l_2 = 50.0$ cm. Speed of sound and end correction?

$\lambda = 2(l_2 - l_1) = 68$ cm; $v = f\lambda = 512 \times 0.68 \approx 348$ m/s; $e = \dfrac{l_2 - 3l_1}{2} = 1.0$ cm

HALF DEFLECTION

With $R = 2970\ \Omega$ the galvanometer deflects fully; a shunt $S = 30\ \Omega$ halves the deflection. Resistance G?

$$G = \frac{RS}{R - S} = \frac{2970 \times 30}{2940} \approx 30.3\ \Omega$$

METRE BRIDGE

$R = 10\ \Omega$ in the left gap, balance at $l = 40$ cm. Unknown X?

$$X = \frac{R(100 - l)}{l} = \frac{10 \times 60}{40} = 15\ \Omega$$

REFRACTIVE INDEX

Microscope readings: mark alone $R_1 = 2.000$ cm; through the slab $R_2 = 2.400$ cm; top surface $R_3 = 3.200$ cm. μ?

$$\mu = \frac{R_3 - R_1}{R_3 - R_2} = \frac{1.200}{0.800} = 1.5$$

6 Last-minute checklist

BEFORE YOU ANSWER

Which instrument and which coinciding division? Are all readings in the same unit? Is the zero error positive or negative, and did you subtract it with its sign? For errors: relative errors, powers as multipliers.

- Vernier $LC = 1\ \text{MSD} - 1\ \text{VSD}$; n MSD $= (n+1)$ VSD gives $\text{MSD}/(n+1)$; reading $= \text{MSR} + \text{VSR} \times LC - e$.
- Screw gauge $LC = \text{pitch}/N$; pitch $=$ advance per rotation; reading $= \text{MSR} + \text{CSR} \times LC - e$.
- Least count from data: the place value of the last recorded digit.
- Errors: relative errors add, multiplied by powers; $\Delta g/g = \Delta L/L + 2\Delta T/T$.
- Resonance tube $v = 2f(l_2 - l_1)$, $e = (l_2 - 3l_1)/2$; metre bridge $X = R(100 - l)/l$; half deflection $G = RS/(R - S)$.
- Pendulum: T^2 against L, length to the centre of the bob; prism δ_m from the flat of the curve; $\mu = \text{real}/\text{apparent depth}$.

Now test it. Practise this chapter with past-paper and bank questions on Prep Vault. **Practice this chapter →**