Paper 3 marks you on doing an experiment; Paper 5 marks you on designing one and on handling data you never collected. Neither rewards knowing physics on its own – they reward a small set of habits, and those habits are what this handbook lists. 实验卷考的是操作与数据处理的规范，不是物理知识本身。

Measuring instruments and their precision

Always state the instrument AND the smallest division you can read. The uncertainty in a single reading is normally half a division; in a difference of two readings it is one division, because you read the scale twice.

Metre rule 米尺 — smallest division 1 mm, so a single reading is ±0.5 mm and a length (two readings) is ±1 mm

Vernier calipers 游标卡尺 — reads to 0.1 mm or 0.02 mm; close the jaws first and record any zero error, then subtract it from every reading

Micrometer screw gauge 螺旋测微器 — reads to 0.01 mm; use the ratchet so the pressure is the same each time, and check the zero error before you start

Stopwatch 秒表 — reads to 0.01 s but human reaction time makes a single timing ±0.2 s or worse – time 10 or 20 oscillations and divide

Digital multimeter 数字万用表 — the uncertainty is the last digit displayed; put the ammeter in series and the voltmeter in parallel, and check you are on the right range before connecting

For anything that oscillates, time N oscillations and divide by N. This does not reduce your reaction-time uncertainty; it divides it by N, which is the whole point.

Take readings across the widest range the apparatus allows, and at least six of them. Six points spread over the range beat twelve bunched together, because a graph is only as good as its span.

Recording and processing data

Every column heading needs the quantity AND the unit, written as a ratio: t / s, V / V, 1/d / m^{-1}. This is a mark on nearly every paper and is the one most often thrown away.

Every raw reading in a column has the SAME number of decimal places, set by the instrument – 0.50, 1.00, 1.25, never 0.5, 1, 1.25.

A calculated column carries the significant figures of the least precise measurement that fed it, or one more. Copying a calculator's ten digits loses the mark.

Absolute uncertainty 绝对不确定度 — the ± value in the same unit as the quantity; it ADDS when quantities are added or subtracted

Percentage uncertainty 百分不确定度 — absolute ÷ value × 100%; it ADDS when quantities are multiplied or divided, and multiplies by the power when a quantity is raised to a power

So for $g = 4\pi^2 L/T^2$ the percentage uncertainty is that of L plus TWICE that of T. Time is squared, so timing is where the accuracy of the experiment is won or lost.

To linearise, take logs or reciprocals until the relationship is $y = mx + c$. If you expect $T = kL^n$, plot $\lg T$ against $\lg L$: the gradient is n and the intercept is $\lg k$.

Graphs – where the marks are

Choose a scale so the plotted points fill more than half the grid in BOTH directions. An awkward scale (3 squares per unit) costs a mark and causes plotting errors; use 1, 2 or 5 per two centimetres.

Label both axes with quantity and unit, exactly as in the table.

Plot points as small crosses, accurate to half a small square. Blobs are not credited.

Draw ONE thin straight best-fit line with a transparent ruler, with a balanced scatter above and below. Do not join the points, and do not force the line through the origin unless the physics requires it.

Error bars run from value minus uncertainty to value plus uncertainty, with end caps.

For the gradient, use a triangle spanning at least half the drawn line, mark it on the graph, and show the coordinates of both corners. A gradient with no visible triangle is not credited even when the number is right.

Worst-acceptable line: draw the steepest and shallowest lines that still pass through all the error bars. The uncertainty in the gradient is |best gradient − worst gradient|.

Read the intercept from the graph only when the y-axis starts at zero. If it does not, substitute a point from the LINE (not a data point) into y = mx + c.

Paper 3 – doing the experiment

Set the apparatus up exactly as the diagram shows, and if the question says to draw what you built, draw it with labels.

Record the FIRST reading before you change anything – the zero or starting value is often a mark.

Work quickly and write down every reading as you take it. A blank table is worth nothing; a table with an anomaly in it is worth almost everything.

State the value of a quantity to the precision the instrument gives, then repeat and take a mean.

For the conclusion, compare your calculated value with the expected one using the criterion the question gives (often 'within 10%'), and say explicitly whether the hypothesis is supported.

Improvements must be specific and about THIS experiment: 'use a set square to check the rule is vertical', not 'be more careful'. Two improvements are usually asked for and generic answers score zero.

Paper 5 – planning and analysis

Name the independent variable, the dependent variable, and at least two variables you would control. State how you would control each – 'keep the temperature constant using a water bath', not 'keep the temperature the same'.

Draw a labelled diagram of the arrangement. It must be workable: things must be supported, circuits must be complete, and the quantity you claim to measure must actually be measurable with what you have drawn.

Say what you will measure with what instrument, and how you will process the readings into the quantity you want.

State the relationship you expect and the graph that would test it, with the axes named: 'plot $\ln A$ against t; a straight line of negative gradient supports exponential decay'.

Give one relevant safety precaution with a reason: 'wear eye protection because the wire may snap under tension'.

In the analysis question, the marks are almost entirely in the table (calculated column with correct significant figures and uncertainties), the graph, the gradient, and the final quantity WITH its uncertainty. Work through them in that order.

Express the final answer as value ± uncertainty with a unit, rounded so the uncertainty has one significant figure and the value matches its decimal place.

The errors examiners keep reporting

Confusing precision with accuracy: a precise instrument used with a systematic error gives tightly clustered wrong answers. Repeating readings reduces random error only.

Calling a zero error random. A zero error is systematic – every reading is wrong by the same amount and repeating cannot help; you must subtract it.

Writing 'human error' or 'parallax' with no explanation. Say what the error does to the reading and how you would remove it.

Reporting a mean to more figures than the readings that made it.

Drawing a curve through points that scatter about a straight line – or a straight line through points that clearly curve. Let the data decide.

Forgetting to convert to SI before substituting. Centimetres and grams in a formula expecting metres and kilograms is the commonest way to lose a whole final answer.