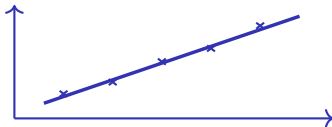


Paper 3: Practical Physics

AS Physics ■ Measurement, analysis and evaluation

A-Level Physics



Practical skills and worked examples

- 1 Measure: endpoints, scales, timing and circuits.
- 2 Record: useful ranges, complete tables and uncertainties.
- 3 Analyse: graphs, gradients, intercepts and constants.
- 4 Work through a complete spring practical.
- 5 Test the supplied model, including an unfamiliar formula.
- 6 Evaluate the actual experiment and check your work.

Keep the companion handbook beside you. The slides follow its examples and add pauses for classroom practice.



What Paper 3 asks you to do

Two questions

Two hours; 40 marks in total. Each question carries 20 marks.

Usually no more than one hour with each question's apparatus.

Follow the actual paper: the number of readings, permitted methods and comparison allowance can change.

Question 1

Usually a range of measurements, a graph and constants from its line.

Question 2

Usually measurements, uncertainty, a relationship test and evaluation; it can also contain a graph.

A workable hour with each apparatus

Time / min	Task
5	Read, identify quantities and check the setup.
25	Take and record all required readings.
25	Process, graph, calculate and evaluate.
5	Check units, missing entries and conclusions.

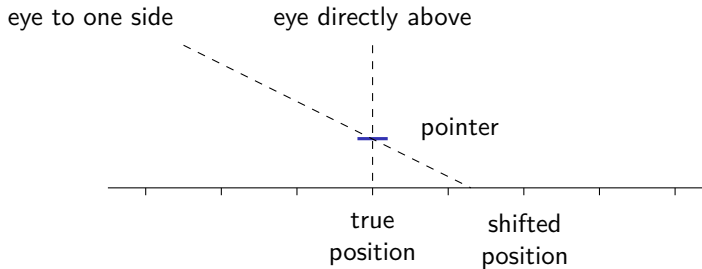
This is a planning guide. Start processing while the apparatus is still available so you can check a doubtful reading.

Read the instructions before touching the setup

- Identify the **independent variable** , the quantity you measure, and what must stay fixed.
- Underline the defined endpoints, number of readings and supplied model.
- Take a trial reading to check the range and whether the motion is clear.
- Record each reading immediately; do not rely on memory.
- Use the stated safety precautions. Ask the supervisor when necessary; assistance is recorded.

You may be given unfamiliar theory. Use the model as instructed; you do not need to invent its derivation.

Parallax: place the eye in front of the mark



Keep the ruler parallel to the measured distance and close to the pointer. Read along a line perpendicular to the scale.

Measure between the defined endpoints

Length from two readings

$$l = r_2 - r_1 = 13.7 - 1.0 = 12.7 \text{ cm}$$

The physical end of a ruler may not be its zero mark. Keep both readings.

Length is not always extension

$$x = L - L_0$$

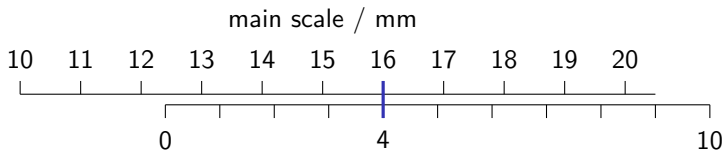
Measure the requested spring endpoints. A coil length, total spring length and extension are different quantities.

For a vertical height, use a vertical ruler and a set square. A sloping path is longer than its vertical height.

Centres, curved edges and repeat readings

- Trap a sphere gently between parallel blocks to measure its diameter.
- Locate a hidden centre from its two edges: $c = (r_{\text{left}} + r_{\text{right}})/2$.
- For equal objects, matching edges can give the separation of centres.
- Repeat the measurement with the required setup held fixed. A changed sample or setting is a new trial.
- A distorted paper cylinder changes its shape: this is not just a scale-reading error.

Read the vernier, then add the two parts

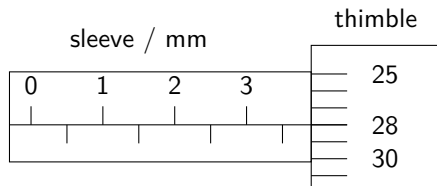


Ten vernier intervals equal nine 1 mm main-scale intervals: resolution $s = 0.1$ mm.

$$d = M + ns = 12 + 4(0.1) = 12.4 \text{ mm}$$

Read the main scale just before the vernier zero. Use the resolution of the actual instrument.

Include the micrometer half-millimetre mark



$$d = S + ns = 3.5 + 28(0.01) = 3.78 \text{ mm}$$

Use the ratchet for gentle, repeatable contact. Digital calipers: check zero, select the unit and record all displayed places.

Zero error has a sign

Check clean, closed jaws before measuring.

$$d_{\text{corrected}} = d_{\text{observed}} - e$$

Observed	Zero error e	Corrected
3.78 mm	+0.03 mm	3.75 mm
3.78 mm	-0.02 mm	3.80 mm

Subtract a positive zero error; subtracting a negative error increases the corrected reading.

Try it: correct the thickness

A micrometer reading

Observed thickness: 2.46 mm.

Zero error: -0.02 mm.

Find the corrected thickness. Write the signed correction before substituting.

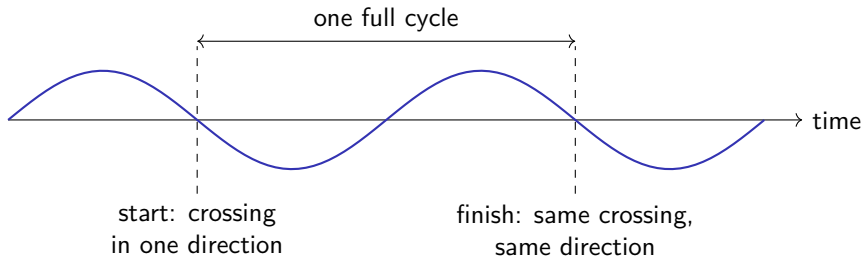
Thickness: the signed correction

$$d_{\text{corrected}} = d_{\text{observed}} - e$$

$$d_{\text{corrected}} = d_{\text{observed}} - e = 2.46 - (-0.02) = 2.48 \text{ mm}$$

The closed instrument reads below zero, so the observed reading underestimates the thickness.

One oscillation returns in the same direction



Use a fixed marker. Start at count 0, then count complete cycles. Release without a push and keep the intended mode and amplitude.

Time several cycles to reduce percentage uncertainty

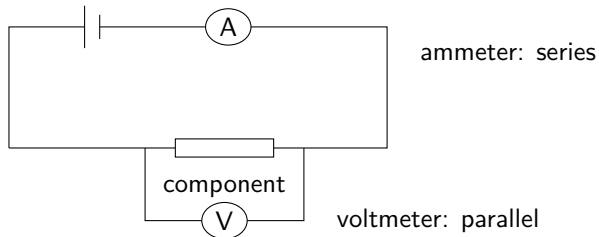
Time N cycles, repeat, then find the period.

$$\bar{t} = \frac{t_1 + t_2}{2} = \frac{24.36 + 24.52}{2} = 24.44 \text{ s}$$

$$T = \frac{\bar{t}}{N} = \frac{24.44}{20} = 1.222 \text{ s}$$

Use 10 or 20 cycles when motion stays clear and the instructions allow it. If repeats use different N , calculate each period before averaging.

Connect meters to measure the intended quantities



Select d.c., the correct sockets and a safe high range. Switch off before rewiring. Never connect an ammeter directly across a cell.

Keep circuit readings comparable

- Zero reading? Check switch, supply, socket, range and connections in order.
- A negative reading may mean reversed leads; do not change the circuit to manufacture an expected value.
- For resistance, keep heating small: use low current and switch off between readings when allowed.
- Wire length is between electrical contacts; measure diameter at several positions, excluding insulation.
- A rheostat uses a slider and an end terminal. For an LDR, keep ambient light, direction and shading fixed.

Other instruments: use the correct reference

Instrument	What to check
Balance	Tare; include hanger, attachments and adhesive if they are part of the moving mass.
Newton meter	Zero in the working orientation; force is in newtons.
Protractor	Correct centre, baseline and choice of scale.
Thermometer	Bulb in the liquid; wait; stir if allowed; avoid the vessel wall.
Measuring cylinder	Eye level; read the bottom of a water meniscus.

An analogue reading depends on the selected range

An instrument has a 0–10 scale and is set to a 0.50 A range. The pointer reads 6.

$$I = \frac{s}{s_{\max}} I_{\text{range}} = \frac{6}{10}(0.50) = 0.30 \text{ A}$$

Record the selected range. On a mirrored scale, align the pointer with its reflection to reduce parallax.

Safety during the practical

- Use low-voltage supplies as directed; keep water away from electrical equipment.
- Support masses over the bench, where a falling mass can be contained.
- Handle hot water carefully and keep the apparatus stable.
- Keep clear of stretched wires and moving objects.

Follow the paper's safety instructions and ask the supervisor if the apparatus is unsafe or faulty.



Plan a table before taking readings

- Use the number of settings asked for: five and six both occur in recent papers.
- Spread readings across the usable range; do not cluster them.
- Include raw readings, repeats, means and calculated quantities.
- Put the symbol and unit in every heading; keep units out of the data cells.
- If a sample changes during the experiment, use fresh comparable samples when needed.

A table that preserves the original readings

All timings below are for 20 cycles.

l/cm	t_1/s	t_2/s	$\bar{t}/\text{s}$	T/s	T^2/s^2
30.0	21.92	22.04	21.98	1.099	1.208
40.0	25.34	25.42	25.38	1.269	1.610
50.0	28.36	28.44	28.40	1.420	2.016

$$T = \frac{t_1 + t_2}{2N} = \frac{21.92 + 22.04}{2(20)} = 1.099 \text{ s}$$

Trailing zeros matter: 30.0 cm and 28.40 s record the precision of the original reading.

Raw precision and calculated precision

Readings

Use consistent decimal places appropriate to the instrument: e.g. all ruler readings to 0.1 cm.

A sum or difference follows the decimal-place precision of its inputs.

Calculated quantities

Usually use the same significant figures as the least precise input used, or one more.

Keep extra digits in the calculator until the final answer.

For $R = V/I$, a 3 s.f. voltage and 2 s.f. current normally justify 2 or 3 s.f. in R .
Follow any explicit paper instruction.

Absolute and percentage uncertainty

Absolute uncertainty has the same unit as the reading.

Percentage uncertainty compares it with the size of that reading.

$$u_x = \frac{\Delta x}{|x|} \times 100\%$$

For $h = 3.2 \text{ cm}$ and $\Delta h = 2 \text{ mm} = 0.2 \text{ cm}$:

$$u_h = \frac{\Delta h}{|h|} \times 100\% = \frac{0.2}{3.2} \times 100\% = 6.25\% \approx 6.3\%$$

Convert the uncertainty and the reading to the same unit before dividing.

Estimate uncertainty from the measurement method

- Clear analogue reading: half a smallest division may be a starting estimate.
- Digital instrument: one last displayed digit may be a starting estimate unless specifications say otherwise.
- Blurred endpoints, moving pointers and reaction time can make the uncertainty larger.
- A stopwatch displaying 0.01 s does not give a hand-timed event an uncertainty of only 0.01 s.
- Identical repeat readings do not establish zero uncertainty.

Repeated readings show scatter

Repeated lengths: 12.4, 12.6, 12.5 cm.

$$\bar{l} = \frac{l_1 + l_2 + l_3}{3} = \frac{12.4 + 12.6 + 12.5}{3} = 12.5 \text{ cm}$$

$$\Delta l = \frac{l_{\max} - l_{\min}}{2} = \frac{12.6 - 12.4}{2} = 0.1 \text{ cm}$$

Half the range is an estimate of scatter. Consider the instrument and the method as well, especially if all repeats are identical.

Propagate uncertainty through the calculation

Calculation	Rule	Example form
Sum or difference	Add absolute uncertainties	$\Delta(a - b) = \Delta a + \Delta b$
Product or quotient	Add percentage uncertainties	$u_{ab} = u_a + u_b$
Power	Multiply percentage by $ n $	$u_{x^n} = n u_x$

Exact counts and exact constants add no uncertainty. For $T = t/N$ with an exact cycle count, $\Delta T = \Delta t/N$.

Timing uncertainty belongs to the total interval

Suppose $t = 24.44 \text{ s}$ for $N = 20$ cycles and the estimated total timing uncertainty is $\Delta t = 0.20 \text{ s}$.

$$T = \frac{t}{N} = \frac{24.44}{20} = 1.222 \text{ s}$$

$$\Delta T = \frac{\Delta t}{N} = \frac{0.20}{20} = 0.010 \text{ s}$$

$$u_T = \frac{\Delta T}{T} \times 100\% = \frac{0.010}{1.222} \times 100\% \approx 0.82\%$$

The example assumes an uncertainty for the whole start-to-stop interval. If you estimate start and stop separately, combine them first.

A small extension can have a large uncertainty

Two ruler readings each have uncertainty 0.1 cm.

$$x = L - L_0 = 24.6 - 22.3 = 2.3 \text{ cm}$$

$$\Delta x = \Delta L + \Delta L_0 = 0.1 + 0.1 = 0.2 \text{ cm}$$

$$u_x = \frac{\Delta x}{|x|} \times 100\% = \frac{0.2}{2.3} \times 100\% = 8.7\%$$

The uncertainty is attached to both endpoint readings, even though the extension is their difference.

Try it: difference and repeated timing

- 1 A length is found from $18.4 - 16.7$ cm. Each endpoint has uncertainty 0.1 cm. Find the length and its percentage uncertainty.
- 2 Two timings of 15 cycles are 18.30 s and 18.42 s. Find the mean period.

Answers: preserve the measured precision

Endpoint difference

$$l = r_2 - r_1 = 18.4 - 16.7 = 1.7 \text{ cm}$$

$$\Delta l = \Delta r_1 + \Delta r_2 = 0.2 \text{ cm}$$

$$u_l = \frac{\Delta l}{l} \times 100\% = \frac{0.2}{1.7} \times 100\% \approx 12\%$$

Mean period

$$T = \frac{t_1 + t_2}{2N}$$

$$T = \frac{t_1 + t_2}{2N} = \frac{18.30 + 18.42}{2(15)} = 1.224 \text{ s}$$

The count is 15 full cycles, not 15 half-cycles.

Repeats reduce random scatter, not a fixed bias

Random effects

Reaction-time variation; a pointer read slightly differently each time.

Repeat and average to reduce their effect.

Systematic effects

An uncorrected zero error; a ruler consistently tilted away from vertical.

Correct the method or instrument.
Repeating the same biased method preserves the bias.



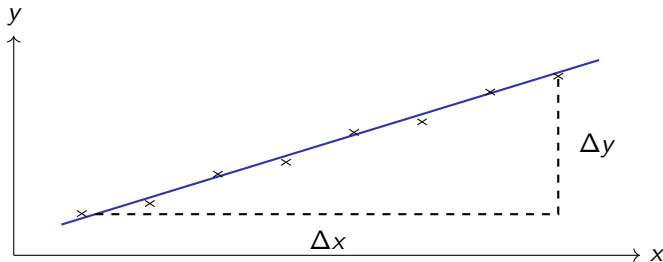
Choose the axes and scale before plotting

- For “y against x”, put y vertically and x horizontally.
- Use the requested transformed quantity: T^2 , $1/x$, $\sqrt{T}$ or a ratio.
- Label symbols and units. For $\sqrt{T}$, the unit is $\text{s}^{1/2}$.
- Choose simple scales based on 1, 2 or 5 times powers of ten; mark labels at intervals no larger than 2 cm.
- Make the points cover at least half the grid in both directions. A clearly labelled false origin can help.

Draw a line supported by the observations

- Use fine crosses or dots smaller than about 1 mm. Plot to better than 1 mm.
- Plot every observation; draw one thin, balanced best-fit line.
- Do not join successive points. Do not force the line through zero.
- Investigate an anomalous point while apparatus is available; preserve the original reading and clearly identify any exclusion.
- If excluding one of six points, retain at least five. Follow the question if it asks for a curve or tangent.

A gradient belongs to the fitted line



$G = \Delta y / \Delta x$. Use two widely separated points on the fitted line and a triangle spanning more than half its length; they need not be measured points.

Match the supplied model to the line equation

$$y = Gx + C$$

Model and plotted axes	Gradient	Intercept
$L = aZ + b$: L against Z	a	b
$T^2 = Am + B$: T^2 against m	A	B
$T/T_0 = Ph + Q$: T/T_0 against h	P	Q
$V = E - rl$: V against l	$-r$	E

Identify the coefficient of the horizontal-axis quantity, including its sign. Derive units from the plotted axes.

Use a line point to calculate the intercept

For $L = aZ + b$, fitted-line points are (1.20, 4.10 cm) and (2.00, 6.50 cm); Z is dimensionless.

$$a = \frac{L_2 - L_1}{Z_2 - Z_1} = \frac{6.50 - 4.10}{2.00 - 1.20} = 3.00 \text{ cm}$$

$$b = L - aZ = 4.10 - 3.00(1.20) = 0.50 \text{ cm}$$

The intercept means the value at the true $x = 0$. The left edge of a graph with a false horizontal origin is not automatically the intercept.

Convert a gradient using its axis units

For $V = E - rI$, suppose the fitted gradient is -0.020 V/mA .

$$G_{\text{SI}} = G_{\text{plotted}} \times 1000 \frac{\text{mA}}{\text{A}} = -0.020 \times 1000 = -20 \text{ V/A}$$

$$r = -G_{\text{SI}} = -(-20) = 20 \Omega$$

Both the negative sign and the milliampere conversion matter. A straight line shows direct proportionality only when its intercept is consistent with zero.

Try it: a dimensionless vertical axis

The model is

$$\frac{T}{T_0} = Ph + Q.$$

Two points on the fitted line are (2.00 cm, 1.120) and (8.00 cm, 1.480).

- 1 Find P , including its unit.
- 2 Calculate Q .

Ratio graph: gradient and intercept

Let $y = T/T_0$, the dimensionless vertical-axis quantity.

$$P = \frac{y_2 - y_1}{h_2 - h_1} = \frac{1.480 - 1.120}{8.00 - 2.00} = 0.0600 \text{ cm}^{-1}$$

$$Q = \frac{T}{T_0} - Ph = 1.120 - 0.0600(2.00) = 1.000$$

T/T_0 and Q have no unit. The gradient has reciprocal-length units because the horizontal axis is a length.



Spring practical: start with the supplied model

$$T^2 = \frac{4\pi^2}{k}m + B$$

m : total moving mass.

k : spring constant in N/m.

B : intercept in s^2 .

Measurements

Balance readings to 0.1 g.

Two timings of 20 full cycles at each of six masses, to 0.01 s.

Release gently; keep the same oscillation mode and avoid excessive amplitude.

Plot T^2 against m . The gradient represents $4\pi^2/k$, so k is inversely proportional to the gradient.

Spring data: six settings, with genuine repeats

m/g	t_1/s	t_2/s	T/s	T^2/s^2
50.0	11.08	11.16	0.5560	0.3091
100.0	13.98	14.06	0.7010	0.4914
150.0	16.84	16.96	0.8450	0.7140
200.0	18.74	18.86	0.9400	0.8836
250.0	21.04	21.16	1.0550	1.1130
300.0	22.68	22.76	1.1360	1.2905

Include the hanger and any attachments in the total moving mass. Each time is for 20 cycles. These are original teaching data.

Process one spring row before doing all six

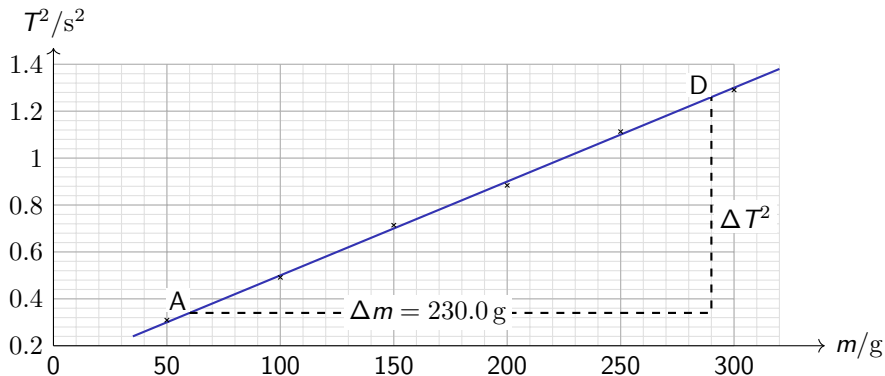
$$T = \frac{t_1 + t_2}{2N} = \frac{11.08 + 11.16}{2(20)} = 0.5560 \text{ s}$$

$$T^2 = \left(\frac{t_1 + t_2}{2N} \right)^2 = \left(\frac{11.08 + 11.16}{2(20)} \right)^2 = 0.309136 \text{ s}^2$$

$$T^2 \approx 0.3091 \text{ s}^2$$

Keep calculator precision through the square. Check one complete row before repeating the calculation.

Spring graph: a useful scale and a large triangle



All six points; balanced fitted line; axes begin at (0, 0.20). Triangle corners A and D are on the line.

Spring gradient: grams must become kilograms

From the line: A (60.0 g, 0.340 s²); D (290.0 g, 1.260 s²).

$$G = \frac{T_D^2 - T_A^2}{m_D - m_A} = \frac{1.260 - 0.340}{290.0 - 60.0} = 0.00400 \text{ s}^2/\text{g}$$

$$G_{\text{SI}} = G \times 1000 \frac{\text{g}}{\text{kg}} = 0.00400 \times 1000 = 4.00 \text{ s}^2/\text{kg}$$

The triangle spans 230 g. Use the gradient in s²/kg when the formula expects mass in kilograms.

Recover the spring constant and intercept

$$G_{\text{SI}} = \frac{4\pi^2}{k} \quad \Rightarrow \quad k = \frac{4\pi^2}{G_{\text{SI}}} = \frac{4\pi^2}{4.00} = 9.87 \text{ N/m}$$

$$B = T_A^2 - Gm_A = 0.340 - 0.00400(60.0) = 0.100 \text{ s}^2$$

For B , use matching graph units: grams with s^2/g . The bottom of the plotted grid is 0.20, which is not the intercept.

Use the line to predict a new period

For $m = 175 \text{ g}$, inside the measured range:

$$T = \sqrt{Gm + B} = \sqrt{0.00400(175) + 0.100} = 0.894 \text{ s}$$

$$t = NT = 20(0.894) \approx 17.9 \text{ s}$$

The nonzero intercept means T^2 is not directly proportional to m . A prediction at 500 g would extrapolate beyond the measured range and needs caution.



Calculate a constant separately from each trial

For the supplied model $t^2 = kx$, rearrange:

$$k = \frac{t^2}{x}$$

$$k_1 = \frac{t_1^2}{x_1} = \frac{0.640^2}{0.200} = 2.048 \text{ s}^2/\text{m}$$

$$k_2 = \frac{t_2^2}{x_2} = \frac{0.890^2}{0.400} = 1.98025 \text{ s}^2/\text{m}$$

Use each trial's own readings. With these 3 s.f. inputs, 3 or 4 s.f. in k is appropriate; retain extra digits for the comparison.

State how you calculate percentage difference

A symmetric convention uses the mean magnitude as the reference:

$$D = \frac{|k_1 - k_2|}{(|k_1| + |k_2|)/2} \times 100\%$$

$$k_{\text{ref}} = \frac{|k_1| + |k_2|}{2} = \frac{2.048 + 1.98025}{2} = 2.014125$$

$$D = \frac{|k_1 - k_2|}{k_{\text{ref}}} \times 100\% = \frac{|2.048 - 1.98025|}{2.014125} \times 100\% = 3.36\%$$

If the question gives a denominator, use it. Otherwise state your convention and apply it consistently.

Compare with the allowance the paper gives

A conclusion using evidence

The constants differ by 3.36%, which is below the stated 10% allowance. The results therefore support the relationship within this allowance.

Some papers specify 10%, 20% or 30%; there is no universal tolerance.

Do not claim the model is proved. Do not double a stated allowance or replace it with an unrelated uncertainty calculated earlier.

Try it: how strong is the agreement?

Two constants, in the same unit, are 0.420 and 0.455.

- 1 Find the percentage difference using the mean as reference.
- 2 Do the results support the model within a 10% allowance?
- 3 Would the conclusion change for a 5% allowance?

Agreement depends on the stated tolerance

$$D = \frac{|k_1 - k_2|}{(|k_1| + |k_2|)/2} \times 100\% = \frac{|0.420 - 0.455|}{(0.420 + 0.455)/2} \times 100\% = 8.0\%$$

Allowance	Conclusion
10%	Supports the model within this allowance.
5%	Does not support the model within this allowance.

Unfamiliar model: protect the brackets

9702/34, November 2025: supplied rolling model

$$t^2 h = k \left(5 + \frac{2}{1 - (x/d)^2} \right)$$

Break the calculation into intermediate quantities:

$$q = 1 - (x/d)^2, \quad F = 5 + \frac{2}{q}, \quad k = \frac{t^2 h}{F}.$$

The ratio x/d requires the same unit for both lengths. Use the question's definitions; keep h in metres when reporting k in m s^2 .

Rolling model: first trial

Given $x = 1.60 \text{ cm}$, $d = 2.00 \text{ cm}$, $h = 0.032 \text{ m}$ and $t = 5.20 \text{ s}$:

$$q_1 = 1 - (x/d_1)^2 = 1 - (1.60/2.00)^2 = 0.360$$

$$F_1 = 5 + \frac{2}{q_1} = 5 + \frac{2}{0.360} = 10.5556$$

$$k_1 = \frac{t_1^2 h}{F_1} = \frac{5.20^2 (0.032)}{10.5556} = 0.0819739 \text{ m s}^2 \approx 0.0820 \text{ m s}^2$$

Rolling model: change the trial, recalculate the factor

For the second cylinder, $d_2 = 2.50 \text{ cm}$ and $t_2 = 4.80 \text{ s}$. The same x and h apply.

$$F_2 = 5 + \frac{2}{1 - (x/d_2)^2} = 5 + \frac{2}{1 - (1.60/2.50)^2} = 8.38753$$

$$k_2 = \frac{t_2^2 h}{F_2} = \frac{4.80^2 (0.032)}{8.38753} = 0.0879019 \text{ m s}^2 \approx 0.0879 \text{ m s}^2$$

A changed diameter changes the bracket factor. Do not reuse F_1 for the second cylinder.

Rolling model: test and diagnose the result

$$k_{\text{ref}} = \frac{|k_1| + |k_2|}{2} = \frac{0.0819739 + 0.0879019}{2} = 0.0849379 \text{ m s}^2$$

$$D = \frac{|k_1 - k_2|}{k_{\text{ref}}} \times 100\% = \frac{|0.0819739 - 0.0879019|}{0.0849379} \times 100\% = 6.98\%$$

This is below the stated 30% allowance: the data support the relationship within that allowance.

When d is close to x , the small denominator is sensitive to diameter errors. If it is zero or negative, recheck readings and definitions; do not insert an absolute value.



A useful limitation names the affected measurement

Quantity + cause + consequence

Replace “parallax error” with an explanation

The spring end is separated from the ruler, so its apparent position changes with eye position and the length reading is uncertain.

“Human error”, “inaccurate apparatus” and “repeat more” do not identify a specific problem and remedy.

Find independent limitations in the actual setup

Look at	Ask
Reading	Is the endpoint hidden, blurred or far from the scale?
Motion	Does the pointer move, the motion decay or the path wander?
Apparatus	Does the track bend, the pivot stick or the sample deform?
Model or evidence	Is a control drifting, or are there too few different settings to test the model?

Give the number of distinct limitations and improvements requested. Four pairs are common, but the actual question controls the answer.

Match a remedy to the reading problem

Specific limitation	Matching improvement
A small height is hard to read with a ruler.	Use suitable depth calipers.
The spring end moves beside a distant scale.	Add a pointer and clamp the ruler close to it.
The object's centre is hidden.	Measure both edges and calculate the centre.
A paper cylinder becomes oval.	Form it on a circular template; remove the template without deforming it.

Match a remedy to motion and construction

Specific limitation	Matching improvement
A ball's travel time is short and hand timing varies.	Use light gates or video with a known frame rate or visible timer.
Oscillations decay before counting is clear.	Use video to track cycles; avoid increasing amplitude beyond the model's conditions.
A track bends under the ball.	Use a rigid track with support along its length.
A card catches on its pivot.	Use a thinner pin and a smooth, clear hole.

Control the sample and improve the evidence

- If adhesive adds moving mass, include it in the measured total.
- If wet paper changes during the experiment, use fresh identical samples.
- More repeats at one setting assess scatter. More different settings test whether the proposed relationship holds over a range.
- Use additional settings to compare several constants or produce a suitable graph.
- An improvement should be realistic, preserve the investigation and go beyond instructions already carried out.

Try it: explain why a rigid track helps

A ball rolls down a flexible track. The track bends differently as the ball moves.

- 1 State one specific limitation and its effect on the experiment.
- 2 Suggest an improvement that directly addresses it.

Avoid the phrases “human error” and “use better equipment”.

Evaluation answer: cause and remedy are linked

Limitation

The track bends under the moving ball, changing the local slope and making the travel time depend on a changing path.

Improvement

Use a rigid track supported along its length so that the path and slope stay fixed during each run.

A computer or a finer stopwatch display would not fix a changing track geometry.

Before you leave the apparatus

- 1 Required number and range of readings; original observations preserved.
- 2 Units in table headings; consistent raw precision; plausible repeats.
- 3 All points plotted; suitable scale; thin fit; large gradient triangle.
- 4 Supplied equation rearranged; brackets, signs and units checked.
- 5 Percentage comparison uses a stated reference and the given allowance.
- 6 Specific limitations paired with improvements to their causes.

Check a doubtful reading while the apparatus is available. A complete record is more useful than a tidy table reconstructed from memory.

Companion handbook and exam scope

AS Physics Paper 3 practical handbook

The 18-page handout contains the measurement guidance, uncertainty rules, graph methods and worked examples used in this deck.

Scope: Cambridge International AS & A Level Physics 9702, 2025–2027 syllabus, practical assessment guidance (pp. 42–48).

Handbook review: November 2025 papers 31, 34 and 35; June 2025 papers 31, 32, 34 and 35.

The spring data and teaching diagrams are original. The rolling model is from November 2025 Paper 34; its numerical walkthrough follows the handbook.

Check yourself

- 1 A stopwatch shows 0.01 s. Why can hand timing still have a much larger uncertainty, and how does timing more cycles help?
- 2 A graph of T^2 against mass in grams has gradient $0.00400 \text{ s}^2/\text{g}$. What must you do before using $k = 4\pi^2/G$?
- 3 Two constants differ by 8%, with a stated 10% allowance. Give a justified conclusion, then distinguish an extra repeat from an extra setting.