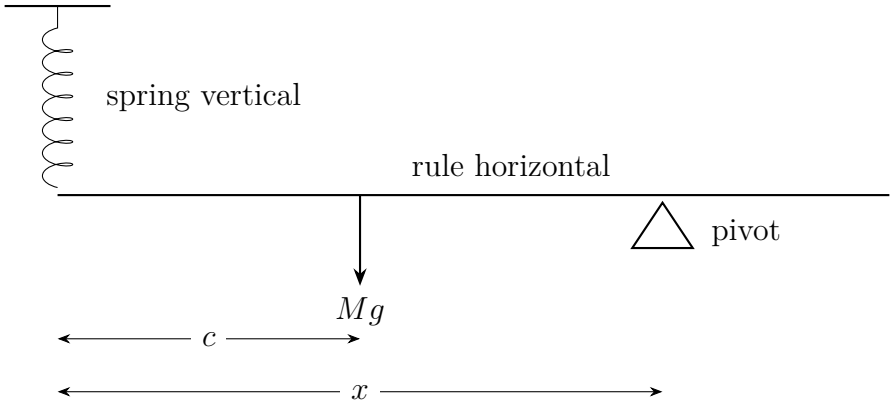
Spring constant from moments

Name: _____ Class: _____ Date: _____

Aim Find a spring constant indirectly by balancing moments. Allow 60–75 minutes.

Key ideas A **moment** is force × perpendicular distance. Below the elastic limit, $F = k(l - l_0)$. Use $g = 9.81\,\mathrm{m\,s^{-2}}$.

Apparatus Metre rule, spring, stand and clamp, string, pivot, taped 100 g mass, millimetre ruler and balance.



Measure c and x from the *same spring attachment point*; $x > c$. The combined weight acts at c. Diagram not to scale.

Safety Weight the stand base and keep masses over the bench. Do not overstretch the spring. Ask the teacher to check the setup before loading it.

1 Set up and measure

1. Balance the unloaded rule on the pivot. Tape the 100 g mass at its balance point. Check the combined rule still balances there. Measure c and total mass M, including tape.
2. Measure the unstretched *coiled section* length l_0. Use the same two coil endpoints in every later reading.
3. Attach the spring near one end. Place the pivot beyond c. Adjust the clamp height until the rule is horizontal and the spring vertical.
4. Measure pivot distance x and coil length l. View scales at right angles. Wait for the rule to stop moving.
5. Choose at least six safe pivot positions spread over the usable range. Restore horizontal balance each time. Repeat l after resetting the balance. Revisit the first position at the end to check for spring drift.

Processing check (synthetic data) A fitted gradient is $s = -0.0500 \pm 0.0025\,\mathrm{m^2}$, with $M = 0.200$ kg and $c = 0.500$ m. Taking M, c, g as exact for this check, calculate $k = -Mgc/s$ and its approximate uncertainty.

2 Record measurements

$M =$ _____ kg $c =$ _____ m $l_0 =$ _____ m

Instrument resolution: rule _____; balance _____.

Convert lengths to metres before processing. A 1 mm rule reading is recorded to 0.001 m. Keep guard digits when calculating $1/x$. Repeats belong in the table, not only in a mean.

x/m	l_1/m	l_2/m	$\bar{l}$/m	$(1/x)$/m^{-1}

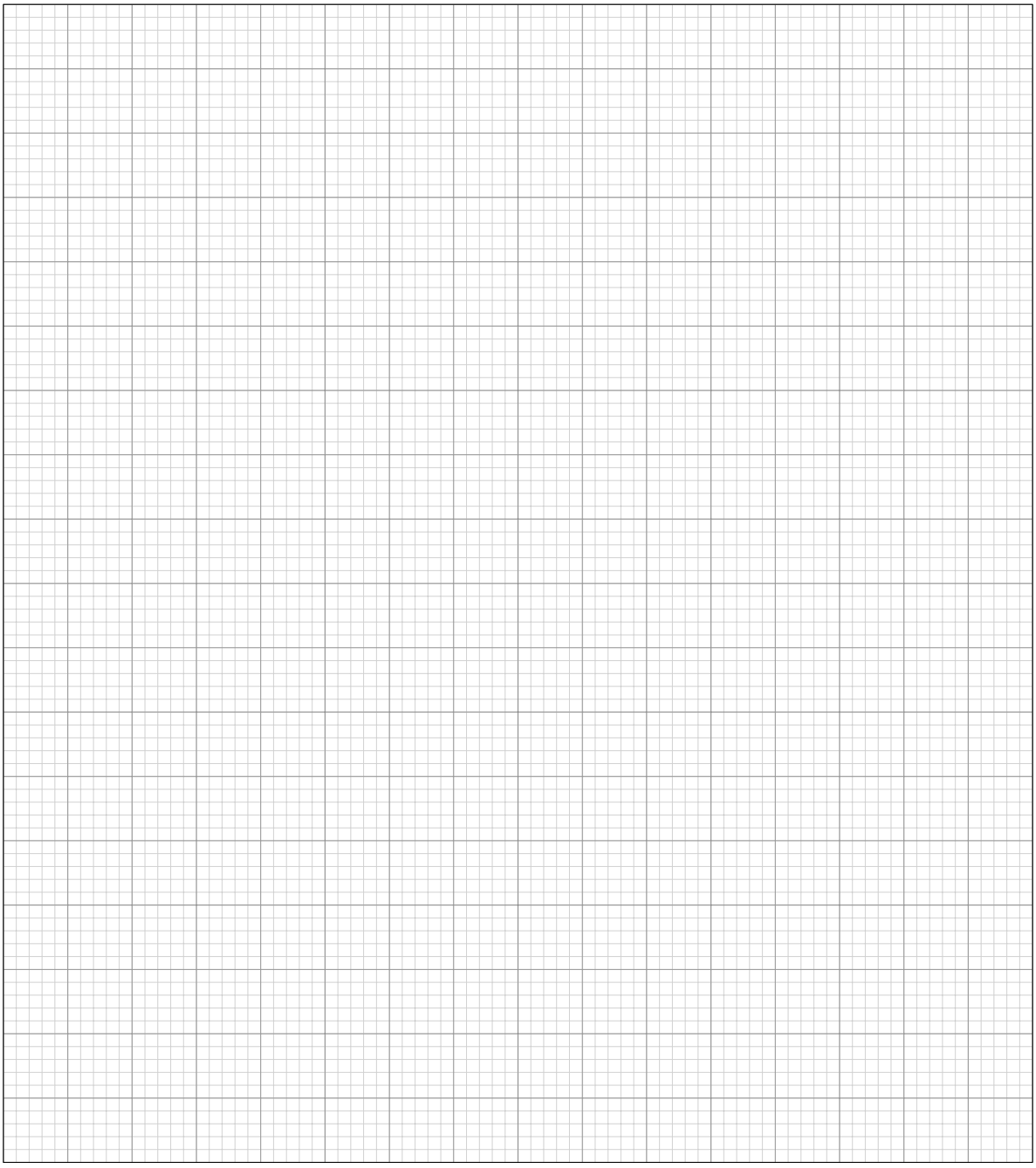
Controls Why must the rule remain horizontal and the spring vertical?

Pilot check Record your usable range and explain why the smallest x must remain greater than c.

Uncertainty Record resolution and estimate Δl and Δx. Consider two-endpoint readings, coil alignment and the spread of repeats. Explain the estimates.

3 Graph

Plot mean coil length $\bar{l}$ against reciprocal distance $1/x$. Draw a best-fit line; do not force it through the origin. Extension beyond Paper 3: add justified uncertainty bars in both variables and a defensible extreme line; use the gradient difference as an estimate of Δs. If no straight line fits the bars, discuss the model or underestimated errors.



Choose scales and label both axes with quantities and units. Mark a large gradient triangle on the best-fit line where appropriate.

4 Analyse and evaluate

Taking moments about the pivot gives

$$k(l-l_0)x = Mg(x-c), \qquad l = \underbrace{\left(l_0 + \frac{Mg}{k}\right)}_{B} - \underbrace{\frac{Mgc}{k}}_{A}\frac{1}{x}.$$

1. Find gradient s and intercept B. Give their units. For a false origin, use a point on the fitted line and $B = l - s/x$.

2. Use $A = -s$ to calculate $k_1 = Mgc/A$. Separately calculate $k_2 = Mg/(B - l_0)$. Show substitutions and give units.

3. Which estimate is more reliable? Consider extrapolation and subtracting two similar lengths in $B - l_0$. Cite your own graph. Explain why the two estimates are linked through the same fitted line.

4. Identify two specific limitations. For each, give an improvement and explain which reading it improves.

Conclusion Use $\Delta k_1/k_1 \simeq \Delta M/M + \Delta c/c + \Delta s/|s|$. Quote your preferred spring constant with uncertainty and justified precision, and say whether the data support the model.

Before you leave Return the apparatus, clear the bench and submit your recorded data.