

Spring required practical graphs and limits

AQA GCSE Combined Trilogy 8464 / Separate Physics 8463 | Foundation and Higher

23 parts | 44 marks | Both routes and tiers | Timing estimated/untrialled

Specification points covered

8463 4.5.3 / 8464 6.5.3: forces and elasticity; spring investigation RP6 / RP18 (Physics Paper 2)

8463 4.5.1.3 / 8464 6.5.1.3: mass, weight and gravitational field strength (Physics Paper 2)

8463 4.1.1.2 / 8464 6.1.1.2: elastic potential energy within the proportional range (Paper 1 link)

A parcel-testing workshop calibrates a model tension-spring buffer for a fragile instrument. Loads are added slowly and allowed to settle; these are not drop tests. Choose a repeatable working range from the evidence.

Original PhysicsUK practice, not an official AQA resource. All 23 parts / 44 marks are both-tier and shared by Trilogy/Separate Physics, not Synergy. Paper-based preparation for RP6/RP18, not evidence of completing the physical practical. Model data isolate proportionality from recovery; use only teacher-approved loads in a real investigation.

1 Checking length and load

The unloaded length is 12.0 cm. With 150 g of slotted masses on a 30 g hanger, the length is 15.6 cm. Use the combined hanging mass, not just the slotted masses.

1(a) Calculate the extension of the loaded spring in cm. **[1 mark]**

Answer / mark points: Extension = $15.6 - 12.0 = 3.6$ cm. [1] The loaded length 15.6 cm is not the extension.

1(b) Calculate the total downward force applied by the hanger and slotted masses. **[2 marks]**

Answer / mark points: Total mass = $150 + 30 = 180$ g = 0.180 kg. [1 for correct total in kg] $W = mg = 0.180 \times 10 = 1.8$ N. [1] Use the supplied g, not an assumed different value.

1(c) A technician uses only 150 g and labels this load 1.5 N. State the size of the force error and explain its cause. **[2 marks]**

Answer / mark points: The force is underestimated by $1.8 - 1.5 = 0.3$ N. [1] The hanger also has weight and must be included in the total load. [1] The missing 30 g is not weightless.

1(d) The stretched spring remains stationary. Explain why the downward pull at its lower end is not the only force needed to stretch it in this test. **[2 marks]**

Answer / mark points: The fixed support also pulls upwards at the upper end. [1] Opposing pulls at different ends stretch the spring while it remains stationary. [1] This is the both-tier stationary-deformation idea, not a Higher-only free-body construction.



2 Making the readings valid

Figure 1 shows the bench apparatus. Its ruler has unnumbered ticks: do not measure a numerical reading from this schematic. The pointer is fixed to the lower end of the spring, above the mass hanger.

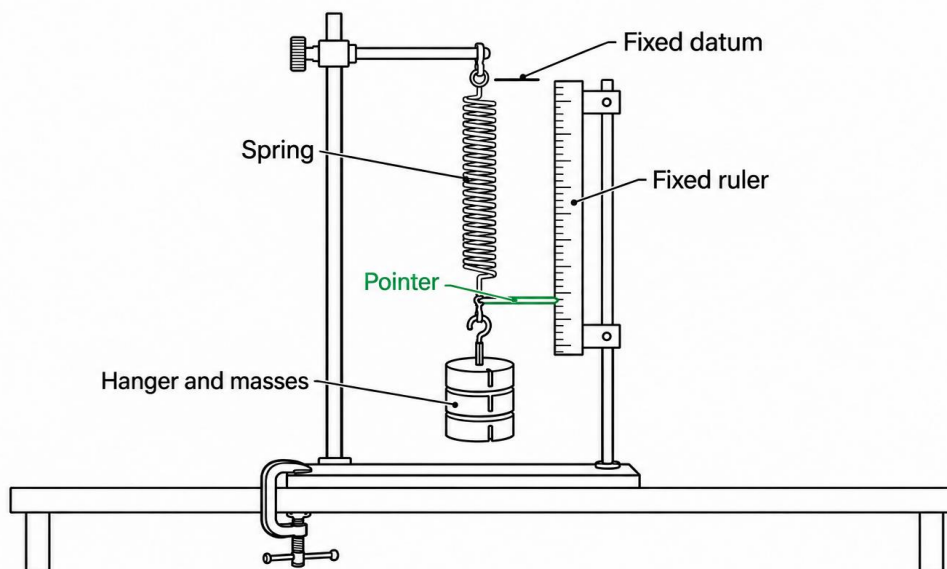


Figure 1

2(a) Describe two actions that improve the pointer reading before it is recorded. **[2 marks]**

Answer / mark points: Allow the spring/load to stop oscillating and settle. [1] Read the pointer against the ruler at eye level, with the line of sight perpendicular to the scale, to reduce parallax. [1] Do not read the bottom of the masses instead of the pointer.

2(b) A technician repositions the ruler between the unloaded and loaded readings. Explain why this can spoil the extension calculation and state how to prevent the problem. **[2 marks]**

Answer / mark points: The two readings then use different reference positions, so their difference includes ruler movement rather than just spring extension. [1] Keep the ruler and top datum fixed for the unloaded and all loaded readings. [1] If the setup moves, restore it and recheck the zero/baseline.

2(c) Explain one way the G-clamp securing the stand reduces a risk in this investigation. **[1 mark]**

Answer / mark points: It prevents/reduces the risk of the stand tipping so the spring or masses fall. [1] Accept a clear equivalent link to stabilising the apparatus; merely naming the clamp does not explain the risk reduction.



3 Building the calibration graph

Table 1 gives idealised loading data for a fresh spring with unloaded length 12.0 cm. Total mass includes the hanger except at zero load, when it is removed. Use $g = 10 \text{ N/kg}$.

Table 1

Total mass / g	Loaded length / cm	Force / N	Extension / cm
0	12.0	0	0
50	13.0	0.5	1.0
100	14.0	1.0	2.0
150	15.0	1.5	3.0
200	16.0	2.0	4.0
250	17.8	2.5	5.8
300	20.0	3.0	8.0

3(a) Complete the force and extension columns of Table 1. Use the original 12.0 cm length for every extension, not the previous row. **[2 marks]**

Answer / mark points: Completed columns are shown in Table 1. [1 for the correct force column; 1 for the correct extension column] Extension is measured from 12.0 cm, not the previous row.

3(b) Plot all seven points on Figure 2, estimating 5.8 cm carefully between the ticks. Add light subdivisions if useful. Draw a straight best-fit line for the proportional region only. Leave the two higher-load measurements as unjoined points. **[3 marks]**

Answer / mark points: Figure 2 shows all seven points. [2 if all are within $\pm 0.1 \text{ cm}$ and $\pm 0.05 \text{ N}$; 1 if four to six are correct] Straight line through the origin and first five points, ending at (4 cm, 2 N). [1] Leave the last two measurements unjoined.

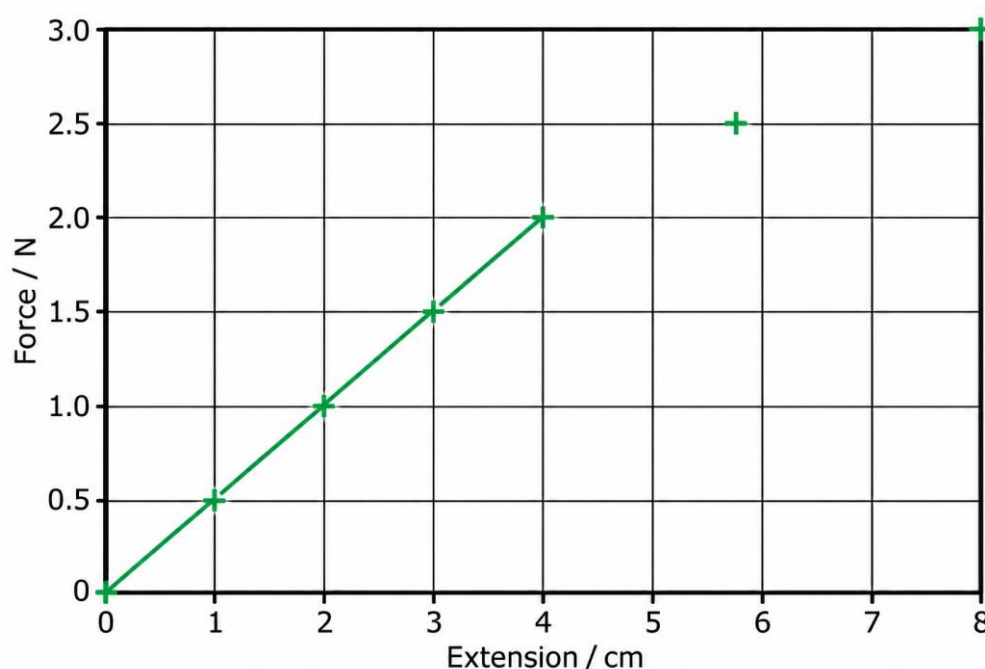


Figure 2

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3 Building the calibration graph continued

3(c) Which two measured force values do not fit the original straight-line trend in Figure 2? [1 mark]

Answer / mark points: 2.5 N and 3.0 N. [1 for both] These correspond to extensions 5.8 cm and 8.0 cm; do not state the extensions as if they were forces.

4 Using only the linear region

Use your completed graph on page 3. Extension is horizontal in cm; force is vertical in N. Keep the linear calibration separate from the non-linear measurements.

4(a) Determine k in N/m from the gradient of the straight part of your graph. Use two widely separated points and show the unit conversion. [2 marks]

Answer / mark points: For example, $\Delta F / \Delta e = (2.0 - 0) / (4.0 - 0) = 0.5 \text{ N/cm}$; converting the 4.0 cm run to 0.040 m gives $k = 2.0 / 0.040 = 50 \text{ N/m}$. [1 for a valid gradient using SI extension or a correct N/cm-to-N/m conversion; 1 for 50 N/m] Accept a sensible value from the pupil's correctly drawn line. It is not 0.5 N/m.

4(b) A small test package gives a loaded length of 15.0 cm from the 12.0 cm original length. Calculate its downward force using the linear calibration. [2 marks]

Answer / mark points: Extension = $15.0 - 12.0 = 3.0 \text{ cm} = 0.030 \text{ m}$. [1] $F = ke = 50 \times 0.030 = 1.5 \text{ N}$. [1] Do not substitute the total length 0.150 m.

4(c) A technician extends the straight-line calibration to 3.0 N. Show the extension it would predict and use the actual loading data to explain why that prediction is not valid. [2 marks]

Answer / mark points: Linear prediction: $e = F/k = 3.0/50 = 0.060 \text{ m} = 6.0 \text{ cm}$. [1] Actual extension is 8.0 cm, so this load is outside the measured proportional region; continuing the first straight line gives the wrong response. [1] The 2.0 cm discrepancy is not evidence of a valid constant k at this load.

4(d) Do the measurements establish that the limit of proportionality is exactly 2.0 N? State what interval the data support. [1 mark]

Answer / mark points: No exact value is established: 2.0 N is the last measured proportional load, and 2.5 N is already non-proportional. [1 for this bracket] The onset can be at/above 2.0 N but below 2.5 N; finer measurements are needed. A drawn guide between points does not locate an exact threshold.

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5 Checking recovery after unloading

Table 2 gives separate trials on fresh identical model springs. Each starts at 12.0 cm and has the loading behaviour in Table 1. All load is removed after reaching the stated peak. The workshop requires both proportional calibration and return to the original length.

Table 2

Trial	Peak force / N	Final unloaded length / cm
A	2.0	12.0
B	2.5	12.0
C	3.0	12.6

5(a) Calculate the permanent extension left after trial C. **[1 mark]**

Answer / mark points: Permanent extension = $12.6 - 12.0 = 0.6$ cm (0.006 m). [1] Use the final unloaded length, not the peak loaded length.

5(b) Trial B was non-proportional during loading but returned to 12.0 cm. Explain why a curved loading graph alone does not prove permanent deformation. **[2 marks]**

Answer / mark points: B returns to its original length after unloading, so it has not acquired a permanent extension in this model. [1] Non-proportional force/extension and failure to recover are different tests; a non-linear response can still be elastic. [1] Do not treat the proportionality limit as automatically the onset of permanent deformation.

5(c) Choose the largest tested peak load that satisfies both workshop conditions: proportional calibration and return to the original length. Justify the choice using both kinds of evidence. **[2 marks]**

Answer / mark points: 2.0 N: it is within the demonstrated straight-line proportional range. [1 for load and loading evidence] Trial A also returns to 12.0 cm. [1] Although B recovers, 2.5 N fails the proportional-calibration condition. This is a choice from tested loads, not an exact universal safety threshold.

5(d) Within a supervisor's prechecked safe range, suggest two changes that would locate the first departure from proportionality more precisely and test whether it causes permanent deformation. Do not propose very large overloads. **[2 marks]**

Answer / mark points: Use smaller load increments between the last proportional and first non-proportional results, measuring the new force/extension points. [1] Unload after selected peaks and compare the no-load reading with the original baseline; use a fresh spring if permanent change occurs. [1] A narrower loading interval alone does not test recovery.



6 Using repeats and checking energy

At a total force of 1.5 N, four recorded loaded lengths are 15.0 cm, 15.1 cm, 14.9 cm and 17.5 cm. The unloaded length is 12.0 cm. Use $k = 50 \text{ N/m}$ for the proportional region.

6(a) Before rejecting the 17.5 cm reading as anomalous, what should the technician do? **[1 mark]**

Answer / mark points: Recheck the written/ruler reading and repeat the measurement at the same force using the unchanged setup. [1] Do not discard a value merely because it does not fit the expected line.

6(b) A check confirms 17.5 cm was a transcription error. Use the three valid readings to find the mean loaded length, then the mean extension in metres. **[2 marks]**

Answer / mark points: Mean length = $(15.0 + 15.1 + 14.9)/3 = 15.0 \text{ cm}$. [1] Mean extension = $(15.0 - 12.0)/100 = 0.030 \text{ m}$. [1] Exclusion is justified by the supplied confirmed error, not simply by the desired result.

6(c) Calculate the elastic potential energy at the mean extension from (b), using $k = 50 \text{ N/m}$. **[1 mark]**

Answer / mark points: Elastic potential energy = $0.5 \times 50 \times (0.030)^2 = 0.0225 \text{ J}$, about 0.023 J. [1] Accept either value or consistent sensible follow-through from (b).

6(d) At the 8.0 cm extension the technician quotes $0.5 \times 50 \times (0.080)^2 = 0.16 \text{ J}$ as recoverable elastic energy. Give two reasons why the earlier calibration does not justify this answer. **[2 marks]**

Answer / mark points: The 50 N/m constant and $0.5ke^2$ equation apply only within the proportional range, which 8.0 cm is outside. [1] The corresponding 3.0 N unloading trial leaves permanent extension, so all loading work cannot be assumed recoverable as elastic energy. [1] No area/hysteresis calculation is required.



7 Planning a repeatable investigation

The teacher approves a maximum test force of 2.5 N for a fresh spring. Plan measurements up to this approved load; do not deliberately overload the spring or test it to failure. The aim is a useful proportional calibration and a check of recovery.

7(a) Describe a method to find the relationship between force and extension and choose a repeatable working range. Include original and loaded readings, mass-to-force conversion, repeats, a labelled graph and a check after unloading. Explain a suitable safety precaution. Use the approved maximum of 2.5 N. **[6 marks]**

Answer / mark points: Original best-fit rubric, not an official AQA mark scheme. Level 3 (5–6): a logical method would produce valid force/extension data and a defensible working-range decision, with the original baseline, total loads, repeated measurements/graph and unloading check linked correctly; includes suitable risk control. Level 2 (3–4): most essential measurements and some analysis are correct, but an important link such as baseline subtraction, total load, repeat/mean or recovery check is missing or unclear. Level 1 (1–2): isolated relevant equipment/actions with little useful sequence. 0: no relevant content. Choose within a level by accuracy/completeness, not six independent ticks.

Example: Secure the stand with a G-clamp, keep the masses over its base and wear eye protection. Fix the ruler beside a pointer attached at the spring's lower end. Record the settled no-load pointer reading with the hanger removed. Add known total hanging masses, including the hanger, in small steps up to the approved 2.5 N maximum. Convert grams to kg and calculate $F = mg$ using $g = 10 \text{ N/kg}$. Let each load settle, read at eye level and subtract the original reading to obtain extension. Repeat valid readings and calculate means after checking anomalies. Plot force in N vertically against extension, with units, horizontally. Find the proportional straight-line region and its gradient in N/m. After selected loads, remove all masses and compare the no-load reading with the baseline. Select a tested range that is proportional and recovers; stop if permanent change occurs and do not exceed the approved load.

Review and improve

Distinguish the proportionality limit from permanent deformation. With force vertical and extension horizontal the gradient is k , after converting cm to m; reversing the axes would give the reciprocal. A reliable working range needs recovery as well as the intended calibration. The supplied data do not establish an exact threshold or predict impact protection.

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