

Hooke's law, springs and elastic energy

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Papers 1 and 2 | Foundation and Higher

Suggested: 35–40 minutes + 15–20 minutes review | 32 parts | 58 marks

Specification points covered

Forces, extension, elastic/inelastic deformation and linear/non-linear behaviour: 8463 4.5.3; 8464 6.5.3

Elastic energy calculations: 8463 4.1.1.2 and 4.5.3; 8464 6.1.1.2 and 6.5.3

Force–extension investigation: 8463 required practical 6; 8464 required practical 18

Related skill — weight of a load: 8463 4.5.1.3; 8464 6.5.1.3

A workshop tests springs for a cradle that carries a delicate field instrument. Use bench-test data to check extension, stored energy and spring choice. The acceptance limits supplied are for this exercise; these tests alone do not establish that a real instrument will survive transport.

Complete all questions; show working and units. Use $F = ke$ and $E = 0.5ke^2$, where E is elastic energy, k is spring constant and e is extension or compression in metres. These equations apply in the proportional range. Use weight = mass $\times$ gravitational field strength, with $g = 10 \text{ N kg}^{-1}$. $1 \text{ cm} = 0.01 \text{ m}$; $1 \text{ mm} = 0.001 \text{ m}$.

1 Checking the basic calculations

Each part refers to a separate spring test.

1(a) A spring is held fixed at the top and pulled down at the bottom. It stretches but remains stationary. Explain why more than one force is needed to stretch it in this test. **[2 marks]**

1(b) A spring's unloaded length is 12.0 cm and its loaded length is 14.4 cm. Calculate its extension in cm. **[1 mark]**

1(c) Convert the 2.4 cm extension to metres. **[1 mark]**



1 Checking the basic calculations continued

1(d) A spring in a compression pad has spring constant 250 N m^{-1} . It is compressed by 2.4 cm within its proportional range. Calculate the force on it. **[1 mark]**

1(e) A spring has spring constant 200 N m^{-1} and unloaded length 0.120 m. A force of 8.0 N stretches it within its proportional range. Calculate its extension and its total loaded length. **[2 marks]**

1(f) A spring extends by 0.030 m under a force of 6.0 N, within its proportional range. Calculate its spring constant. **[1 mark]**

2 Measuring extension from a ruler

For spring T, a pointer at the bottom of the unloaded spring reads 80 mm. Table 1 gives readings for total applied forces, not successive force increases.

Table 1

Total force / N	Pointer reading / mm
0	80
2.0	90
4.0	100
6.0	110

2(a) Use Table 1 to calculate the extension at 6.0 N, first in mm and then in m. **[2 marks]**

2(b) Calculate the spring constant of spring T using the 6.0 N reading. **[1 mark]**

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2 Measuring extension from a ruler continued

2(c) The spring remains in its proportional range at 8.0 N. Predict the pointer's ruler reading in mm at this force.

[2 marks]

2(d) A trainee uses 110 mm as the extension when calculating k at 6.0 N. Explain why this gives a spring constant that is too low. **[2 marks]**

2(e) After the 6.0 N load is removed, the pointer returns to 80 mm. Explain why this is elastic deformation.

[1 mark]

2(f) A separate 12 N test leaves the pointer at 84 mm after the load is removed. State the permanent extension in mm and identify this type of deformation. **[2 marks]**

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3 Interpreting the force–extension graph

Figure 1 shows a loading test on an initially undeformed spring of type T. Use the marked axes; extension is in cm.

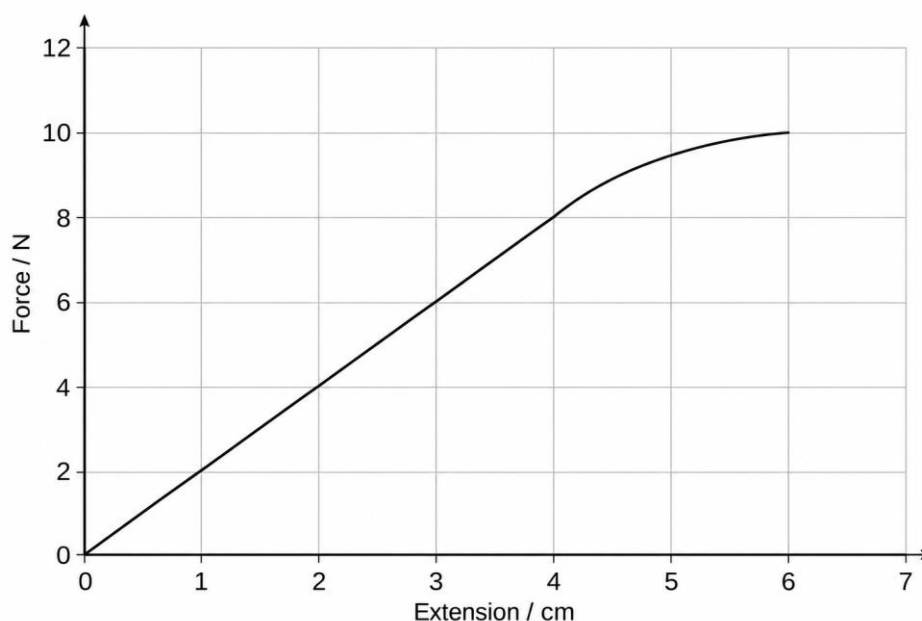


Figure 1

3(a) Use Figure 1 to find the force at an extension of 3.0 cm. **[1 mark]**

3(b) Use Figure 1 to find the extension at a force of 4.0 N. **[1 mark]**

3(c) Use values from the straight region of Figure 1 to calculate the spring constant in N m^{-1} . Show the conversion to metres. **[2 marks]**

3(d) Determine the force at the limit of proportionality in Figure 1. **[1 mark]**

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3 Interpreting the force–extension graph continued

3(e) A trainee uses $k = 200 \text{ N m}^{-1}$ in $F = ke$ at an extension of 6.0 cm. Calculate their predicted force, read the actual force from Figure 1, and explain why the values differ. **[3 marks]**

3(f) Does the curved region of Figure 1 alone prove that the spring has been permanently deformed? Explain how to check. **[2 marks]**

4 Energy stored by springs

Each spring below is loaded slowly from its unloaded length, within its proportional range. Ignore energy losses.

4(a) A spring has $k = 200 \text{ N m}^{-1}$ and extension 0.020 m. Calculate the elastic energy stored. **[1 mark]**

4(b) The same spring is extended by 0.040 m. Calculate its elastic energy. **[1 mark]**

4(c) Compare the energy in parts (a) and (b). Explain why doubling the extension does not just double the energy. **[2 marks]**

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4 Energy stored by springs continued

4(d) How much work is done to extend the spring in part (b) from its unloaded length to 0.040 m? Ignore energy losses. **[1 mark]**

4(e) Two springs, with $k = 300 \text{ N m}^{-1}$ and $k = 150 \text{ N m}^{-1}$, are each extended by 0.030 m. Calculate the energy in each. **[2 marks]**

4(f) A spring with $k = 150 \text{ N m}^{-1}$ must store 0.120 J. Calculate the required extension in m. **[2 marks]**

5 Choosing a cradle spring

Table 2 gives two candidate springs. At a steady bench-test force of 6.0 N, the acceptable extension is 2.5–4.5 cm inclusive, and the spring must store at least 0.090 J. Both remain within their proportional ranges at 6.0 N.

Table 2

Spring	Spring constant / N m^{-1}	Force at limit of proportionality / N
A	150	9.0
B	300	15

5(a) Calculate the extension in m of spring A and spring B at the 6.0 N bench-test force. **[2 marks]**

5(b) Which spring meets the 2.5–4.5 cm extension requirement? Compare both springs with the permitted range. **[2 marks]**

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5 Choosing a cradle spring continued

5(c) Calculate the energy stored in each spring at 6.0 N. Use the energy and extension requirements together to choose a spring for this bench test. **[3 marks]**

5(d) After the cradle moves down and stretches its spring, why does an elastic spring alone not guarantee that the instrument will settle without bouncing? **[2 marks]**

6 Investigating force and extension

Figure 2 shows a force–extension experiment. Its ruler ticks have no numerical scale; no readings are taken from this schematic. Ignore the mass of the spring and pointer.

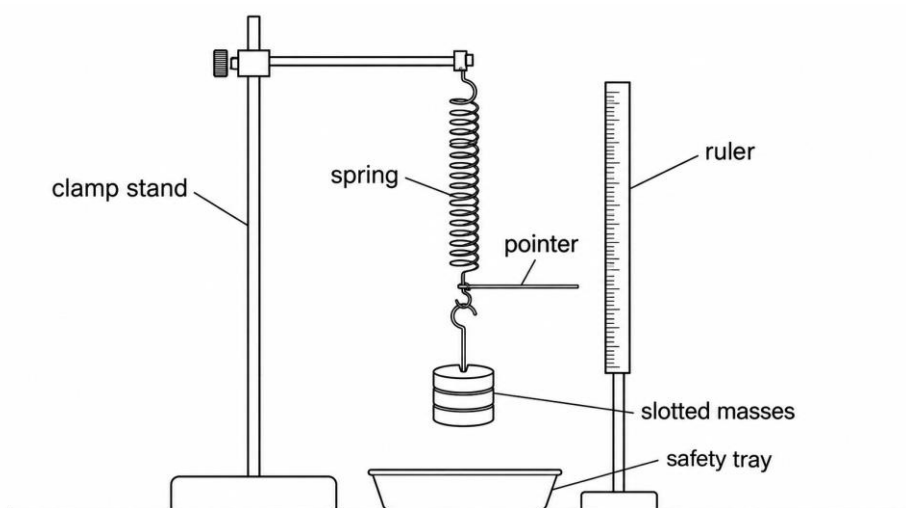


Figure 2

6(a) State how to position the ruler and your eye to reduce parallax when reading the pointer in Figure 2. **[2 marks]**



6 Investigating force and extension continued

6(b) The mass hanger is 50 g and the added slotted masses total 150 g. Calculate the total force stretching the spring. Use $g = 10 \text{ N kg}^{-1}$. **[2 marks]**

6(c) A technician tests only 1 N and 2 N, although the cradle's bench-test force is 6 N within the spring's proportional range. Suggest two improvements: one to the force range and one to the treatment of repeat readings. **[2 marks]**

6(d) Describe a method using Figure 2 to investigate the relationship between force and extension and determine the spring constant. Include reliable measurements and safe loading. Structure your answer: unloaded reading → known forces and extension → repeats and range → graph and spring constant. **[6 marks]**

Review: correct one extension/length error and one explanation about proportionality or permanent deformation.

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