OCR A A Level Physics | Hooke's law worksheet

35-40 minutes independent practice + 15-20 minutes review | 38 marks

Specification points covered

- 3.4.1(a) Describe tensile and compressive deformation, extension and compression.
- 3.4.1(b) State and apply Hooke's law.
- 3.4.1(c) Define the force constant k of a spring or wire using F = kx.
- 3.4.1(d)(i) Interpret force-extension or force-compression graphs for springs and wires.
- 3.4.1(d)(ii) Use procedures to investigate force-extension characteristics.
- 3.4.2(a)-(b) Use the area under a force-deformation graph and calculate elastic potential energy.

How to use this worksheet

Attempt every question independently. Show numerical working in the blank spaces and use the ruled lines for precise written explanations. Convert kN to N and mm to m before using F = kx or elastic-energy equations.

1. Language and Hooke's law [4 marks]

The Asteria Observatory uses sealed spring cartridges to protect a giant segmented telescope mirror from vibrations.

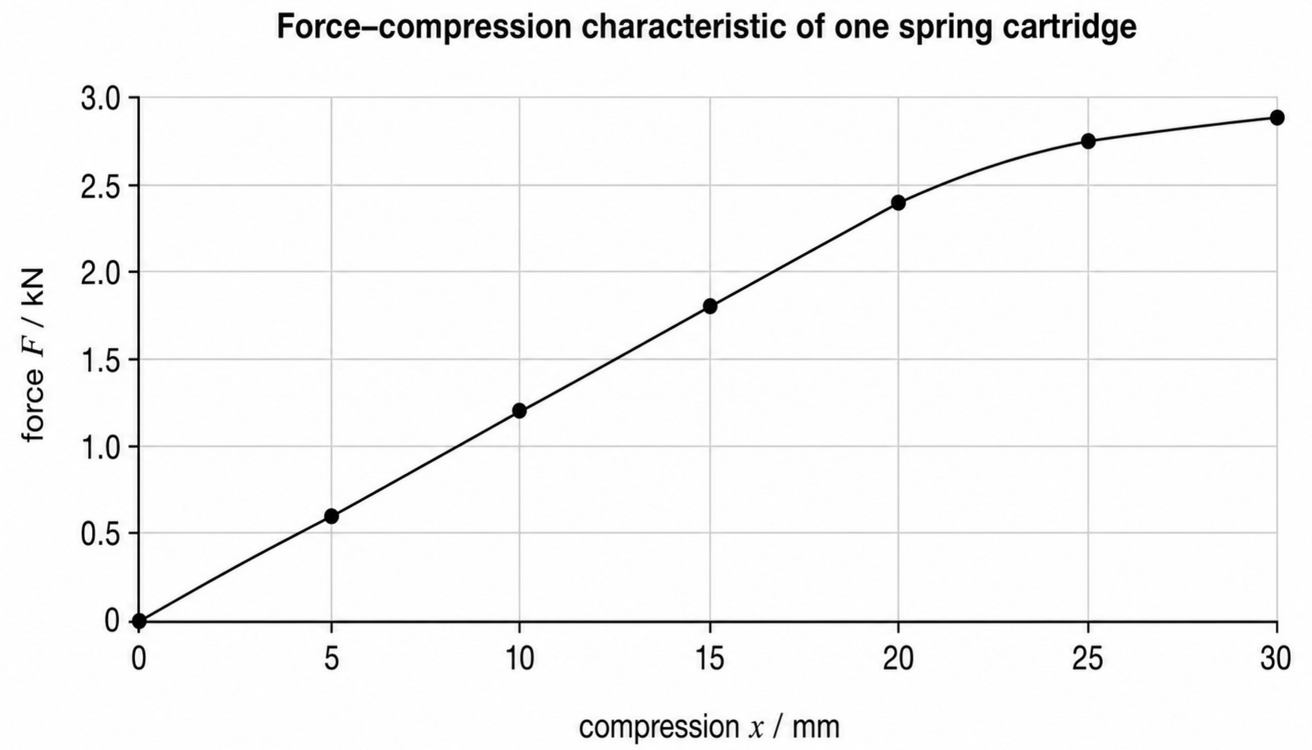
(a) A loaded cartridge becomes shorter. State the type of deformation taking place. **[1 mark]**

(b) State Hooke's law, including the condition needed for it to apply. **[2 marks]**

(c) Define the force constant k and state its SI unit. **[1 mark]**

2. Calibrating one spring cartridge [6 marks]

A technician records the force-compression characteristic of one cartridge. Use the straight-line region when calculating the force constant.



(a) Use the graph to calculate the force constant of the cartridge. Give your answer in N m^{-1}. [2 marks]

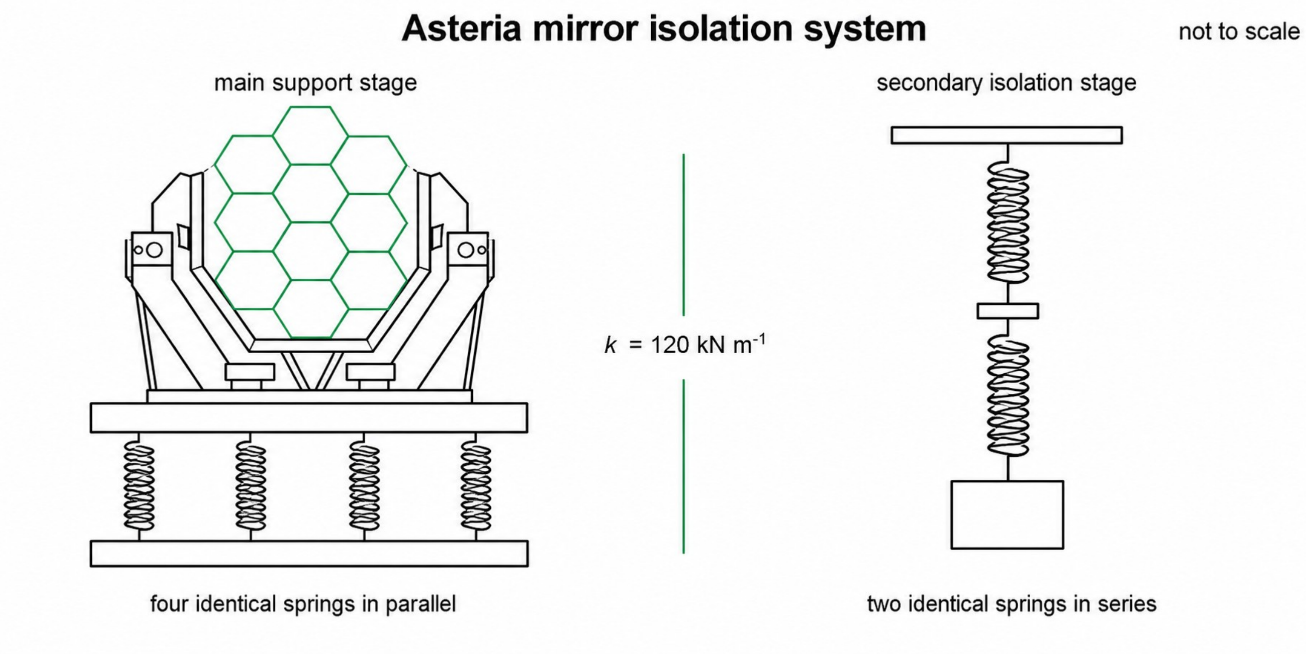
(b) State the compression and force at the limit of proportionality. [1 mark]

(c) Describe how the graph shows that the cartridge no longer obeys Hooke's law beyond this point. [2 marks]

(d) Calculate the elastic potential energy stored when the compression is 20.0 mm. [1 mark]

Scenario: the Asteria mirror isolation system

A large telescope mirror is protected by modular spring cartridges. The main stage uses cartridges in parallel to carry the mirror cradle; a secondary stage uses cartridges in series to provide a softer response.



3. One cartridge under load [3 marks]

During a bench test, a compressive force of 1.50 kN acts on one cartridge. Its force constant is 120 kN m⁻¹.

(a) Calculate the compression of the cartridge in mm. **[1 mark]**

(b) Calculate the elastic potential energy stored in the cartridge. **[2 marks]**

4. The main support stage: springs in parallel [5 marks]

A 650 kg mirror cradle is supported by four identical spring cartridges in parallel. The load is shared equally and each cartridge has force constant 120 kN m⁻¹. Use g = 9.81 N kg⁻¹.

(a) Calculate the weight of the mirror cradle. **[1 mark]**

(b) Calculate the force supported by each cartridge. **[1 mark]**

(c) Calculate the compression of the support stage in mm. **[1 mark]**

(d) Calculate the equivalent force constant of the four-cartridge support stage. **[1 mark]**

(e) Calculate the total elastic potential energy stored in the support stage. **[1 mark]**

5. The secondary stage: springs in series [5 marks]

A secondary isolation stage uses two identical cartridges connected in series. Each cartridge has force constant 120 kN m^{-1} and the stage supports a load of 1.80 kN.

(a) State the force acting on each cartridge. **[1 mark]**

(b) Calculate the compression of each cartridge. **[1 mark]**

(c) Calculate the total compression of the two-cartridge stage. **[1 mark]**

(d) Calculate the equivalent force constant of the stage. **[1 mark]**

(e) Calculate the total elastic potential energy stored in the stage. **[1 mark]**

6. Unequal springs in series [4 marks]

A redesigned stage places a 160 kN m^{-1} cartridge and a 240 kN m^{-1} cartridge in series. The same compressive force of 2.40 kN acts through both cartridges.

(a) Calculate the compression of the 160 kN m^{-1} cartridge. **[1 mark]**

(b) Calculate the compression of the 240 kN m^{-1} cartridge. **[1 mark]**

(c) Calculate the total compression of the stage. **[1 mark]**

(d) Calculate the equivalent force constant of the stage. **[1 mark]**

7. Choosing a transport support [4 marks]

A 720 kg transport pod must be supported by six identical 120 kN m⁻¹ cartridges. Arrangement A uses all six in parallel. Arrangement B uses three parallel branches, with two cartridges in series in each branch. The maximum permitted compression is 12.0 mm. Use g = 9.81 N kg⁻¹.

(a) Calculate the compression of arrangement A. **[1 mark]**

(b) Calculate the compression of arrangement B. **[2 marks]**

(c) Recommend an arrangement. Justify your answer using the calculated compressions. **[1 mark]**

8. Energy during a vibration [3 marks]

Arrangement A has an equivalent force constant of 720 kN m⁻¹. During a vibration, its compression increases from 4.00 mm to 12.0 mm.

(a) Calculate the increase in elastic potential energy stored in the support. **[2 marks]**

(b) State what this energy change represents during the compression of the support. **[1 mark]**

9. Testing a replacement cartridge [4 marks]

A replacement cartridge is tested using a set of known masses and a millimetre scale.

(a) Describe how the technician should obtain reliable force-compression data and use the results to determine both the force constant and the limit of proportionality. **[4 marks]**

Review and improve

- ☐ I can state Hooke's law with its limiting condition.
- ☐ I can interpret force-deformation graphs and calculate elastic energy.
- ☐ I can analyse springs connected in series, parallel and mixed arrangements.