6. Deformation of Solids

6.1 Stress and strain

Paper 1

Question Paper

1 When a force of 0.80 N is applied to a spring, the length of the spring is 90 mm.

When a force of 1.30 N is applied to the same spring, its length is 115 mm.

The spring obeys Hooke's law.

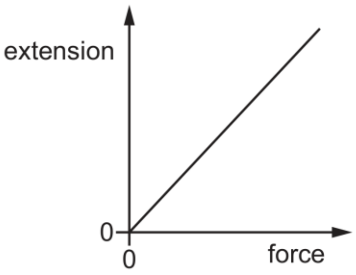
What is the spring constant of the spring?

A $8.9\,N\,m^{-1}$ **B** $10\,N\,m^{-1}$ **C** $11\,N\,m^{-1}$ **D** $20\,N\,m^{-1}$

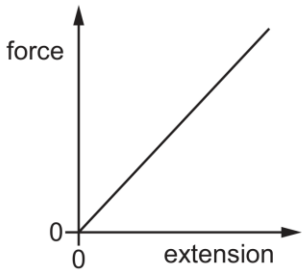
2 An experiment is carried out using a metal wire to investigate how it responds to a varying tensile force. The cross-sectional area of the wire is constant.

Which graph has a gradient that is equal to the Young modulus of the metal?

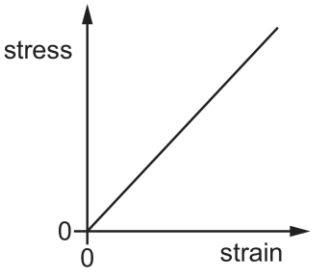
A



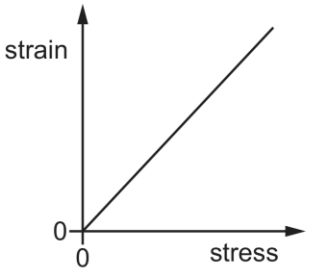
B



C

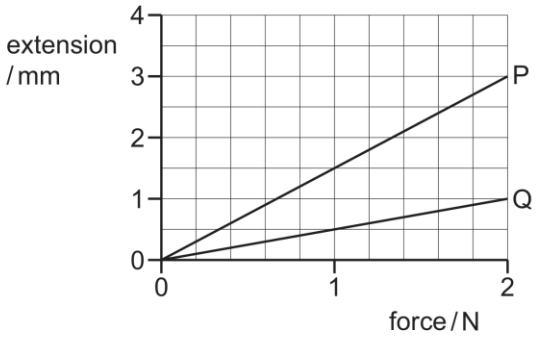


D



3 Two wires, P and Q, made of the same material, are stretched with an increasing force.

A graph is plotted of the variation with force of the extension of each wire.

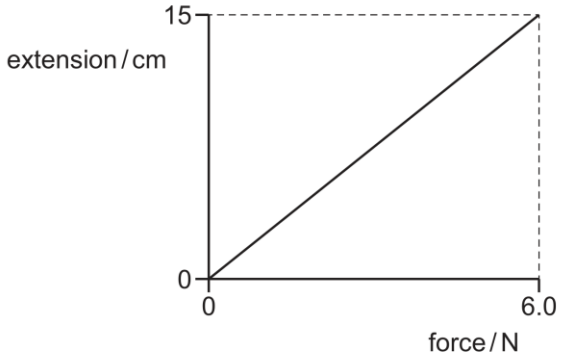


The wires have the same original length but different diameters.

What is the ratio $\frac{\text{diameter of wire Q}}{\text{diameter of wire P}}$?

A $\frac{1}{3}$ **B** $\frac{1}{\sqrt{3}}$ **C** $\sqrt{3}$ **D** 3

4 An extension–force graph for a spring is shown.



What is the spring constant of the spring?

A $0.025\,\text{N m}^{-1}$ **B** $0.40\,\text{N m}^{-1}$ **C** $2.5\,\text{N m}^{-1}$ **D** $40\,\text{N m}^{-1}$

5 A wire has original length L and cross-sectional area A. A tensile force F is applied to the wire which causes it to have extension x. The wire obeys Hooke's law.

What is an expression for the Young modulus of the material from which the wire is made?

A $\frac{\text{stress} \times x}{L}$ **B** $\frac{F}{A \times \text{strain}}$ **C** $\frac{F \times x}{A \times L}$ **D** $\frac{\text{strain}}{\text{stress}}$

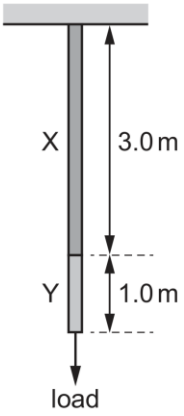
6 A spring has an unstretched length of 0.30 m and a spring constant of 400 N m^{-1}. An object is suspended from the spring and the spring is deformed within its limit of proportionality. The new length of the spring is 0.50 m.

What is the elastic potential energy stored in the spring?

A 8.0 J **B** 16 J **C** 40 J **D** 50 J

7 A wire consists of a 3.0 m length of metal X joined to a 1.0 m length of metal Y.

The cross-sectional area of the wire is uniform.



A load hung from the wire causes metal X to extend by 1.5 mm and metal Y to extend by 1.0 mm.

The same load is then hung from a second wire of the same cross-sectional area, consisting of a 1.0 m length of metal X and a 3.0 m length of metal Y.

Both wires are extended within their limit of proportionality.

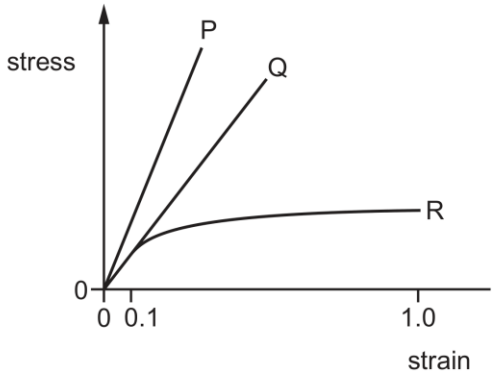
What is the total extension of this second wire?

A 2.5 mm **B** 3.5 mm **C** 4.8 mm **D** 5.0 mm

8 What is a unit for stress?

A $kg\,m^{-1}\,s^{-2}$ **B** $kg\,m^{-2}\,s^{-2}$ **C** $N\,m^{-1}$ **D** $N\,m$

9 The graph shows the relationship between stress and strain for three wires of the same linear dimensions but made from different materials.



Which statements are correct?

1 The extension of P is approximately twice that of Q for the same stress.

2 The ratio of the Young modulus for P to that of Q is approximately two.

3 For strain less than 0.1, R obeys Hooke's law.

A 1, 2 and 3 **B** 1 and 3 only **C** 2 and 3 only **D** 2 only

10 Four solid steel rods equally support an object weighing 10 kN. Each rod is of length 2.0 m and cross-sectional area 250 mm^2. The weight of the object causes the rods to contract by 0.10 mm. The rods obey Hooke's law.

What is the Young modulus of steel?

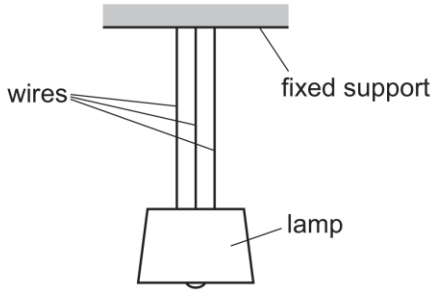
A $2.0 \times 10^{8}\,N\,m^{-2}$

B $2.0 \times 10^{11}\,N\,m^{-2}$

C $8.0 \times 10^{8}\,N\,m^{-2}$

D $8.0 \times 10^{11}\,N\,m^{-2}$

11 A lamp is suspended in equilibrium from a fixed support by three long identical wires.



The weight of the lamp causes each wire to have an extension of 0.40 cm. The height h of the lamp above the floor is measured.

The middle wire suddenly breaks and the lamp falls a small distance as the extensions of the remaining two wires increase. The wires obey Hooke's law.

When the lamp is in equilibrium, the height h of the lamp above the floor is measured again.

What is the difference between the two values of h?

A 0.20 cm **B** 0.27 cm **C** 0.40 cm **D** 0.60 cm

12 What is meant by the spring constant of a spring?

A extension per unit force

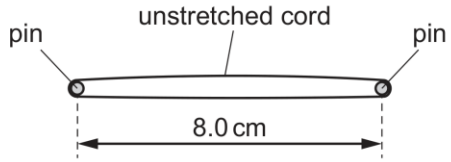
B $\frac{1}{2} \times$ force $\times$ extension

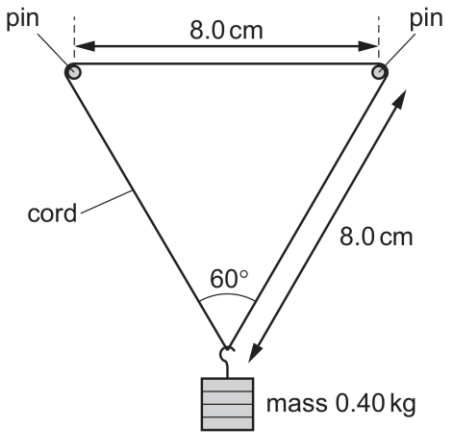
C force $\times$ extension

D force per unit extension

13 An elastic cord of unstretched total length 16.0 cm and cross-sectional area $2.0 \times 10^{-6}\,m^2$ is held horizontally by two smooth pins a distance 8.0 cm apart.

The cord obeys Hooke's law. A load of mass 0.40 kg is suspended centrally on the cord. The angle between the two sides of the cord supporting the load is 60°.





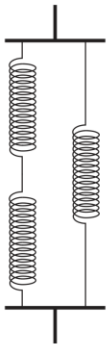
What is the Young modulus of the cord material?

A $5.7 \times 10^5\,Pa$ **B** $1.1 \times 10^6\,Pa$ **C** $2.3 \times 10^6\,Pa$ **D** $3.9 \times 10^6\,Pa$

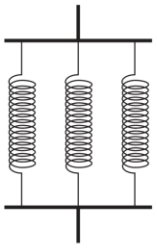
14 Three identical springs, each with the same spring constant, are connected together in four different arrangements, as shown.

Which arrangement has the largest combined spring constant?

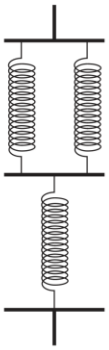
A



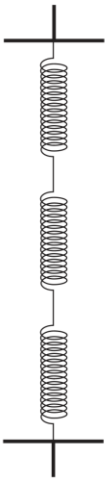
B



C



D



15 Two wires, P and Q, are made from the same metal and hang vertically from a steel girder.

Wire Q has half the length and twice the diameter of wire P.

Identical masses are attached to the bottom of each wire. Both wires obey Hooke's law as they are stretched by the weight of the masses.

What is the ratio $\frac{\text{extension of wire P}}{\text{extension of wire Q}}$?

A $\frac{8}{1}$ **B** $\frac{4}{1}$ **C** $\frac{1}{1}$ **D** $\frac{1}{2}$

16 A metal wire obeys Hooke's law and has a Young modulus of 2.0×10^{11} Pa. The wire has an original length of 1.6 m and a diameter of 0.48×10^{-3} m.

What is the spring constant of the wire?

A $7.2 \times 10^{3}\,\text{N m}^{-1}$

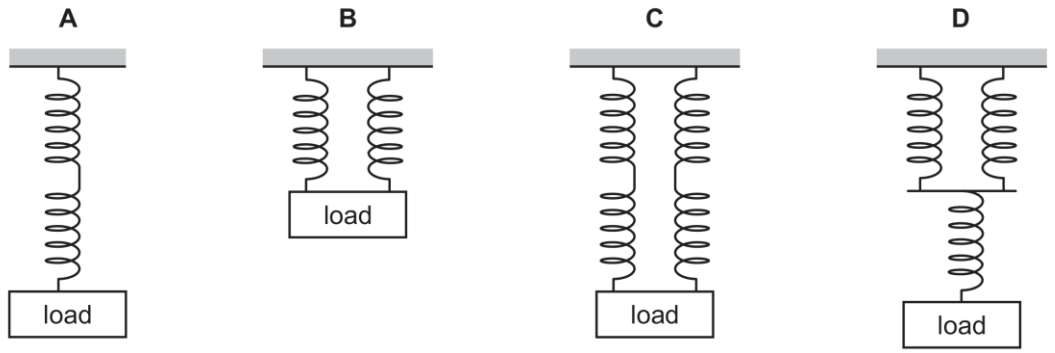
B $2.3 \times 10^{4}\,\text{N m}^{-1}$

C $2.9 \times 10^{4}\,\text{N m}^{-1}$

D $9.0 \times 10^{4}\,\text{N m}^{-1}$

17 Identical springs are joined in four arrangements.

Which arrangement has the same spring constant as a single spring?



18 A known tensile force acts on a metal wire. The wire does not exceed its limit of proportionality.

Which two measurements enable the strain of the wire to be calculated?

A the unstretched length of the wire and the cross-sectional area of the wire

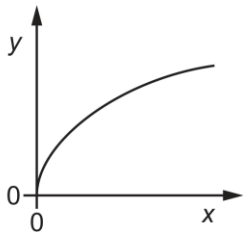
B the unstretched length of the wire and the extension of the wire

C the Young modulus of the metal and the extension of the wire

D the Young modulus of the metal and the unstretched length of the wire

19 A wire is extended by different forces. The wire obeys Hooke's law.

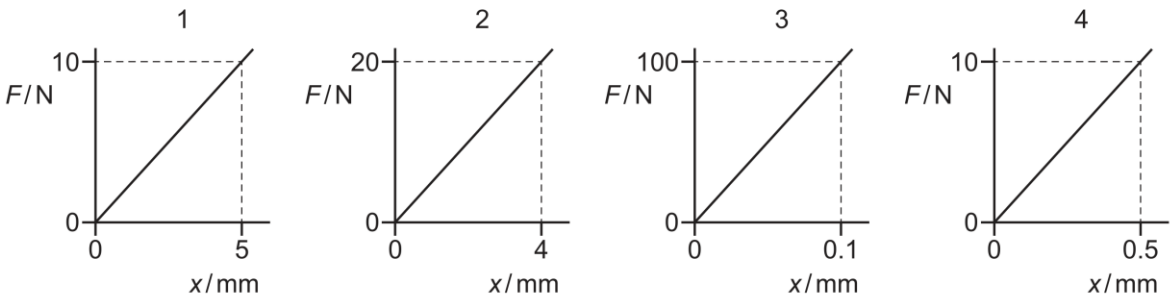
A graph is plotted to show the variation of a quantity *y* with a quantity *x*.



What could *x* and *y* represent?

	x	*y*
A	elastic potential energy	extension
B	extension	force
C	force	extension
D	extension	elastic potential energy

20 The spring constants of four springs are determined by plotting the following graphs of force F against extension x.



Which order of the graphs shows **decreasing** spring constants?

A $2 \rightarrow 1 \rightarrow 3 \rightarrow 4$

B $3 \rightarrow 4 \rightarrow 2 \rightarrow 1$

C $4 \rightarrow 2 \rightarrow 1 \rightarrow 3$

D $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

21 A steel bar of circular cross-section is under tension T, as shown.

The diameter of the wide portion is double the diameter of the narrow portion.



What is the value of $\frac{\text{stress in the wide portion}}{\text{stress in the narrow portion}}$?

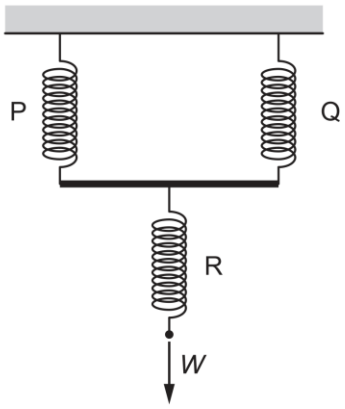
A 0.25 **B** 0.50 **C** 2.0 **D** 4.0

22 A metal wire, of cross-sectional area A and unstretched length l, is subjected to stress σ. As a result it has strain ε.

Which expression gives the Young modulus of the metal?

A $\frac{\varepsilon}{\sigma}$ **B** $\frac{\varepsilon A}{\sigma l}$ **C** $\frac{\sigma}{\varepsilon}$ **D** $\frac{\sigma l}{\varepsilon A}$

23 Three springs are arranged vertically as shown.

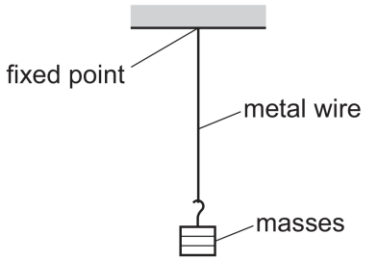


Springs P and Q are identical and each has spring constant k. Spring R has spring constant $3k$.

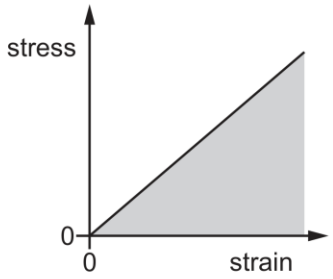
What is the increase in the overall length of the arrangement when a force W is applied as shown?

A $\frac{5}{6}\frac{W}{k}$ **B** $\frac{4}{3}\frac{W}{k}$ **C** $\frac{7}{2}kW$ **D** $4kW$

24 A length of metal wire is attached to a fixed point and hangs vertically. Masses are then suspended from the wire. Assume that the cross-sectional area of the wire remains constant.



A stress–strain graph for the wire is plotted, as shown.



What is represented by the shaded area under the graph?

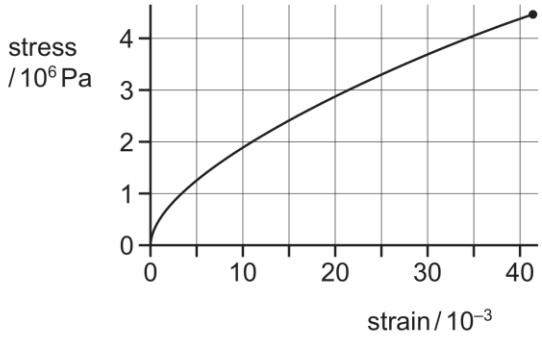
A strain energy in the wire

B $\frac{\text{strain energy in the wire}}{\text{cross-sectional area of the wire}}$

C $\frac{\text{strain energy in the wire}}{\text{original length of the wire}}$

D $\frac{\text{strain energy in the wire}}{\text{original volume of the wire}}$

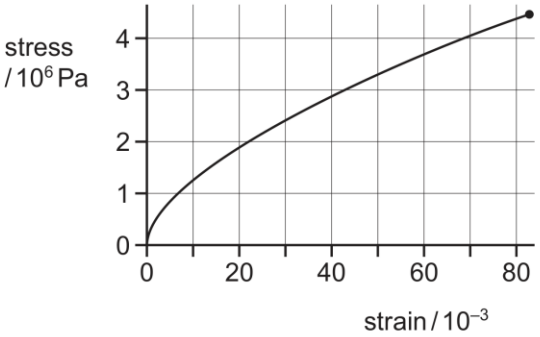
25 A student is investigating the mechanical properties of a metal. He applies different loads to a long thin wire up to its breaking point, and measures the extension of the wire for each load. He then plots a graph of stress against strain.



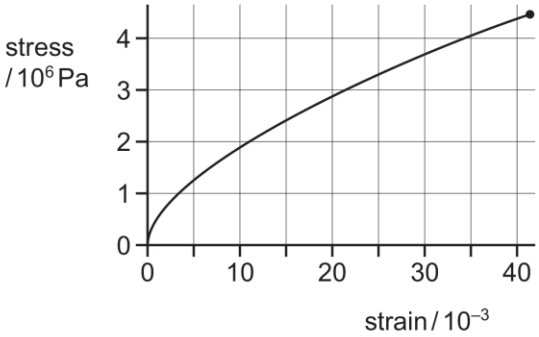
The student repeats the experiment with a wire made from the same metal, with twice the original length and half the diameter.

Which graph is obtained?

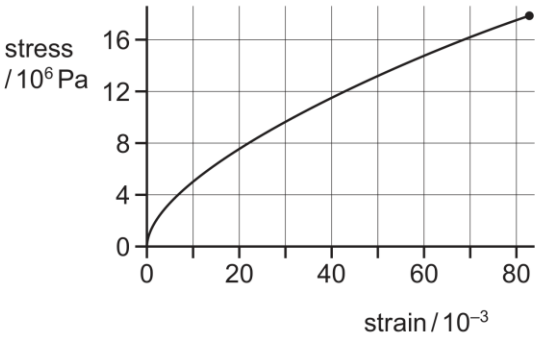
A



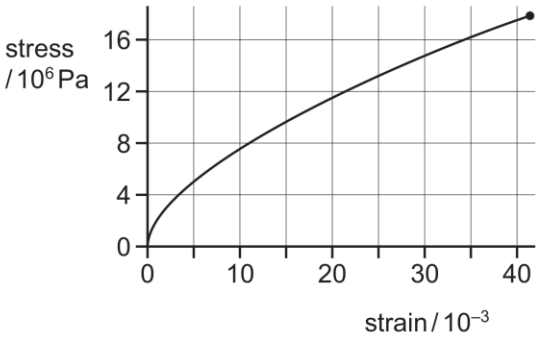
B



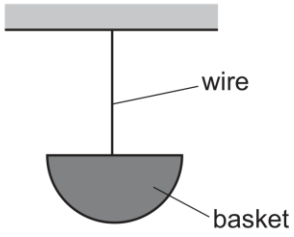
C



D



26 A wire of circular cross-section, which obeys Hooke's law, is used to suspend a basket as shown.



The Young modulus for the material of the wire is 2.5×10^{11} Pa.

When a weight of 34 N is added to the basket, the strain in the wire increases by 6.0×10^{-5}.

What is the radius of the wire?

A 7.2×10^{-7} m **B** 2.3×10^{-6} m **C** 8.5×10^{-4} m **D** 1.7×10^{-3} m

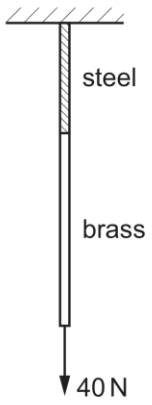
27 A mass of 60.0 g is suspended from a spring and the distance from the bottom of the spring to the floor is measured to be 16.4 cm.

The mass is replaced with a 100.0 g mass and the distance from the bottom of the spring to the floor is now measured to be 12.6 cm. The spring obeys Hooke's law.

What is the spring constant of the spring?

A $1.05\,\text{N m}^{-1}$ **B** $1.35\,\text{N m}^{-1}$ **C** $10.3\,\text{N m}^{-1}$ **D** $103\,\text{N m}^{-1}$

28 A 0.80 m length of steel wire and a 1.4 m length of brass wire are joined together. The combined wires are suspended from a fixed support and a force of 40 N is applied, as shown.



The Young modulus of steel is 2.0×10^{11} Pa.

The Young modulus of brass is 1.0×10^{11} Pa.

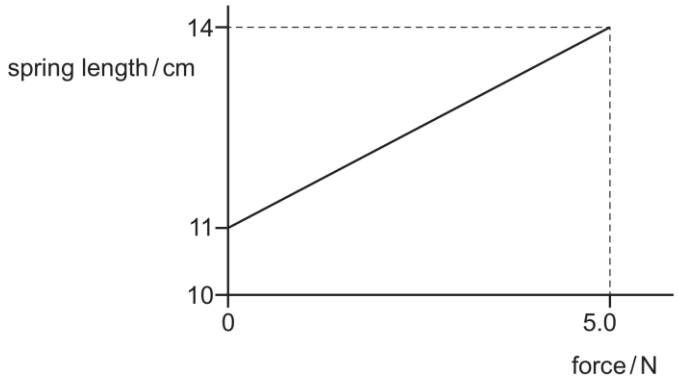
Each wire has a cross-sectional area of 2.4×10^{-6} m^2.

The wires obey Hooke's law.

What is the total extension? Ignore the weights of the wires.

A 1.7×10^{-4} m **B** 3.0×10^{-4} m **C** 3.9×10^{-4} m **D** 9.0×10^{-4} m

29 The graph shows the effect of applying a force of up to 5.0 N to a spring.

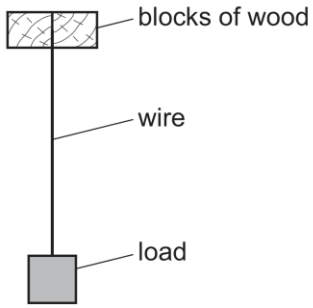


The spring obeys Hooke's law for forces up to 7.0 N.

What is the total extension of the spring produced by a 7.0 N force?

A 4.2 cm **B** 5.6 cm **C** 15 cm **D** 20 cm

30 The diagram shows a wire of diameter *D* and length *L* that is firmly clamped at one end between two blocks of wood. A load is applied to the wire which extends its length by *x*.



A second wire is made of the same material, but of diameter 2*D* and length 3*L*. Both wires obey Hooke's law.

What is the extension of the second wire when the same load is applied?

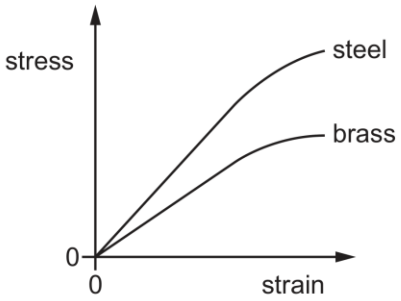
A $\frac{2}{3}x$ **B** $\frac{3}{4}x$ **C** $\frac{4}{3}x$ **D** $\frac{3}{2}x$

31 Two wires, one made of brass and the other of steel, are stretched in an experiment. Both wires obey Hooke's law during this experiment.

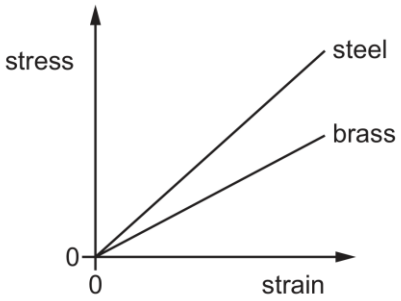
The Young modulus for brass is less than the Young modulus for steel.

Which graph shows how the stress varies with strain for both wires in this experiment?

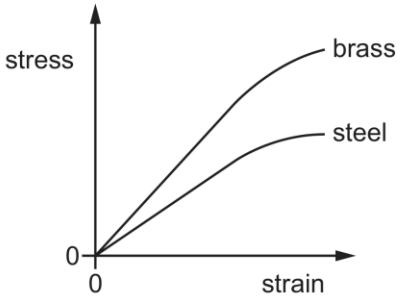
A



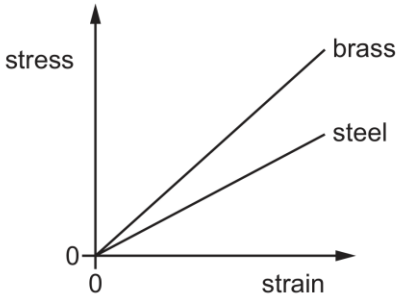
B



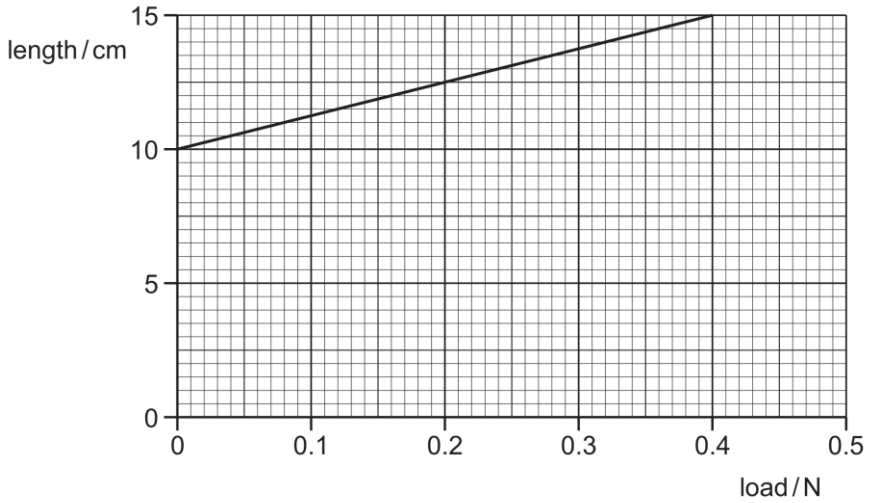
C



D



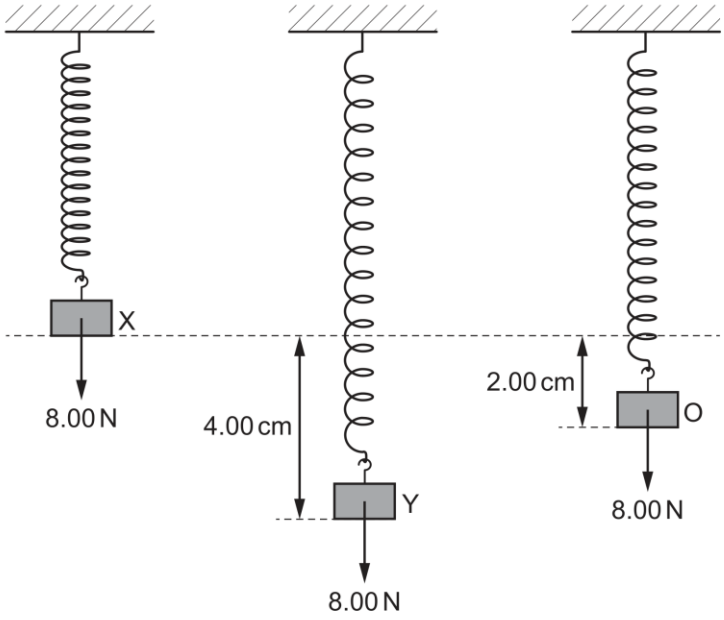
32 The graph shows the length of a spring as it is stretched by an increasing load.



What is the spring constant of the spring?

A $0.080\,\text{N m}^{-1}$ **B** $0.13\,\text{N m}^{-1}$ **C** $2.7\,\text{N m}^{-1}$ **D** $8.0\,\text{N m}^{-1}$

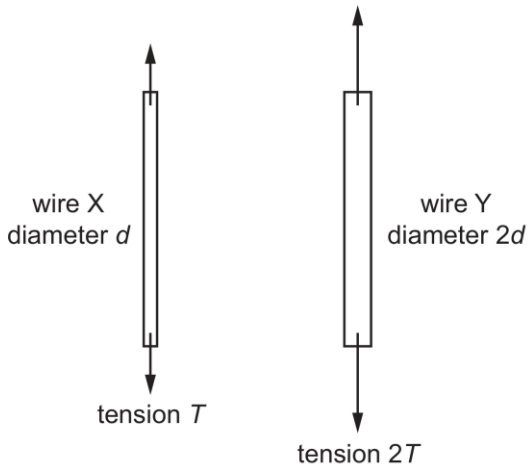
33 An 8.00 N weight is attached to the lower end of a spring which is fixed at its upper end. The weight is initially held at rest at position X and the spring is unstretched. The weight is then released and falls to position Y, which is 4.00 cm below X. The weight oscillates and then eventually comes to rest at O, which is 2.00 cm below X.



How much energy is lost from the system?

A 0.04 J **B** 0.08 J **C** 0.16 J **D** 0.32 J

34 Two wires X and Y are made from the same material. Wire Y has twice the diameter and experiences twice the tension of wire X. The wires obey Hooke's law and have the same original length.



Wire X has extension e.

What is the extension of wire Y?

A $\frac{e}{4}$ **B** $\frac{e}{2}$ **C** e **D** $2e$

35 What is represented by the gradient of a graph of force (vertical axis) against extension (horizontal axis) for a wire obeying Hooke's law?

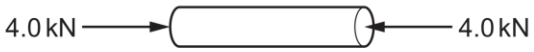
A elastic limit

B spring constant

C stress

D Young modulus

36 A metal cylinder is able to withstand a compressive force of 4.0 kN without deforming plastically.



The cylinder has cross-sectional area A and would be at its elastic limit when a stress σ is applied.

What is a possible pair of values for A and σ?

	A / m^2	σ / MPa
A	1.5×10^{-5}	50
B	1.5×10^{-5}	80
C	7.5×10^{-5}	50
D	7.5×10^{-5}	80