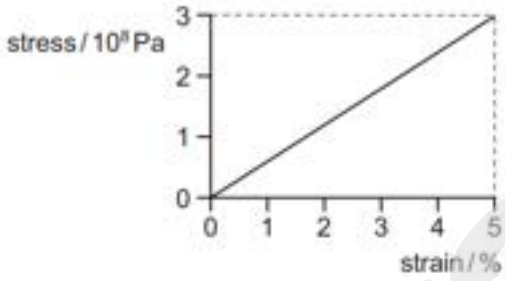
Deformation of Solids

(Past Year Topical Questions 2010-2015)

May/June 2010 (11)

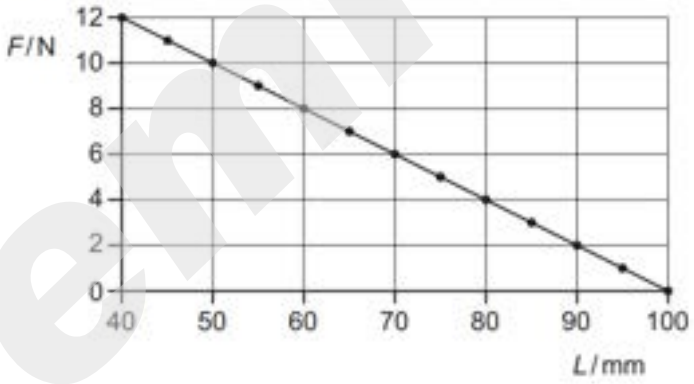
19 In stress-strain experiments on metal wires, the stress axis is often marked in units of 10^8 Pa and the strain axis is marked as a percentage. This is shown for a particular wire in the diagram.



What is the value of the Young modulus for the material of the wire?

A 6.0×10^7 Pa **B** 7.5×10^8 Pa **C** 1.5×10^9 Pa **D** 6.0×10^9 Pa

20 A spring is compressed by a force. The graph shows the compressing force *F* plotted against the length *L* of the spring.

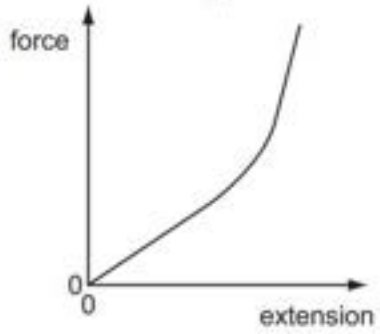


What is the spring constant of this spring?

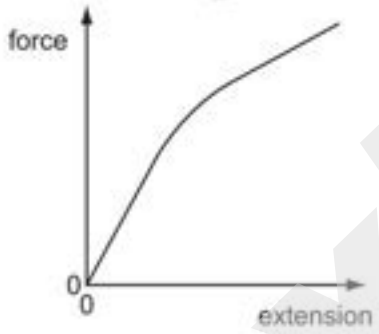
A $0.2\,N\,m^{-1}$ **B** $5\,N\,m^{-1}$ **C** $100\,N\,m^{-1}$ **D** $200\,N\,m^{-1}$

21 Which graph represents the force-extension relationship of a rubber band that is stretched almost to its breaking point?

A



B



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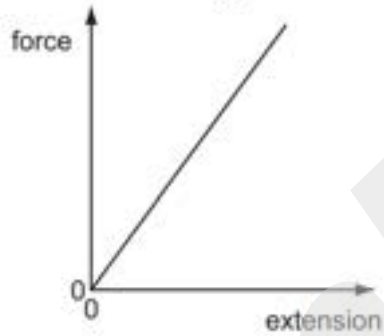

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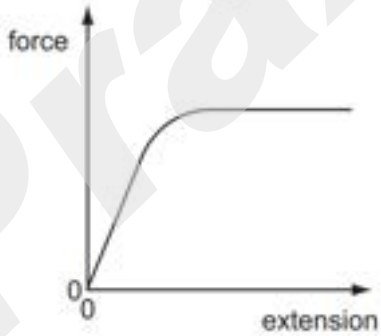

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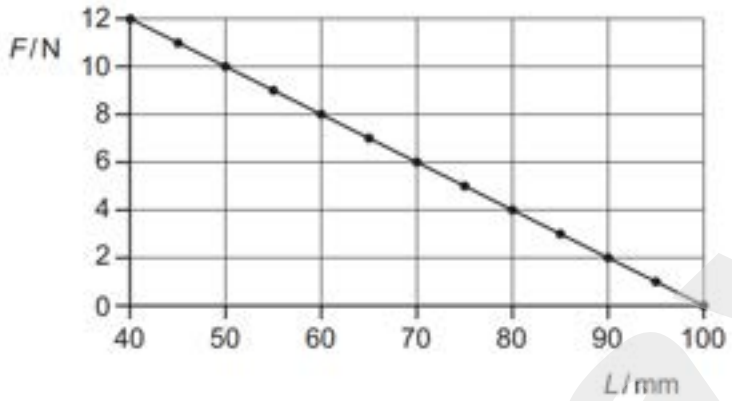
May/June 2010 (12)

19 A spring is compressed by a force. The graph shows the compressing force F plotted against the length L of the spring.



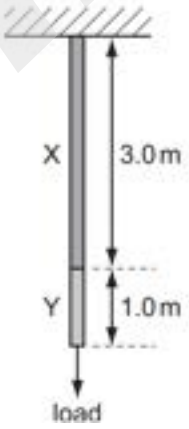
What is the spring constant of this spring?

A $0.2\,N\,m^{-1}$ **B** $5\,N\,m^{-1}$ **C** $100\,N\,m^{-1}$ **D** $200\,N\,m^{-1}$

October/November 2010 (11)

22 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 stretch by 1.5 mm and metal Y to stretch by 1.0 mm.

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

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

October/November 2010 (12)

21 Two wires P and Q are made from the same material.

Wire P is initially twice the diameter and twice the length of wire Q. The same force, applied to each wire, causes the wires to extend elastically.

What is the ratio of the extension in P to that in Q?

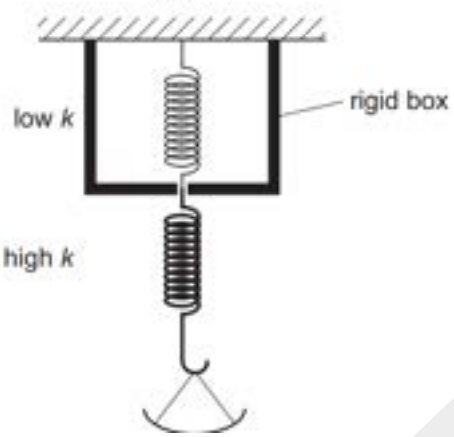
A $\frac{1}{2}$ **B** 1 **C** 2 D 4

22 To determine the mass of food in a pan, a scale is used that has high sensitivity for small masses but low sensitivity for large masses.

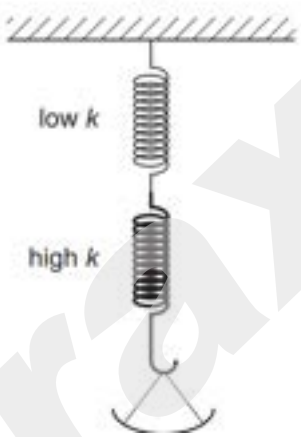
To do this, two springs are used, each with a different spring constant k. One of the springs has a low spring constant and the other has a high spring constant.

Which arrangement of springs would be suitable?

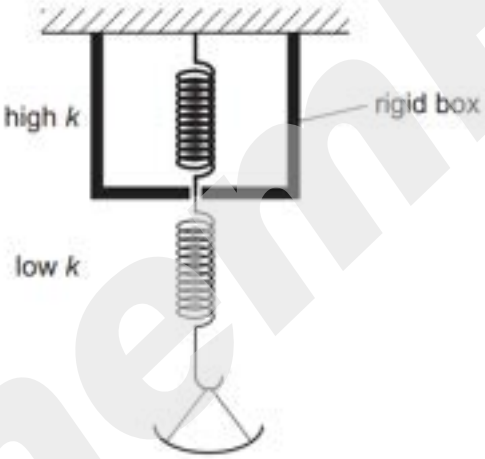
A



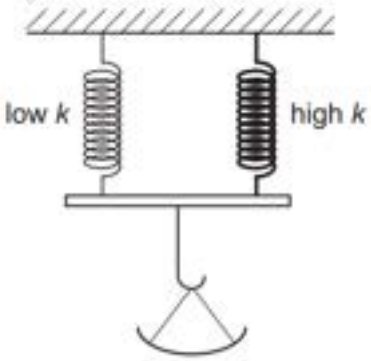
B



C



D

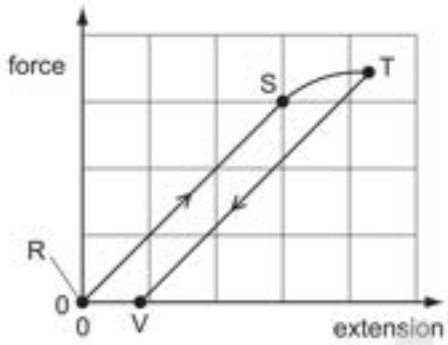


May/June 2011 (11)

20 A long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

The load on the lower end is increased from zero and then decreased again back to zero.

The diagram shows the force-extension graph produced.



Where on the graph would the elastic limit be found?

A anywhere between point R and point S

B beyond point S but before point T

C exactly at point S

D exactly at point T

21 The Young modulus *E* can be determined from measurements made when a wire is stretched.

Which quantities would be measured in order to determine *E*?

A	mass of stretching load	original length of wire	diameter of wire	extension of wire
B	mass of stretching load	new length of wire	cross-sectional area of wire	diameter of wire
C	mass of wire	original length of wire	cross-sectional area of wire	new length of wire
D	mass of wire	new length of wire	diameter of wire	extension of wire

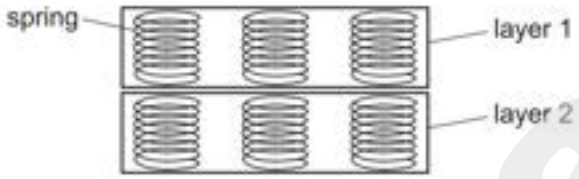
May/June 2011 (12)

23 The behaviour of a wire under tensile stress may be described in terms of the Young modulus E of the material of the wire and of the force per unit extension k of the wire.

For a wire of length L and cross-sectional area A, what is the relation between E and k?

A $E = \frac{A}{kL}$ **B** $E = \frac{kA}{L}$ **C** $E = \frac{kL}{A}$ **D** $E = \frac{L}{kA}$

24 The diagram shows the structure of part of a mattress.



The manufacturer wants to design a softer mattress (one which will compress more for the same load).

Which change will **not** have the desired effect?

A using more layers of springs

B using more springs per unit area

C using springs with a smaller spring constant

D using springs made from wire with a smaller Young modulus

October/November 2011 (11)

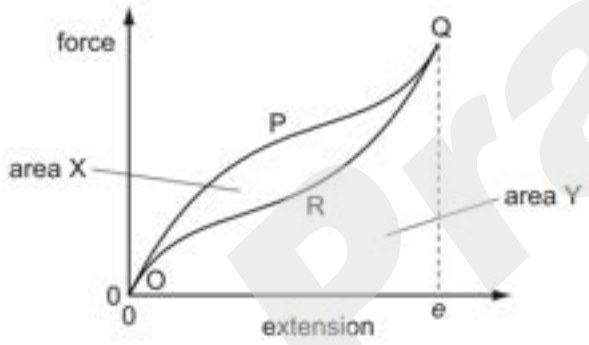
23 The Young modulus of steel is determined using a length of steel wire and is found to have the value *E*.

Another experiment is carried out using a wire of the same steel, but of half the length and half the diameter.

What value is obtained for the Young modulus in the second experiment?

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

24 A rubber band is stretched and then relaxed to its original length. The diagram shows the force-extension graph for this process.



As the force is increased, the curve follows the path OPQ to extension *e*. As the force is reduced, the curve follows the path QRO to return to zero extension.

The area labelled X is between the curves OPQ and QRO. The area labelled Y is bounded by the curve QRO and the horizontal axis.

Which statement about the process is correct?

A Area X is the energy which heats the band as it is stretched to *e*.

B (Area X + area Y) is the minimum energy required to stretch the band to *e*.

C Area X is the elastic potential energy stored in the band when it is stretched to *e*.

D (Area Y – area X) is the net work done on the band during the process.

25 When describing the behaviour of a spring, the spring constant is used.

Different loads are used to extend the spring by different amounts.

To find the spring constant, which quantities are required?

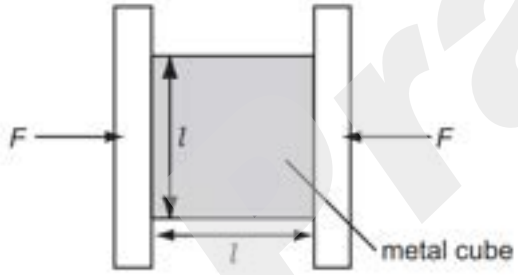
A the elastic limit and the loads

B the elastic limit, extensions and the length of the spring

C the loads and the extensions of the spring

D the loads and the length of the spring

26 A metal cube of side l is placed in a vice and compressed elastically by two opposing forces F.

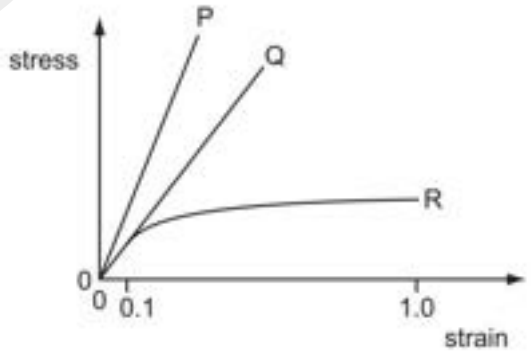


How will Δl, the amount of compression, relate to l?

A $\Delta l \propto \frac{1}{l^2}$ **B** $\Delta l \propto \frac{1}{l}$ **C** $\Delta l \propto l$ **D** $\Delta l \propto l^2$

October/November 2011 (12)

21 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?

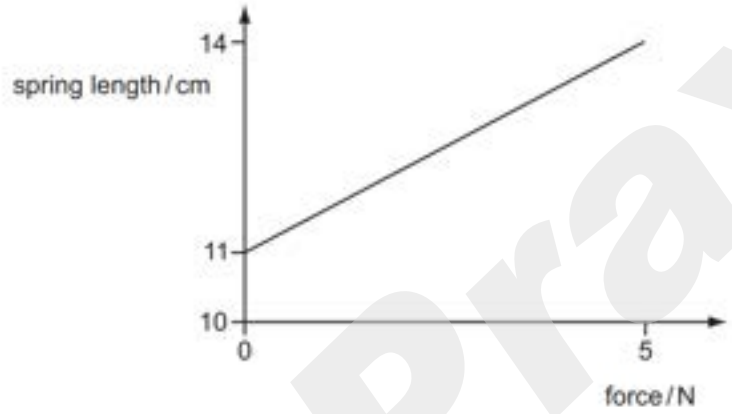
1 The extension of P is approximately twice that of Q for the same stress.

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

22 The graph shows the effect of applying a force of up to 5 N to a spring.

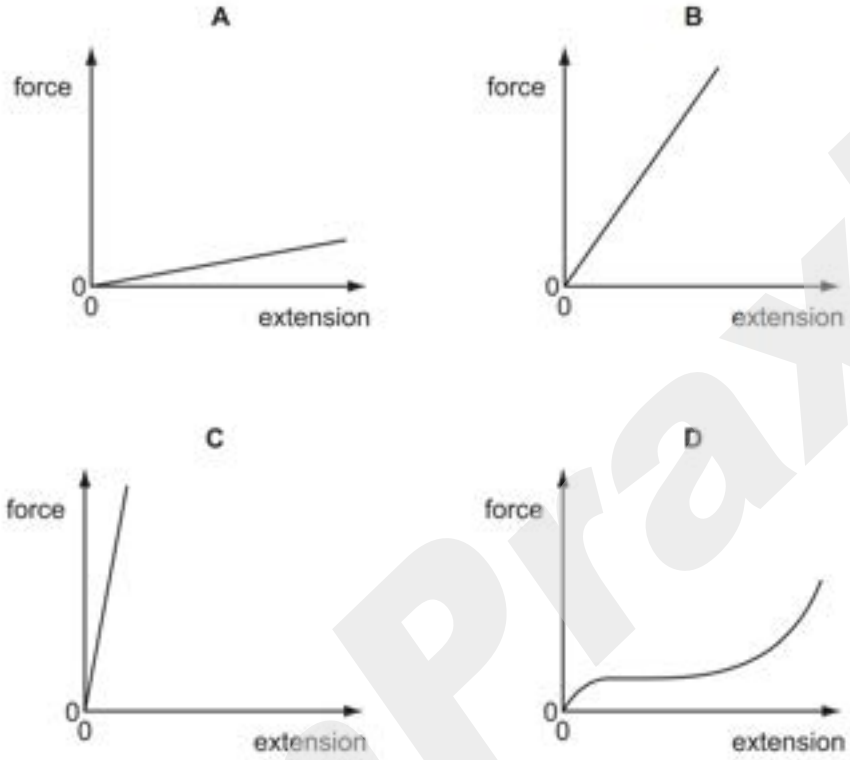


What is the total increase in length produced by a 7 N force, assuming the spring obeys Hooke's law?

A 4.2 cm **B** 5.6 cm **C** 15.2 cm **D** 19.6 cm

23 The following force-extension graphs are drawn to the same scale.

Which graph represents the deformed object with the greatest amount of elastic potential energy?



May/June 2012 (11)

23 Which property of a metal wire depends on its Young modulus?

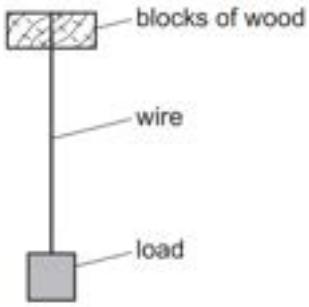
A ductility

B elastic limit

C spring constant

D ultimate tensile stress

24 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 causes it to extend by an amount *x*.



By how much would a wire of the same material, but of diameter 2*D* and length 3*L*, extend when the same load is applied?

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

25 What is represented by the gradient of a graph of force (vertical axis) against extension (horizontal axis)?

A elastic limit

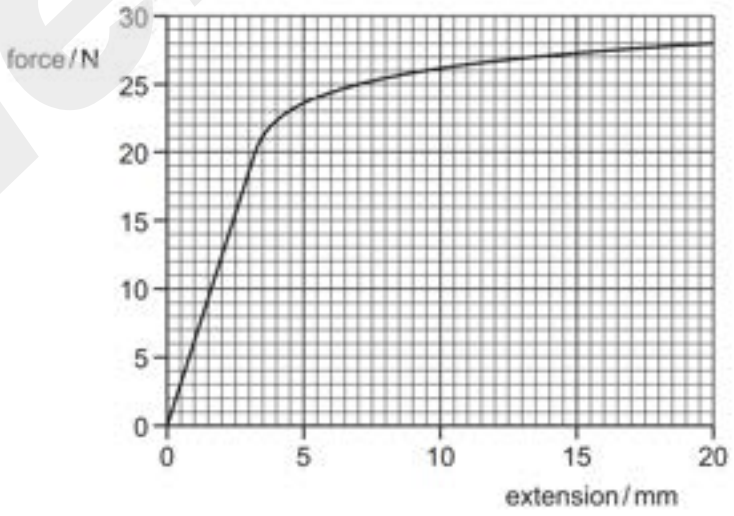
B spring constant

C stress

D Young modulus

May/June 2012 (12)

24 The graph is a force-extension graph for a wire that is being stretched.



How much work needs to be done by the tensile force, to two significant figures, to cause an extension of 7.0 mm?

A 0.088 J **B** 0.12 J **C** 0.53 J **D** 120 J

25 A wire stretches 8 mm under a load of 60 N.

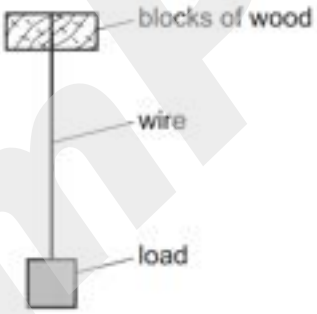
A second wire of the same material, with half the diameter and a quarter of the original length of the first wire, is stretched by the same load.

Assuming that Hooke's law is obeyed, what is the extension of this wire?

A 1 mm **B** 4 mm **C** 8 mm **D** 16 mm

May/June 2012 (13)

21 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 causes it to extend by an amount *x*.



By how much would a wire of the same material, but of diameter 2*D* and length 3*L*, extend when the same load is applied?

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

22 Which property of a metal wire depends on its Young modulus?

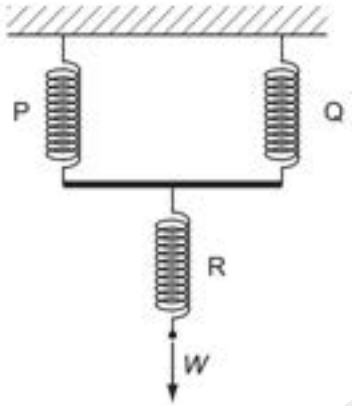
A ductility

B elastic limit

C spring constant

D ultimate tensile stress

23 Three springs are arranged vertically as shown.

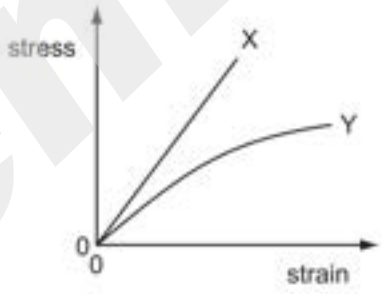


Springs P and Q are identical and have spring constant k. Spring R has spring constant $3k$.

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 The diagram shows the stress-strain graph for two wires X and Y of different materials up to their breaking points. Both wires have the same initial dimensions.



Which statement is **not** correct?

A Material X extends elastically.

B Material X extends more than material Y when loaded with the same force.

C Material X has a larger ultimate tensile stress.

D Material X is brittle.

25 A steel wire and a brass wire are joined end to end and are hung vertically with the steel wire attached to a point on the ceiling. The steel wire is twice as long as the brass wire and has half the diameter.

A large mass is hung from the end of the brass wire so that both wires are stretched elastically.

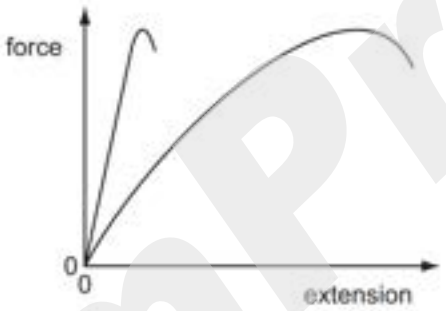
The Young modulus for steel is 2.0×10^{11} Pa and for brass is 1.0×10^{11} Pa.

What is the ratio of the extension of the steel to the extension of the brass?

A 2 **B** 4 **C** 8 **D** 16

October/November 2012 (12)

26 The diagram shows the force-extension graphs for two materials, of the same dimensions, loaded to fracture.



What describes the behaviour of the materials?

A Both materials are brittle.

B Both materials obey Hooke's law.

C Both materials are plastic.

D Both materials have the same ultimate tensile stress.

27 Two wires, X and Y, are made from different metals and have different dimensions. The Young modulus of wire X is twice that of wire Y. The diameter of wire X is half that of wire Y.

Both wires are extended with equal strain and obey Hooke's law.

What is the ratio $\frac{\text{tension in wire X}}{\text{tension in wire Y}}$?

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

October/November 2012 (13)

24 A trolley is held at rest between two steel springs.

Each spring has an unstretched length of 0.10 m.

Spring P has spring constant 60 N m^{-1}.
Spring Q has spring constant 120 N m^{-1}.

Spring P has an extension of 0.40 m.

What is the extension of spring Q?

A 0.10 m **B** 0.20 m **C** 0.30 m **D** 0.80 m

25 A lift is supported by two steel cables, each of length 10 m and diameter 0.5 cm.

The lift drops 1 mm when a man of mass 80 kg steps into the lift.

What is the best estimate of the value of the Young modulus of the steel?

A 2×10^{10} N m^{-2}

B 4×10^{10} N m^{-2}

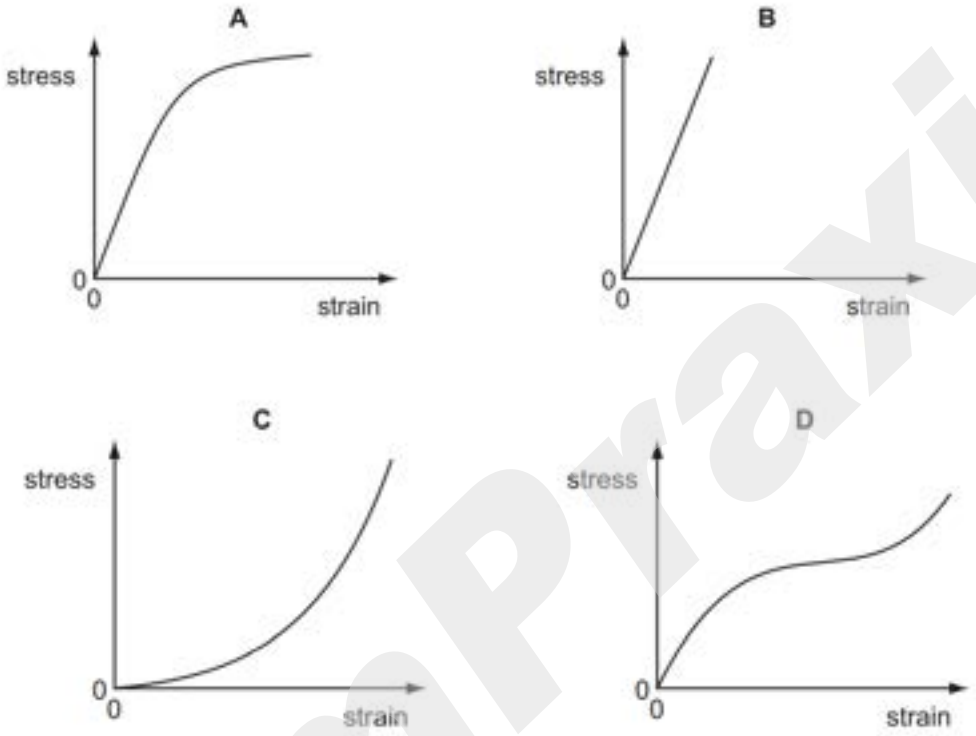
C 2×10^{11} N m^{-2}

D 4×10^{11} N m^{-2}

May/June 2013 (11)

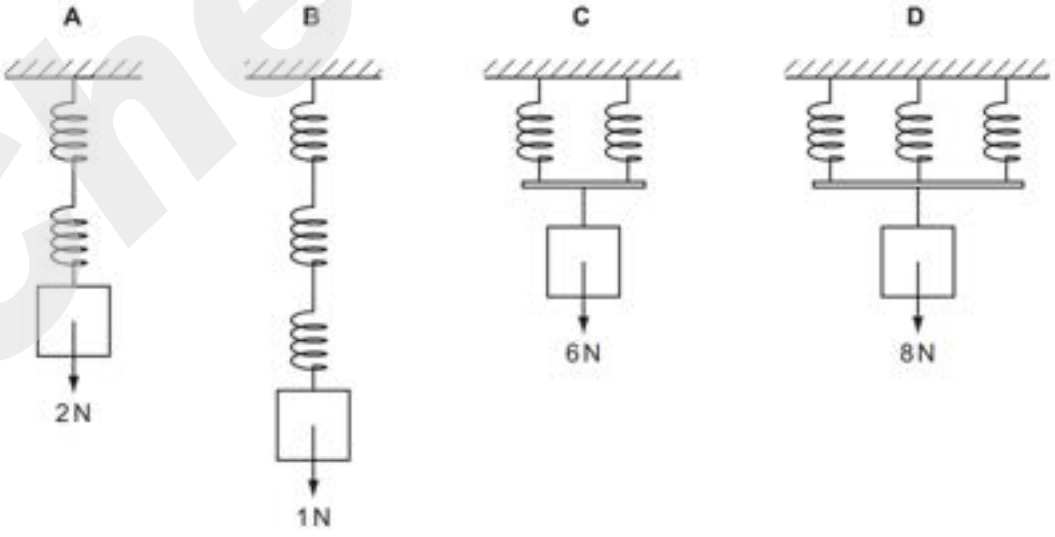
22 The stress-strain graphs for four different materials are shown below.

Which diagram shows the stress-strain graph for a ductile metal?



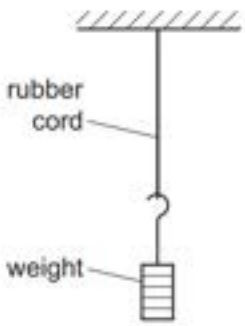
23 A number of identical springs, each having the same spring constant, are joined in four arrangements. A different load is applied to each arrangement.

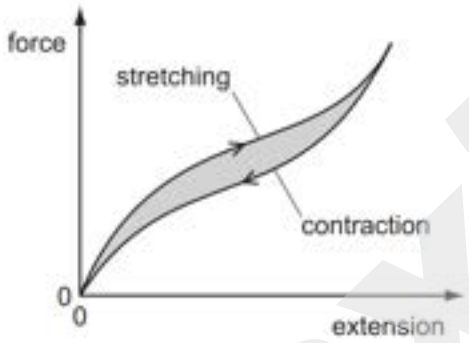
Which arrangement has the largest extension?



May/June 2013 (12)

22 A rubber cord hangs from a rigid support. A weight attached to its lower end is gradually increased from zero, and then gradually reduced to zero.





The force-extension curve for contraction is below the force-extension curve for stretching.

What does the shaded area between the curves represent?

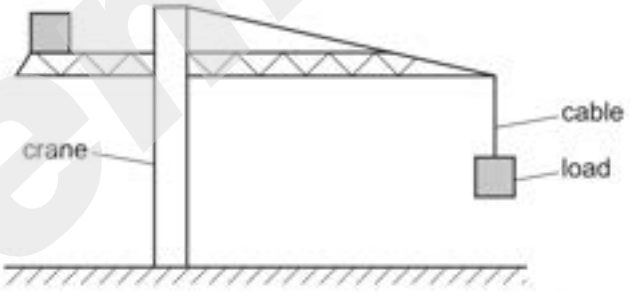
A the amount of elastic energy stored in the rubber

B the amount of thermal energy dissipated in the rubber

C the work done on the rubber cord during stretching

D the work done by the rubber cord during contraction

23 The diagram shows a large crane on a construction site lifting a cube-shaped load.



A model is made of the crane, its load and the cable supporting the load.

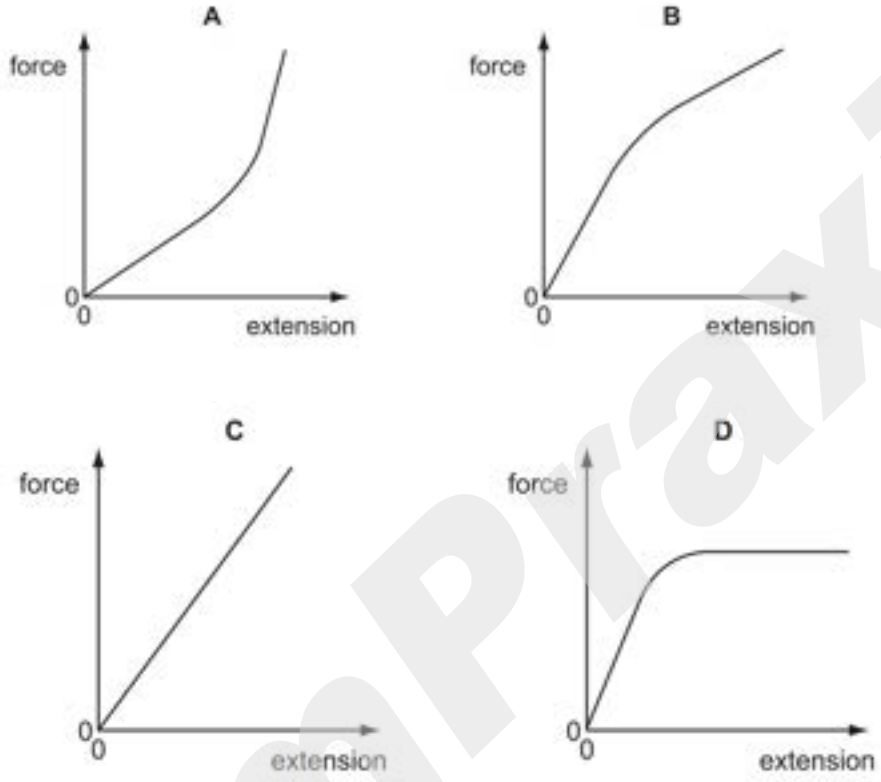
The material used for each part of the model is the same as that in the full-size crane, cable and load. The model is one tenth full-size in all linear dimensions.

What is the ratio $\frac{\text{stress in the cable on the full-size crane}}{\text{stress in the cable on the model crane}}$?

A 10^0 **B** 10^1 **C** 10^2 **D** 10^3

May/June 2013 (13)

20 Which graph represents the force-extension relationship of a rubber band that is stretched almost to its breaking point?



21 A spring is stretched over a range within which elastic deformation occurs. Its spring constant is $3.0\,N\,cm^{-1}$.

Which row, for the stated applied force, gives the correct extension and strain energy?

	force / N	extension / cm	strain energy / mJ
A	3.0	1.0	1.5
B	6.0	2.0	120
C	12.0	3.0	180
D	24.0	8.0	960

October/November 2013 (11) & October/November 2013 (12)

23 Which properties best describe modelling clay?

A brittle and ductile

B ductile and elastic

C elastic and plastic

D plastic and ductile

24 A steel spring has a spring constant of $150\,N\,m^{-1}$. When a 25 N weight is hung from the spring, it has a stretched length of 55 cm.

What was the original length of the spring?

A 0.38 m **B** 0.49 m **C** 0.61 m **D** 0.72 m

October/November 2013 (13)

22 A lift is supported by two steel cables each of length 20 m.

Each of the cables consists of 100 parallel steel wires, each wire of cross-sectional area $3.2 \times 10^{-6}\,m^2$. The Young modulus of steel is $2.1 \times 10^{11}\,N\,m^{-2}$.

Which distance does the lift move downward when a man of mass 70 kg steps into it?

A 0.010 mm **B** 0.020 mm **C** 0.10 mm **D** 0.20 mm

23 What is equal to the Young modulus of a material that is extended elastically within the limit of proportionality?

A area under the force-extension graph

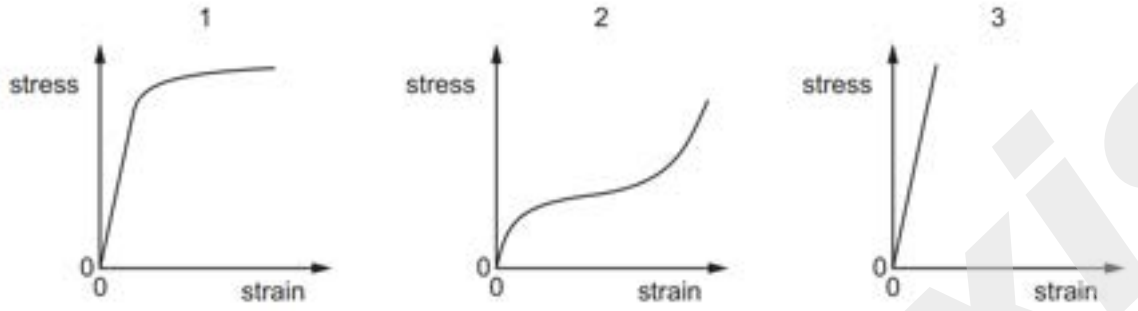
B area under the stress-strain graph

C gradient of the force-extension graph

D gradient of the stress-strain graph

May/June 2014 (11)

20 The stress-strain graphs for three different materials are shown, not drawn to the same scales.

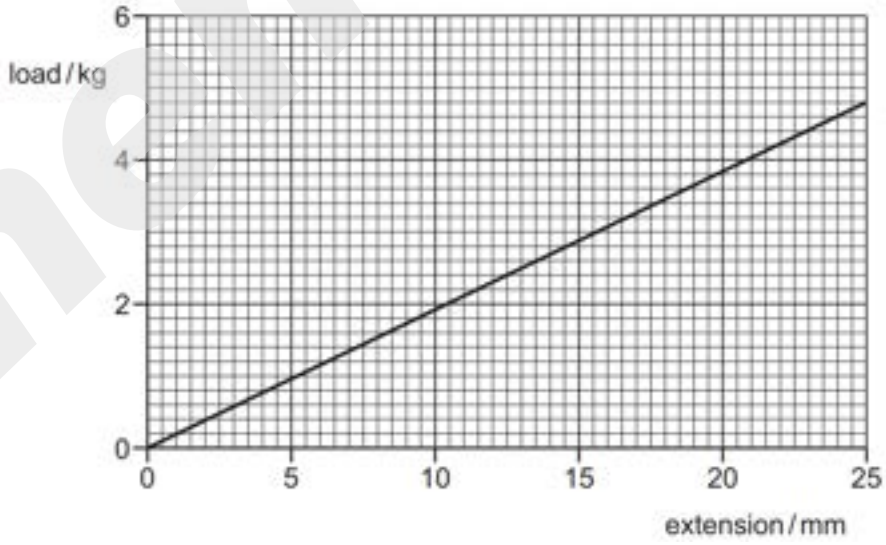


The three materials are copper, rubber and glass.

Which materials are represented by the graphs?

	1	2	3
A	copper	glass	rubber
B	copper	rubber	glass
C	glass	copper	rubber
D	glass	rubber	copper

21 The graph is a load-extension graph for a wire undergoing elastic deformation.

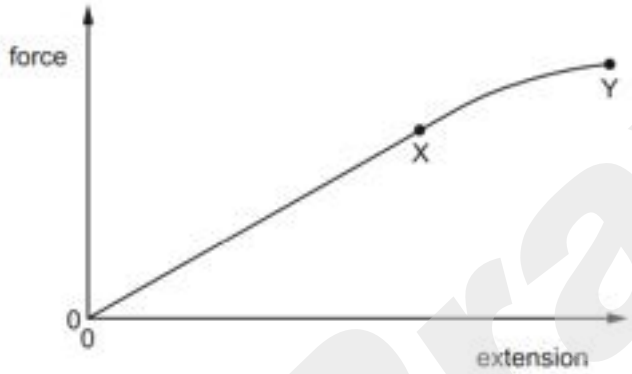


How much work is done on the wire to increase the extension from 10 mm to 20 mm?

A 0.028 J **B** 0.184 J **C** 0.28 J **D** 0.37 J

May/June 2014 (12)

19 A sample of metal is subjected to a force which increases to a maximum value and then decreases back to zero. A force-extension graph for the sample is shown.



When the sample contracts it follows the same force-extension curve as when it was being stretched.

What is the behaviour of the metal between X and Y?

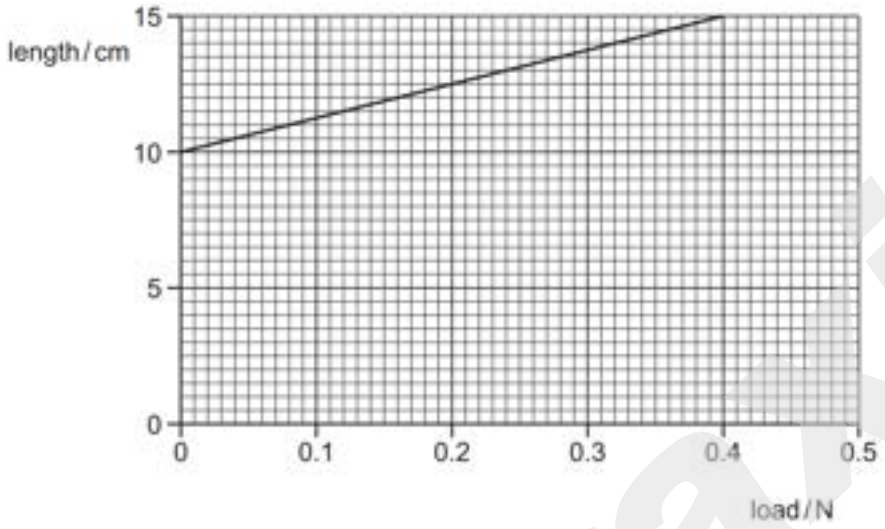
A both elastic and plastic

B not elastic and not plastic

C plastic but not elastic

D elastic but not plastic

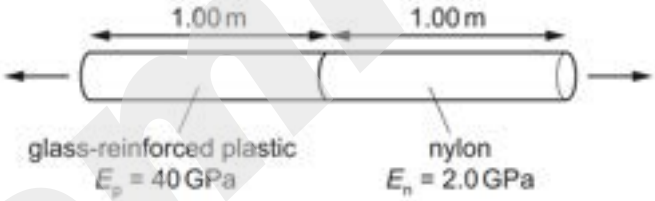
20 The graph shows the length of a spring as it is stretched by an increasing load.



What is the spring constant?

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

21 A composite rod is made by attaching a glass-reinforced plastic rod and a nylon rod end to end, as shown.



The rods have the same cross-sectional area and each rod is 1.00 m in length. The Young modulus E_p of the plastic is 40 GPa and the Young modulus E_n of the nylon is 2.0 GPa.

The composite rod will break when its total extension reaches 3.0 mm.

What is the greatest tensile stress that can be applied to the composite rod before it breaks?

A $7.1 \times 10^{-14}\,Pa$

B $7.1 \times 10^{-2}\,Pa$

C $5.7 \times 10^{6}\,Pa$

D $5.7 \times 10^{9}\,Pa$

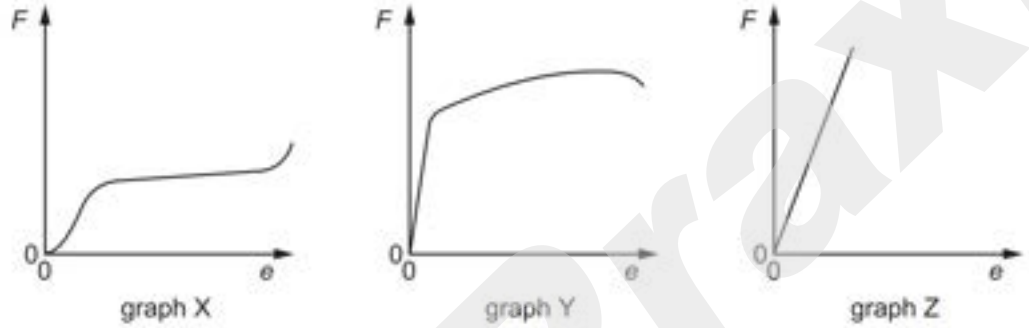
May/June 2014 (13)

23 An elastic material with a Young modulus E is subjected to a tensile stress S. Hooke's Law is obeyed.

What is the expression for the elastic energy stored per unit volume of the material?

A $\frac{S^2}{2E}$ **B** $\frac{S^2}{E}$ **C** $\frac{E}{2S^2}$ **D** $\frac{2E}{S^2}$

24 Cylindrical samples of steel, glass and rubber are each subjected to a gradually increasing tensile force F. The extensions e are measured and graphs are plotted as shown below.



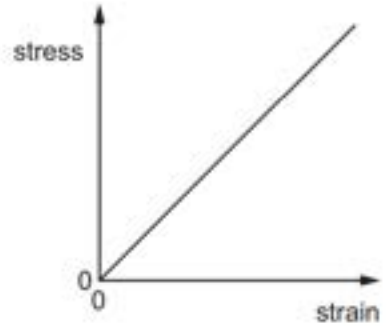
graph X graph Y graph Z

Which row correctly relates the graphs to the materials?

	steel	glass	rubber
A	X	Y	Z
B	X	Z	Y
C	Y	X	Z
D	Y	Z	X

October/November 2014 (11)

20 The stress-strain graph for a glass rod, up to the point at which it breaks, is shown below.



Which statement about the glass rod is correct?

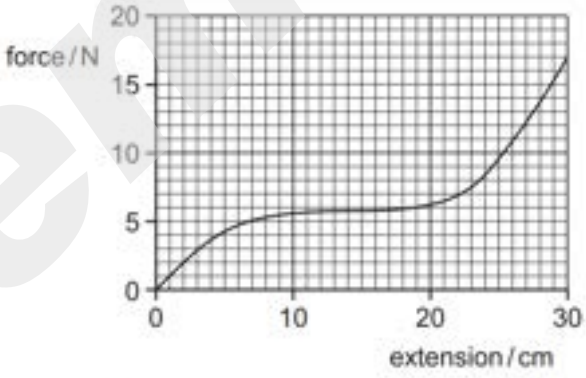
A Hooke's law is obeyed for all values of stress up to the breaking point.

B The glass is ductile.

C The glass shows plastic deformation.

D When the cross-sectional area of the rod is doubled, the ultimate tensile stress of the rod is halved.

21 A rubber band is stretched by hanging weights on it and the force-extension graph is plotted from the results.



What is the best estimate of the strain energy stored in the rubber band when it is extended 30 cm?

A 1.8 J **B** 2.6 J **C** 5.1 J **D** 200 J

October/November 2014 (12)

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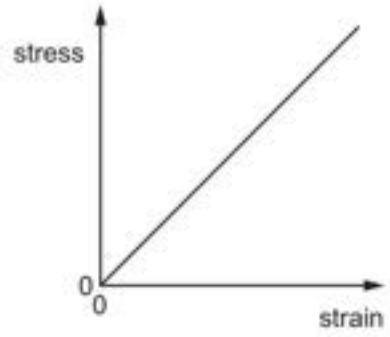

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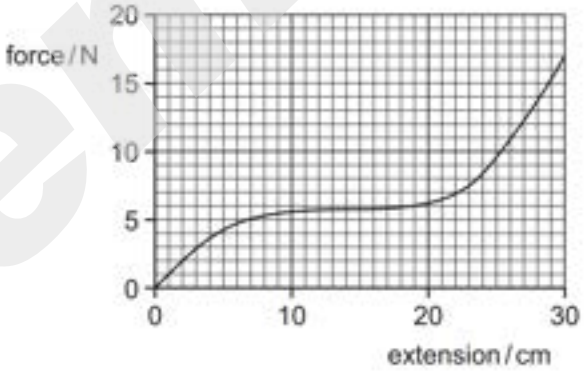

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October/November 2014 (13)

23 What is meant by the ultimate tensile stress of a material?

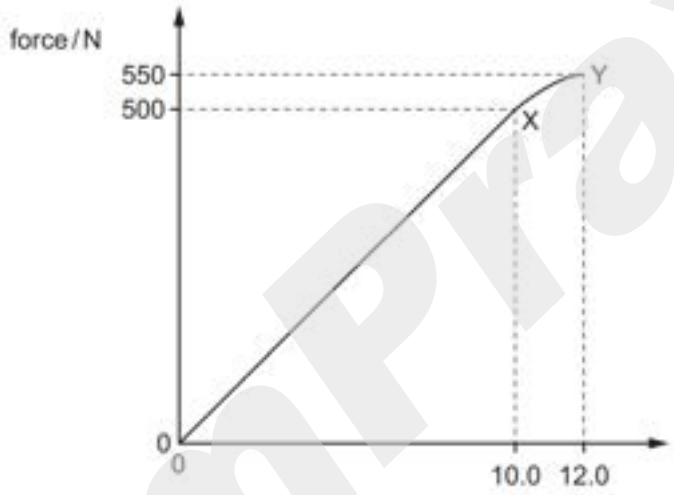
A the maximum force that can be applied to a bar of the material before it bends

B the maximum inter-atomic force before the atomic bonds of the material break

C the maximum stretching force per unit cross-sectional area before the material breaks

D the maximum tensile force in a wire of the material before it breaks

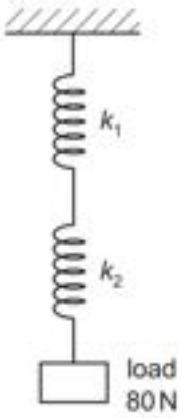
24 The graph shows the behaviour of a sample of a metal when it is stretched until it starts to undergo plastic deformation.



What is the total work done in stretching the sample from zero to 12.0 mm extension? Simplify the calculation by treating the curve XY as a straight line.

A 3.30 J **B** 3.55 J **C** 3.60 J **D** 6.60 J

25 Two springs, one with spring constant $k_1 = 4\,kN\,m^{-1}$ and the other with spring constant $k_2 = 2\,kN\,m^{-1}$, are connected as shown.



What is the total extension of the springs when supporting a load of 80 N?

A 1.3 cm **B** 4 cm **C** 6 cm **D** 60 cm

May/June 2015 (11)

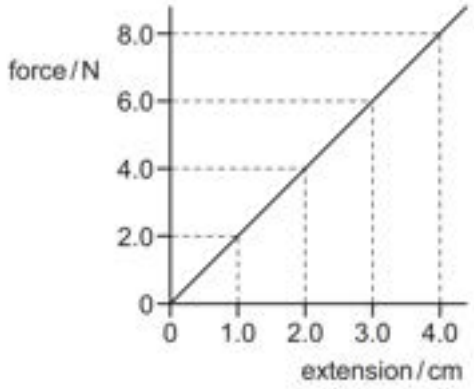
22 The graph shown was plotted in an experiment on a metal wire.

The shaded area represents the total strain energy stored in stretching the wire.

How should the axes be labelled?

	Y	X
A	force	extension
B	mass	extension
C	strain	energy
D	stress	strain

23 The variation with applied force of the extension of a spring is shown in the graph.



When there is no force applied to the spring, it has a length of 1.0 cm.

What is the **increase** in the strain energy stored in the spring when its length is increased from 2.0 cm to 3.0 cm?

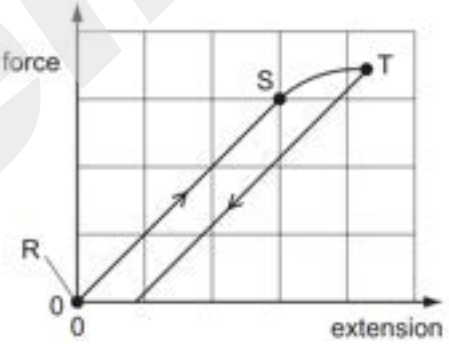
A 0.020 J **B** 0.030 J **C** 0.040 J D 0.050 J

May/June 2015 (12)

22 A long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

The load on the lower end is increased from zero and then decreased again back to zero.

The diagram shows the force-extension graph produced.



Where on the graph would the elastic limit be found?

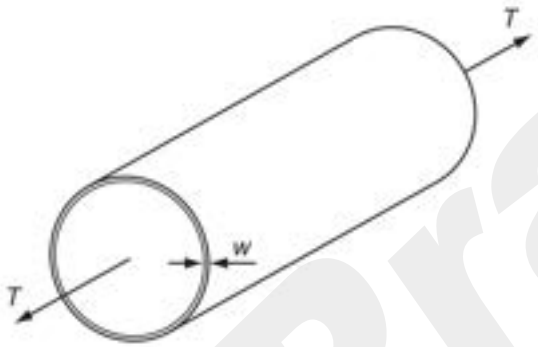
A anywhere between point R and point S

B just beyond point S

C exactly at point S

D exactly at point T

23 The diagram represents a steel tube with wall thickness *w* which is small in comparison with the diameter of the tube.



The tube is under tension, caused by a force *T*, parallel to the axis of the tube. To reduce the stress in the material of the tube, it is proposed to thicken the wall.

The tube diameter and the tension being constant, which wall thickness gives half the stress?

A $\frac{w}{2}$ **B** $\sqrt{2}\,w$ **C** $2w$ **D** $4w$

May/June 2015 (13)

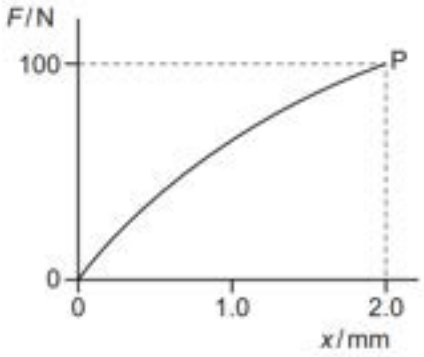
22 A steel bar of circular cross-section is under tension *T*, as shown.

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

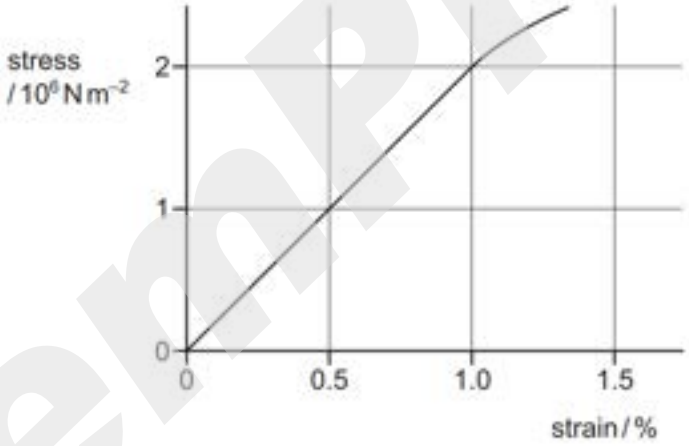
23 The graph shows the non-linear force-extension curve for a wire made from a new composite material.



What could be the value of the strain energy stored in the wire when it is stretched elastically to point P?

A 0.09 J **B** 0.10 J **C** 0.11 J **D** 0.20 J

24 The diagram shows the stress-strain graph for bone.



What is the Young modulus of bone?

A $1 \times 10^6\ N m^{-2}$

B $2 \times 10^6\ N m^{-2}$

C $1 \times 10^8\ N m^{-2}$

D $2 \times 10^8\ N m^{-2}$

October/November 2015 (11)

20 A known tensile force acts on a wire. The wire does not exceed its elastic limit.

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 wire's material and the extension of the wire

D the Young modulus of the wire's material and the unstretched length of the wire

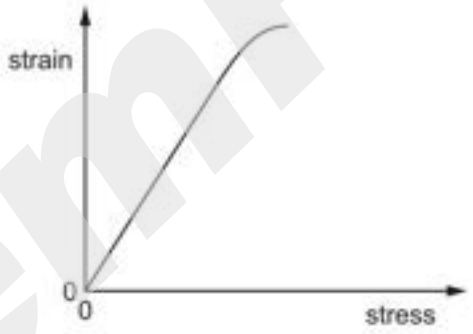
21 The Young modulus of steel is determined using a length of steel wire and is found to have the value E.

Another experiment is carried out using a wire of the same steel, but of half the length and half the diameter.

Which value is obtained for the Young modulus in the second experiment?

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

22 The graph shows the variation with stress of the strain of a material as it is extended elastically.



Why is the strain energy per unit volume of the material **not** the area under the graph?

A The axes are the wrong way round.

B The graph is not a straight line.

C The graph is strain-stress instead of extension-force.

D The material is polymeric.

23 A wire has a final length of 6.0 m after undergoing a strain of 200%.

What is the original length of the wire?

A 1.5 m **B** 2.0 m **C** 3.0 m **D** 4.0 m

October/November 2015 (12)

21 A force acts on a wire to produce extension *e*. The same force then acts on a second wire of the same material, but of half the diameter and three times the length of the first wire. Both wires obey Hooke's law.

What is the extension of the second wire?

A 3*e* **B** 4*e* **C** 6*e* **D** 12*e*

22 Which statement about elastic and plastic deformation is correct?

A Elastic deformation and plastic deformation are proportional to the applied force.

B Elastic deformation and plastic deformation cause no change in volume.

C Elastic deformation causes heating of the material but plastic deformation does not.

D Elastic deformation is reversible but plastic deformation is not.

23 What is meant by the *ultimate tensile stress* of a ductile metal?

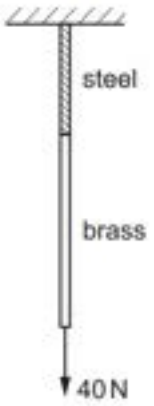
A It is the maximum stress at which the material deforms elastically.

B It is the maximum stress at which the material obeys Hooke's law.

C It is the maximum stress that the material can support without breaking.

D It is the Young modulus multiplied by the maximum possible strain of a material.

24 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 extend without reaching their elastic limits.

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

October/November 2015 (13)

20 The Young modulus of a metal may be determined from the ratio $\frac{\text{stress}}{\text{strain}}$ when the metal is stretched elastically. This can be done by making measurements when loads are added to a wire.

Which measurements are needed to calculate the stress and strain of the wire in such an experiment?

	stress		strain	
A	wire diameter	initial and final positions of load	wire's original length	mass added
B	wire diameter	mass added	wire's original length	initial and final positions of load
C	wire's original length	initial and final positions of load	wire diameter	mass added
D	wire's original length	mass added	wire diameter	initial and final positions of load

21 A copper wire of length 3.6 m and diameter 1.22 mm is stretched elastically by a force of 37 N. The Young modulus of copper is 1.17×10^{11} Pa.

Which extension is caused by this force?

A 0.24 mm **B** 0.76 mm **C** 0.97 mm **D** 3.1 mm