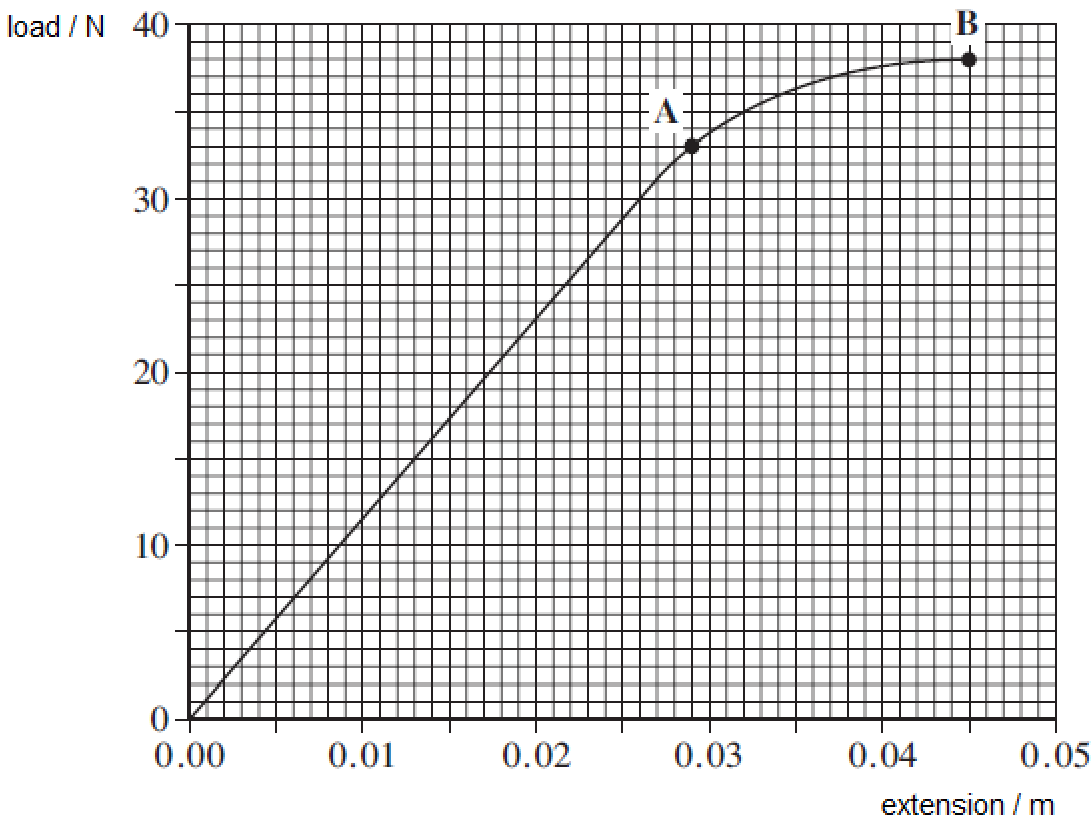
Unit 10 Elastic Properties of Solids

201 minutes

199 marks

Q1. A manufacturer of springs tests the properties of a spring by measuring the load applied each time the extension is increased. The graph of load against extension is shown below.



(a) State Hooke's law.

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(2)

(b) Calculate the spring constant, *k*, for the spring. State an appropriate unit.

spring constant .... unit ....

(3)

(c) Use the graph to find the work done in extending the spring up to point **B**.

work done .... J

(3)

(d) Beyond point **A** the spring undergoes *plastic deformation*.

Explain the meaning of the term plastic deformation.

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(1)

(e) When the spring reaches an extension of 0.045 m, the load on it is gradually reduced to zero. On the graph above sketch how the extension of the spring will vary with load as the load is reduced to zero.

(2)

(f) Without further calculation, compare the total work done by the spring when the load is removed with the work that was done by the load in producing the extension of 0.045 m.

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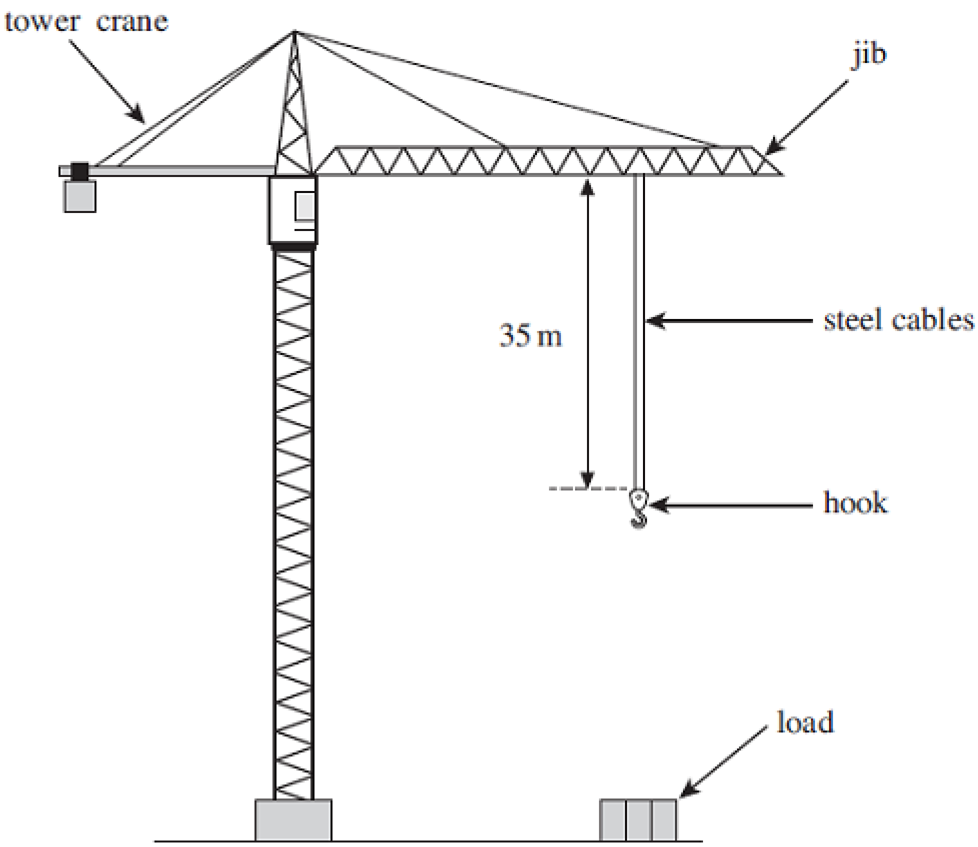
(1)
(Total 12 marks)

Q2. The diagram below shows a tower crane that has two identical steel cables. The length of each steel cable is 35 m from the jib to the hook.



(a) Each cable has a mass of 4.8 kg per metre. Calculate the weight of a 35 m length of one cable.

weight = ... N

(2)

(b) The cables would break if the crane attempted to lift a load of 1.5×10^6 N or more. Calculate the breaking stress of **one** cable.

cross-sectional area of each cable = 6.2×10^{-4} m^2

breaking stress = ... Pa

(2)

(c) When the crane supports a load **each** cable experiences a stress of 400 MPa. Each cable obeys Hooke's law. Ignore the weight of the cables.

Young modulus of steel = 2.1×10^{11} Pa

(i) Calculate the weight of the load.

weight = ... N

(2)

(ii) The unstretched length of each cable is 35 m.

Calculate the extension of each cable when supporting the load.

extension = ... m

(3)

(iii) Calculate the combined stiffness constant, *k*, for the **two** cables.

stiffness constant = ... Nm^{-1}

(2)

(iv) Calculate the total energy stored in both stretched cables.

energy stored = ... J

(2)

(Total 13 marks)

Q3. (a) Describe an experiment to accurately determine the spring constant *k* of a spring that is thought to reach its limit of proportionality when the load is about 20 N.

Include details of the necessary measurements and calculations and describe how you would reduce uncertainty in your measurements. A space is provided for a labelled diagram should you wish to include one.

The quality of your written communication will be assessed in this question.

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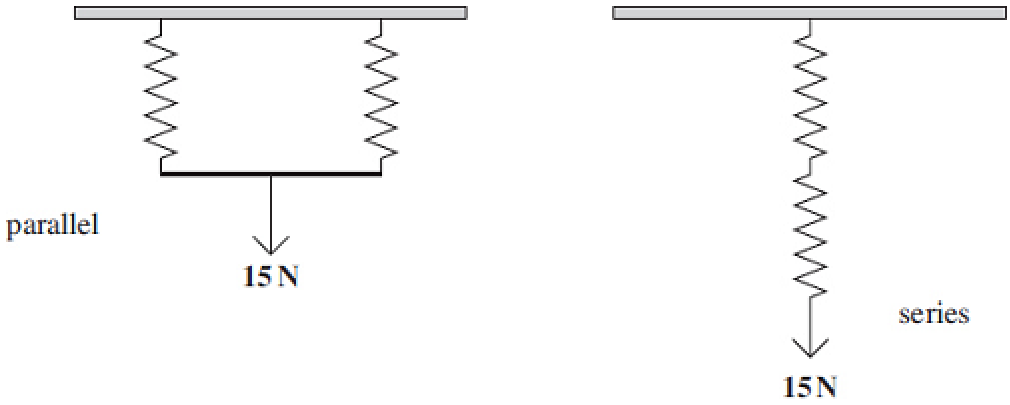
(6)

(b) Two identical springs, each having a spring constant of 85 Nm^{-1}, are shown arranged in parallel and series in the figure below.



A load of 15 N is attached to each arrangement.

(i) Calculate the extension for the parallel arrangement when the load is midway between the lower ends of the springs.

answer = ... m

(2)

(ii) Calculate the extension for the series arrangement.

answer = ... m

(2)

(iii) Calculate the energy stored in the parallel arrangement.

answer = ... J

(2)

(iv) Without further calculation, discuss whether the energy stored in the series arrangement is less, or greater, or the same as in the parallel arrangement.

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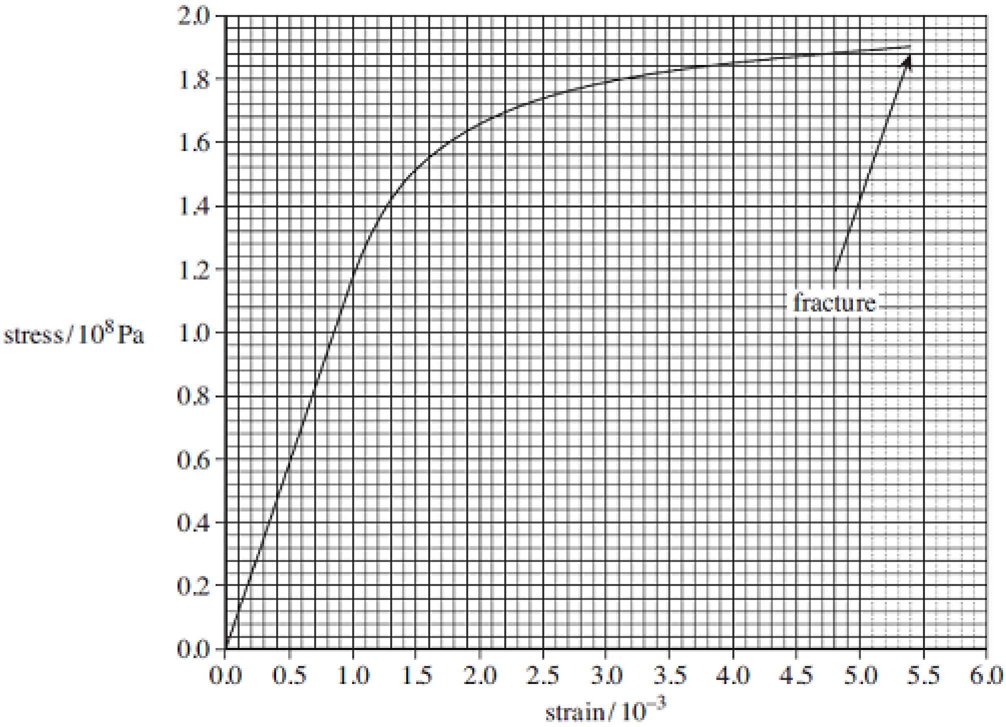
(3)
(Total 15 marks)

Q4. The figure below shows a stress-strain graph for a copper wire.



(a) Define tensile strain.

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....

(1)

(b) State the breaking stress of this copper wire.

answer = ... Pa

(1)

(c) Mark on the figure above a point on the line where you consider plastic deformation may start.Label this point **A**.

(1)

(d) Use the graph to calculate the Young modulus of copper. State an appropriate unit for your answer.

answer = ...

(3)

(e) The area under the line in a stress-strain graph represents the work done per unit volume to stretch the wire.

(i) Use the graph to find the work done per unit volume in stretching the wire to a strain of 3.0×10^{-3}.

answer = ...J m^{-3}

(2)

(ii) Calculate the work done to stretch a 0.015 kg sample of this wire to a strain of 3.0×10^{-3}.

The density of copper = 8960 kg m^{-3}.

answer = ...J

(2)

(f) A certain material has a Young modulus greater than copper and undergoes brittle fracture at a stress of 176 MPa.

On the figure above draw a line showing the possible variation of stress with strain for this material.

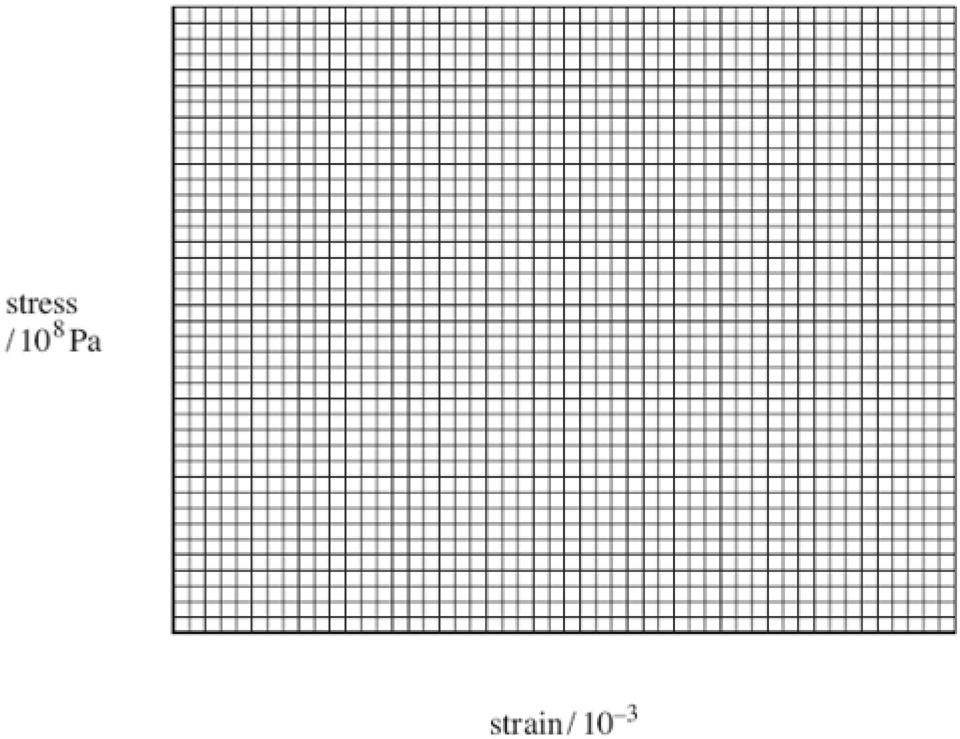
(2)
(Total 12 marks)

Q5. The table below shows the results of an experiment where a force was applied to a sample of metal.

(a) On the axes below, plot a graph of stress against strain using the data in the table.

Strain/	0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00

10^{-3}											
Stress $/10^{8}$ Pa	0	0.90	2.15	3.15	3.35	3.20	3.30	3.50	3.60	3.60	3.50



(3)

(b) Use your graph to find the Young modulus of the metal.

answer = ... Pa

(2)

(c) A 3.0 m length of steel rod is going to be used in the construction of a bridge. The tension in the rod will be 10 kN and the rod must extend by no more than 1.0mm. Calculate the minimum cross-sectional area required for the rod.

Young modulus of steel = 1.90×10^{11} Pa answer = ... m^2

(3)
(Total 8 marks)

Q6. (a) Describe how to obtain, accurately by experiment, the data to determine the Young modulus of a metal wire.

A space is provided for a labelled diagram.

The quality of your written answer will be assessed in this question.

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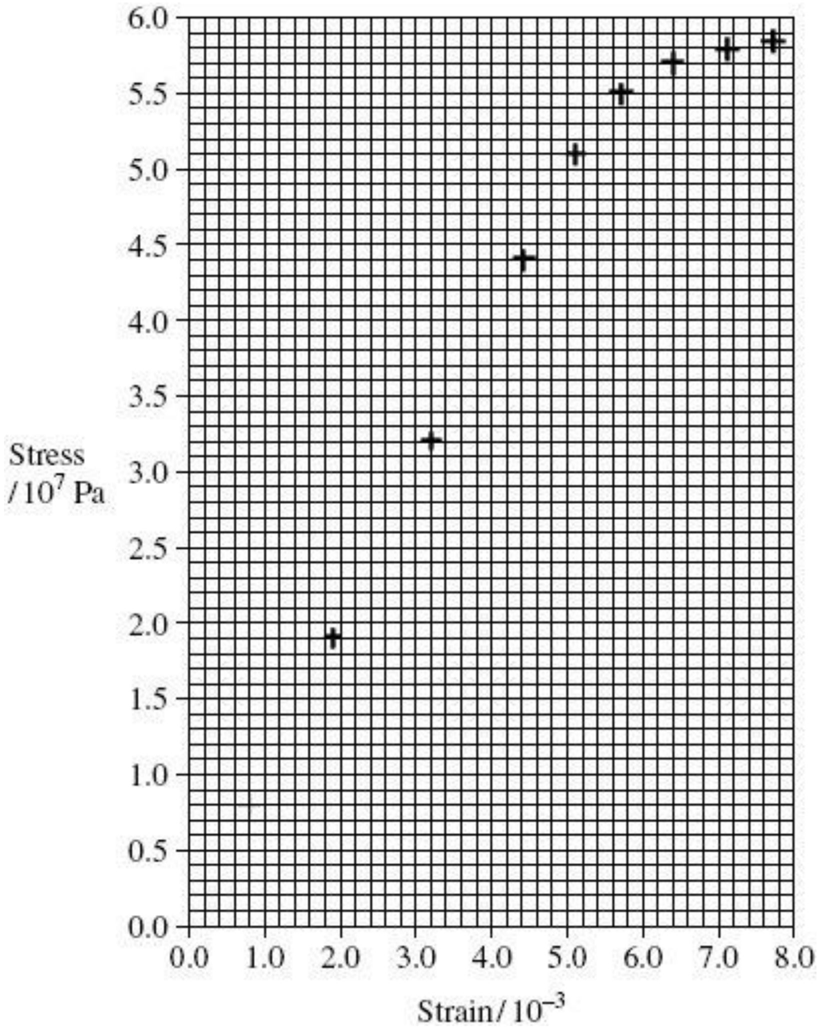
(6)

(b) The diagram below is a plot of some results from an experiment in which a metal wire was stretched.



(i) Draw a best-fit line using the data points.

(1)

(ii) Use your line to find the Young modulus of the metal, stating an appropriate unit.

answer = ...

(4)

(c) After reaching a strain of 7.7×10^{-3}, the wire is to be unloaded. On the diagram above, sketch the line you would expect to obtain for this.

(1)
(Total 12 marks)

Q7. (a) State Hooke's law.

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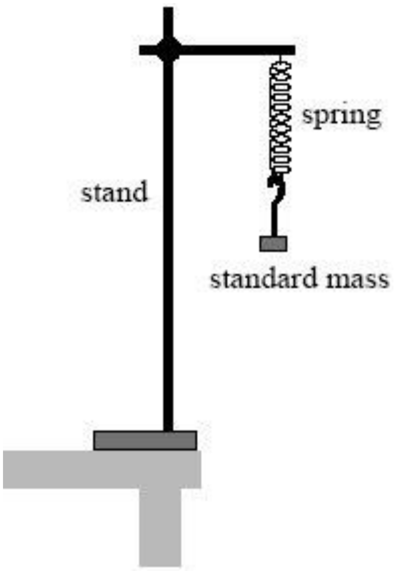
(2)

(b) A student is asked to measure the mass of a rock sample using a steel spring, standard masses and a metre rule. She measured the unstretched length of the spring and then set up the arrangement shown in the diagram below.



(i) Describe how you would use this arrangement to measure the mass of the rock sample. State the measurements you would make and explain how you would use the measurements to find the mass of the rock sample.The quality of your written communication will be assessed in this question.

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(6)

(ii) State and explain **one** modification you could make to the arrangement in the diagram above to make it more stable.

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(2)
(Total 10 marks)

Q8. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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(ii) Explain what is meant by the elastic limit of the wire.

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(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire. A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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(6)
(Total 11 marks)

Q9. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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(ii) Explain what is meant by the elastic limit of the wire.

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(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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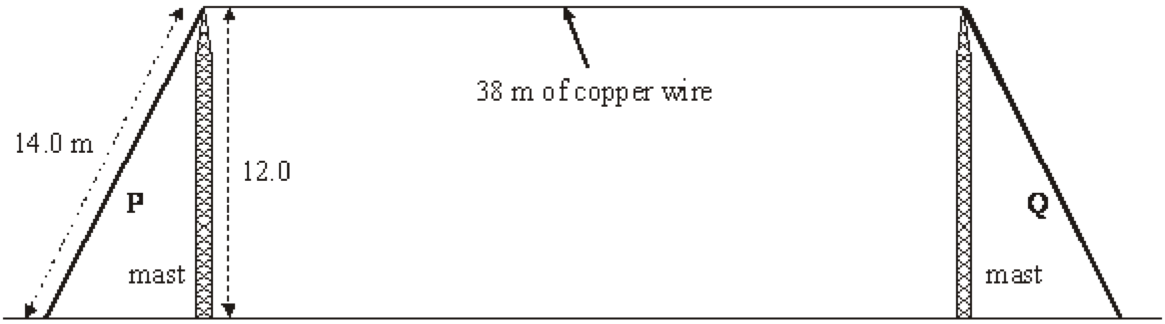
(6)
(Total 11 marks)

Q10. An aerial system consists of a horizontal copper wire of length 38 m supported between two masts, as shown in the figure below. The wire transmits electromagnetic waves when an alternating potential is applied to it at one end.



(a) The wavelength of the radiation transmitted from the wire is twice the length of the copper wire. Calculate the frequency of the transmitted radiation.

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(1)

(b) The ends of the copper wire are fixed to masts of height 12.0 m. The masts are held in a vertical position by cables, labelled **P** and **Q**, as shown in the figure above.

(i) **P** has a length of 14.0 m and the tension in it is 110 N. Calculate the tension in the copper wire.

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(ii) The copper wire has a diameter of 4.0 mm. Calculate the stress in the copper wire.

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(iii) Discuss whether the wire is in danger of breaking if it is stretched further due to movement of the top of the masts in strong winds.

breaking stress of copper = 3.0×10^8 Pa

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(7)
(Total 8 marks)

Q11. (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, …...

....

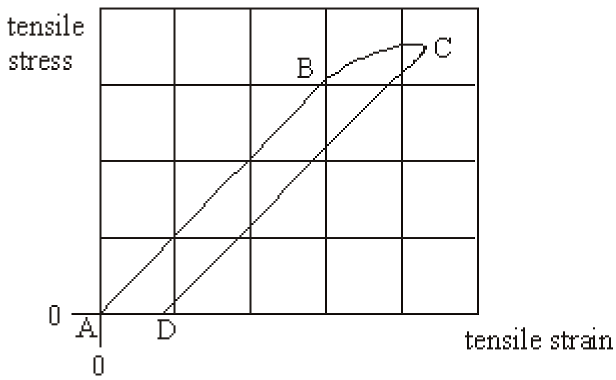
tensile strain. ....

....

(2)

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

As the load on the lower end is increased from zero to a certain value, and then decreased again to zero, the variation of the resulting tensile strain with the applied tensile stress is shown in the graph.



(i) Describe the behaviour of the wire during this process. Refer to the points A, B, C and D in your answer.You may be awarded marks for the quality of written communication in your answer.

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(ii) State, with a reason, whether the material of the wire is ductile or brittle.

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(iii) What does AD represent?

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(iv) State how the Young modulus for the material may be obtained from the graph.

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(v) State how the energy per unit volume stored in the wire during the loadingprocess may be estimated from the graph.

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(9)

(c) The wire described in part (b) has an unstretched length of 3.0 m and cross-sectional area 2.8×10^{-7} m^2. At a certain stage between the points A and B on the graph, the wire supports a load of 75 N. Calculate the extension produced in the wire by this load.
the Young modulus for the material of the wire = 2.1×10^{11} Pa

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(2)

(Total 13 marks)

Q12. (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

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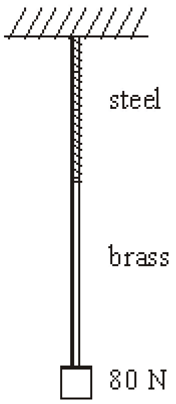
(2)

(b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in the figure below.



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

length of the steel wire = 0.80 mlength of the brass wire = 1.40 mthe Young modulus for steel = 2.0×10^{11} Pathe Young modulus for brass = 1.0×10^{11} Pa

(i) Calculate the total extension produced when the force of 80 N is applied.

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(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = 7.9×10^3 kg m^{-3}

density of brass = 8.5×10^3 kg m^{-3}

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(7)

(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

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(2)
(Total 11 marks)

Q13. (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* is measured.

(i) State the meaning of

tensile stress ....

....

tensile strain ....

....

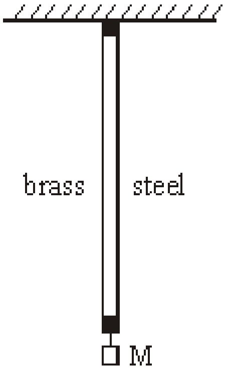
(ii) Define the Young modulus ....

....

(3)

(b) The diagram below shows two wires, one made of steel and the other of brass, firmly clamped together at their ends. The wires have the same unstretched length and thesame cross-sectional area.One of the clamped ends is fixed to a horizontal support and a mass

M is suspended from the other end, so that the wires hang vertically.



(i) Since the wires are clamped together the extension of each wire will be the same. If E_S is the Young modulus for steel and E_B the Young modulus for brass, show that

$$\frac{E_S}{E_B} = \frac{F_S}{F_B},$$

where F_S and F_B are the respective forces in the steel and brass wire.

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(ii) The mass M produces a total force of 15 N. Show that the magnitude of the force F_S = 10 N.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

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(iii) The cross-sectional area of each wire is 1.4×10^{-6} m^2 and the unstretched length is 1.5 m. Determine the extension produced in either wire.

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(6)

(Total 9 marks)

Q14. (a) State *Hooke's law* for a material in the form of a wire.

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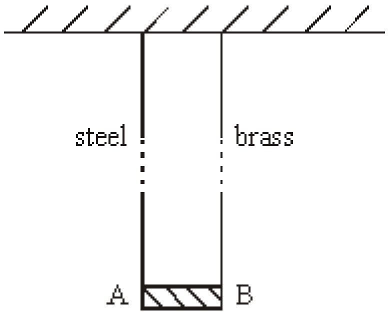
(2)

(b) A rigid bar AB of negligible mass, is suspended horizontally from two long, vertical wires as shown in the diagram. One wire is made of steel and the other of brass. The wires are fixed at their upper end to a rigid horizontal surface. Each wire is 2.5 m long but they have different cross-sectional areas.



When a mass of 16 kg is suspended from the centre of AB, the bar remains horizontal.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) What is the tension in each wire?

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(ii) If the cross-sectional area of the steel wire is 2.8×10^{-7} m^2, calculate the extension of the steel wire.

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(iii) Calculate the cross-sectional area of the brass wire.

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(iv) Calculate the energy stored in the steel wire.

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(7)

(c) The brass wire is replaced by a steel wire of the same dimensions as the brass wire. The same mass is suspended from the midpoint of AB.

(i) Which end of the bar is lower?

....

(ii) Calculate the vertical distance between the ends of the bar.

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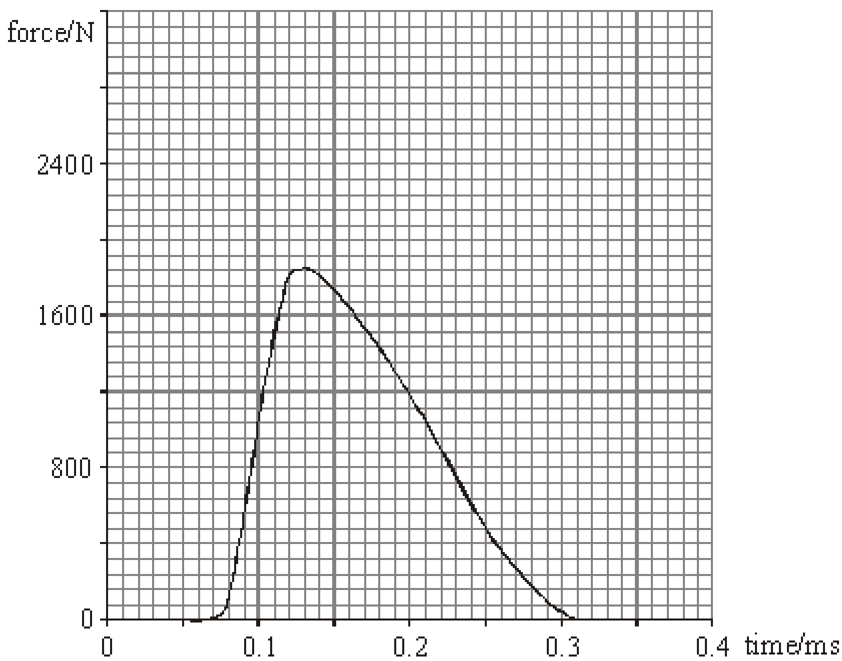
(2)
(Total 11 marks)

Q15. The diagram below shows how the impact force on the heel of a runner's foot varies with time during an impact when the runner is wearing cushioned sports shoes.



(a) Estimate the maximum stress on the cartilage pad in the knee joint as a result of this force acting on the cartilage pad over a contact area of 550 mm^2.

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(4)

(b) On the diagram above, sketch the graph of force against time you would expect to see if a sports shoe with less cushioning had been used.

(3)
(Total 7 marks)

Q16. (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

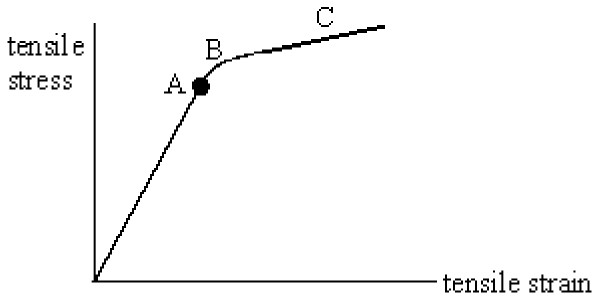
....

tensile strain. ....

....

(2)

(b) A long thin line metallic wire is suspended from a fixed support and hangs vertically. Weights are added to increase the load on the free end of the wire until the wire breaks. The graph below shows how the tensile strain in the wire increases as the tensile stress increases.



With reference to the graph, describe the behaviour of the wire as the load on the free end is increased. To assist with your answer refer to the point A, and regions B and C.

You may be awarded marks for the quality of written communication in your answer.

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(5)
(Total 7 marks)

Q17. (a) Define the *density* of a material.

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(1)

(b) Brass, an alloy of copper and zinc, consists of 70% **by volume** of copper and 30% **by volume** of zinc.

density of copper $= 8.9 \times 10^3$ kg m^{-3}
density of zinc $= 7.1 \times 10^3$ kg m^{-3}

(i) Determine the mass of copper and the mass of zinc required to make a rod of brass of volume 0.80×10^{-3} m^3.

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(ii) Calculate the density of brass.

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(4)
(Total 5 marks)

Q18. A material in the form of a wire, 3.0 m long and cross-sectional area = 2.8×10^{-7} m^2 is suspended from a support so that it hangs vertically. Different masses may be suspended from its lower end. The table shows the extension of the wire when it is subjected to an increasing load and then a decreasing load.

load/N	0	24	52	70	82	88	94	101	71	50	16	0
extension/mm	0	2.2	4.6	6.4	7.4	8.2	9.6	13.0	10.2	8.0	4.8	3.2

(a) Plot a graph of load (on *y* axis) against extension (on *x* axis) both for increasing and decreasing loads.

(Allow one sheet of graph paper)

(4)

(b) Explain what the shape of the graph tells us about the behaviour of the material in the wire. You may be awarded marks for the quality of written communication in your answer.

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(4)

(c) Using the graph, determine a value of the Young modulus for the material of the wire.

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(3)

(d) State how the graph can be used to estimate the energy stored during the loading process.

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(1)
(Total 12 marks)

Q19. A uniform wooden beam of mass 35.0 kg and length 5.52 m is supported by two identical vertical steel cables **A** and **B** attached at either end, as shown in **Figure 1**.

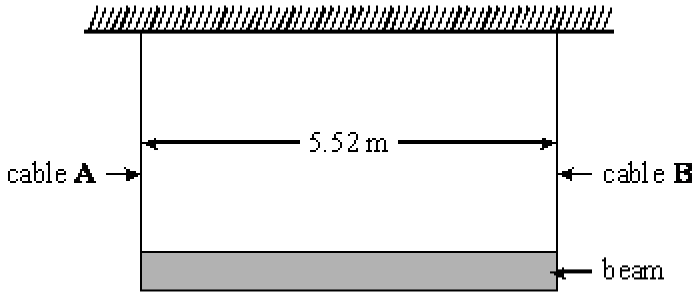

Figure 1

(a) Calculate

(i) the weight of the beam,

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(ii) the tension in each cable.

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(2)

(b) Each unstretched cable has a diameter of 8.26 mm and a length 2.50 m. Calculate the extension of each cable when supporting the beam.

The Young modulus for steel = 2.10×10^{11} Pa

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(4)

(c) An object of mass 20.0 kg is hung from the beam 1.00 m from cable **A**, as shown in **Figure 2**.

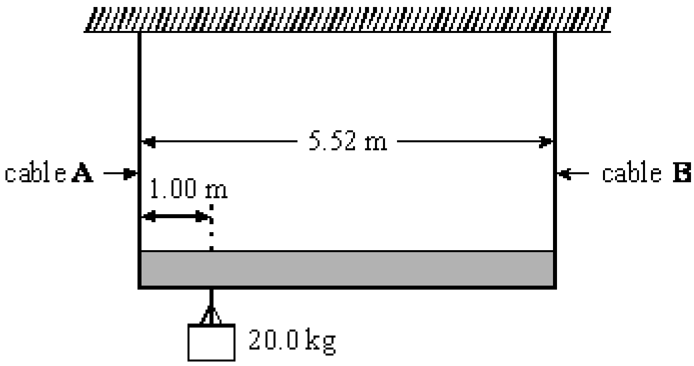

Figure 2

(i) Show that the new tension in cable **A** is 332 N.

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(ii) Calculate the new tension in cable **B**.

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(6)
(Total 12 marks)

M1.(a) Force proportional to extension ✓

up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark

Symbols must be definedAccept word equationallow ‘F=kΔL (or F ∝ ΔL) up to the limit of proportionality ’ ***for the second mark only*** *allow stress ∝ strain up to the limit of proportionality’* ***for the second mark only***

2

(b) Gradient clearly attempted / use of $k=F / \Delta L$ ✓

k = 30 / 0.026 = 1154
or 31 / 0.027 = 1148

correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200)

1100 or 1200 with no other working gets 1 out of 2

OR <u>1154 ± 6</u> seen

Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark.

AND <u>load used >= 15</u> ✓ (= 1100 or 1200 (2sf))

32 / 0.028 is outside tolerance. 32/0.0277 is just inside.

Nm^{-1} / N / m (newtons per metre) ✓ (not n / m, n / M, N / M)

3

(c) any area calculated or link energy with area / use of 1 / 2FΔL ✓

(or 0.001 Nm for little squares)

35 whole squares, 16 part gives 43 ± 1.0
OR equivalent correct method to find whole area ✓

0.025 Nm per (1cm) square × candidates number of squares and correctly evaluated OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓

3

(d) permanent deformation / permanent extension ✓

Allow: ‘doesn’t return to original length’; correct reference to ‘yield’
*e.g. allow ‘**extension beyond the yield point**’*
do not accept: ‘does not obey Hooke’s law’ or ‘ceases to obey Hooke’s law’,

1

(e) any line from B to a point on the x axis from 0.005 to 0.020 ✓

straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓

2

(f) work done by spring < work done by the load

Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

1

[12]

M2.(a) ($W = mg$)

$= 4.8 \times 35 \times 9.81$ ✓

$=1600$ (1648 N) ✓

Allow g=10 : 1680 (1700 N)

g = 9.8 → 1646 N

max 1 for doubling or halving.

Max 1 for use of grammes

2

(b) (stress = tension / area)

For first mark, forgive absence of or incorrect doubling / halving.

$= (0.5 \times)\ 1.5 \times 10^6 / 6.2 \times 10^{-4}$ OR $= 1.5 \times 10^6 / (2 \times)\ 6.2 \times 10^{-4}$ ✓

$= 1.2 \times 10^9$ (1.21 GPa) ✓

Forgive incorrect prefix if correct answer seen.

2

(c) (i) (weight = stress × area)

max 1 mark for incorrect power of ten in first marking point

$= 400 \times (10^6) \times 6.2 \times 10^{-4}$ (= 248 000 N) ✓

max 1 mark for doubling or halving both stress and area

$(\times 2 =)$ 5.0×10^5 (496 000 N) ✓

Forgive incorrect prefix if correct answer seen.Look out for YM ÷ 400k Pa which gives correct answer but scores zero.

2

(ii) $\Delta L = \frac{F\ L}{A\ E}$ **OR** correct substitution into a correct equation (forgive incorrect doubling or halving for this mark only ✓

OR alternative method:

strain = stress / E

then ΔL = L × strain

$= \frac{(\text{Ans 4ci}/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}}$ **OR** $\frac{\text{Ans 4ci} \times 35}{2 \times 6.2\times10^{-4} \times 2.1\times 10^{11}}$ ✓ ecf from 4ci

If answer to 4ci is used, it must be halved, unless area is doubled, for this mark

$\left(= \frac{(4.96\times10^5/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}} = \right)$ 6.7×10^{-2} (6.667×10^{-2} m) ✓ ecf from 4ci

Any incorrect doubling or halving is max 1 mark.

Allow 0.07

3

(iii)

$\left(k = \frac{F}{\Delta L} \right)$

$= \frac{2 \times 248\,000}{6.667 \times 10^{-2}}$ OR correct substitution into $F=k\Delta L$ ✓ ecf ci and cii (answer 4c(i) ÷ answer 4c(ii))

Allow halving extension for force on one cable

$= 7.4(4) \times 10^{6}$ ✓(Nm^{-1})

Correct answer gains both marks

2

(iv) $\left(E = \frac{1}{2}F\Delta L \text{ or } E = \frac{1}{2}k\Delta L^2 \right)$

Correct answer gains both marks

$= ½ \times 496\,000 \times 6.667 \times 10^{-2}$ OR $½ \times 7.4(4) \times 10^{6} \times (6.667 \times 10^{-2})^{2}$ ✓ ecf ci, cii, ciii

$= 1.6(5) \times 10^{4}$ (J) ✓

Forgive incorrect prefix if correct answer seen.

Doubling the force gets zero.

2

[13]

M3. (a) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.** The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

Candidate must suggest

- drawing a graph of F vs ΔL (or *vice versa*)
- AND that k is in some way linked to the gradient
- AND use of a suitable named instrument to measure or determine extension
- AND 1 further means of reducing uncertainty: repeats / minimum 8 different readings / use of vernier scale / check values of mass with balance / parallax elimination with set square, pointer in contact with scale, mirror.

For 6 marks:

must also give suitable range at least up to 10N but not beyond 20N (accept ‘up to 20N’ / ‘not beyond 20N’)

AND minimum **8 different readings** OR **parallax** elimination must be included

AND **repeats** must be included

AND correctly explains how *k* is obtained from their graph.

Intermediate Level (Modest to adequate): 3 or 4 marks

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

Candidate must suggest:

- to measure / determine extension OR initial and final length
- AND to use $F = k\,\Delta L$ or $k = F / \Delta L$
  OR drawing a graph of F vs ΔL (or *vice versa*)
- AND use of suitable **instrument** to measure extension
  OR 1 means of reducing **uncertainty**:
  repeats / use of vernier scale / check values of mass with balance / parallax elimination with set square, pointer in contact with scale,
  mirror / minimum 8 different readings / graphical approach

For 4 marks, **uncertainty** comment AND **instrument** required

Low Level (Poor to limited): 1 or 2 marks

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.

Any relevant statement from the marking points above

For 2 marks: must mention minimum two points including:

- to measure / determine extension OR initial and final length

6

(b) (i) ($k = 2 \times 85 = 170$ (N m^{-1}))

($\Delta L = F / k =$) 15 / 170 (or 7.5 / 85) ✓

= 0.088 ✓ (m) (0.0882)

2

(ii) ($k = ½ \times 85 = 42.5$)

($\Delta L = F / k =$) 15/42.5 (or 2 x 15/85) ✓

= 0.35 ✓ (m) (0.3529)

2

(iii) (W = ½ $F\Delta L$ or ½ $k\ \Delta L^2$)

= ½ × 15 × 0.0882 (or 2 x ½ × 7.5 × 0.0882) ✓ ecf 5bi

= 0.66 ✓ (J) (0.6615) ecf 5bi

2

(iv) (series) **greater** ✓ ecf for answer 'less' or 'same' where candidates incorrect answers to bi and bii support this.

extension is more (in series) and the **force is the same** (in both situations) ✓

AND quotes Energy stored = (½)Fs or ½ $F\Delta L$ OR energy proportional to extension ✓

3

[15]

M4. (a) extension divided by its **original** length ✓

do not allow symbols unless defined ✓

1

(b) 1.9 × 10^8 (Pa) ✓

1

(c) point on line **marked 'A'** between a strain of 1.0 × 10^{-3} and 3.5 × 10^{-3} ✓

1

(d) clear evidence of gradient calculation for **straight section** eg 1.18 (1.2) × 10^8/1.0 × 10^{-3} ✓

= 120 GPa **and stress used $\geq$ 0.6 × 10^8 Pa** ✓ allow range 116 − 120 GPa

Pa or Nm^{-2} or N/m^2 ✓

3

(e) (i) clear attempt to calculate correct area (evidence on graph is sufficient) ✓

(32 whole squares + 12 part/2 = 38 squares)

(38 × 10000 =) 380000 (J m^{-3}) ✓ allow range 375000 to 400000

2

(ii) $V = m/\rho$ **or** 0.015/8960 **or** 1.674 × 10^{-6} (m^3) ✓

380 000 × 1.674 × 10^{-6} = 0.64 (0.6362 J) ✓ ecf from ei

2

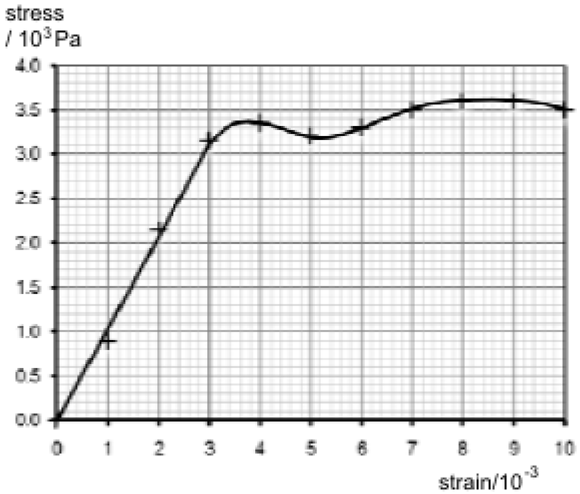
(f) straight line passing through origin (small curvature to the right only above 160 MPa is acceptable) end at 176 MPa ✓ (allow 174 to 178)

straight section to the left of the line for copper (steeper gradient) ✓

2

[12]

M5. (a)



Suitable scale on both axes (eg not going up in 3s) **and** > ½ space used ✓

≥ points correct (within half a small square) ✓

line is straight up to at least stress = 2.5 × 10^8 **and** curve is smooth beyond straight section ✓

3

(b) understanding that E = gradient (= Δ*y*/Δ*x*) ✓

allow y/x if line passes through origin

= 1.05 × 10^{11} (Pa) (allow 0.90 to 1.1) **ecf** from their line in (a) if answer outside this range **and** uses a *y* value ≥ 2 ✓

when values used from table;

- two marks can be scored only if candidates line passes through them
- one mark only can be scored if these points are not on their line

2

(c) correct rearrangement of symbols or numbers ignoring incorrect

powers of ten, eg $A = \frac{FL}{E\Delta L}$ ✓

correct substitution in any correct form of the equation,

eg = $\frac{10(000) \times 3.0}{1.90(\times 10^{11}) \times 1.0(\times 10^{-3})}$ ✓

allow incorrect powers of ten for this mark

= 1.6×10^{-4} ✓ (1.5789) (m^2)

3

[8]

M6. (a) the mark scheme for this part of the question includes an overallassessment for the Quality of Written Communication

QWC	**descriptor**	**mark range**
good-excellent	(i) Uses accurately appropriate grammar, spelling, punctuation and legibility. (ii) Uses the most appropriate form and style of writing to give an explanation or to present an argument in a well structured piece of extended writing.[may include bullet points and/or formulae or equations] **Physics**: describes a workable account of making most measurements accurately. **For 6 marks**: complete description of the measurements required + **how to find the extension** + instruments needed + at least 2 accuracy points **For 5 marks**: all 4 quantities measured including **varying**load + 2 instruments, 2 accuracy points.	**5-6**
modest-adequate	(i) Only a few errors. (ii) Some structure to answer, style acceptable, arguments or explanations partially supported by evidence or examples. **Physics**: describes a workable account of making all or most of the measurements and has some correct	**3-4**

	awareness of at least one accurate measurement. **For 4 marks**: all 4 quantities measured including **varying**load + 2 instruments mentioned + 1 accuracy point. **For 3 marks**: 3 quantities (**load**, **extension**, **diameter** or**cross-sectional area**) may only omit original length + 1 instrument + 1 accuracy point.	
poor-limited	(i) Several significant errors. (ii) Answer lacking structure, arguments not supported by evidence and contains limited information. **Physics**: unable to give a workable account but can describe some of the measurements. **For 2 marks**: load or mass + measure extension + one instrument mentioned. **For 1 mark**: applying a single load/mass + one other quantity or one instrument named or shown.	**1-2**
incorrect, inappropriate or no response		**0**

Quantities to be measured

- describe/show means of applying a **load/force** to a wire
- measure **original length**
- measure **extension**
- measure **diameter**
- extension = extension length ‘ original length (needed for six marks)

Measuring instruments

- use of **rule**/ruler/tape measure
- measure diameter with **micrometer**
- use of **travelling microscope** to measure extension, or extension of wire measured with **vernier** scale for Searle’s apparatus

Accuracy

- varying load/mass

- repeat readings (of length or extension)
- diameter measured in several places
- Searle's 'control' wire negating effect of temperature change
- change in diameter monitored (with micrometer)
- original length of wire ≥ 1.0 m

Additional creditworthy point

- explain how cross-sectional area is found using $A = \pi (D/2)^2$
- showing how Young modulus is found is regarded as neutral

6

(b) (i) good straight line through origin (within one square) up to stress = 5.1×10^7 and line that lies close to data points thereafter **(1)**

1

(ii) evidence of use of gradient or stress/strain **(1)**

Δ strain used ≥ 3.2 ($\times 10^{-3}$) for correct gradient calculation **(1)**

$1.0 \pm 0.05 \times 10^{10}$ **(1)** (0.95 to 1.05) allow 1 sf

ecf form their line – may gain full marks

Pa or N m^{-2} or N/m^2 only **(1)**

4

(c) originates at last point + parallel to their first line + straight + touches *x* axis **(1)**

1

[12]

M7. (a) the force (needed to stretch a spring is directly) is proportional to the extension (of the spring from its natural length) or equation with all terms defined **(1)**

up to the limit of proportionally **(1)**

2

(b) (i) **The explanations expected in a competent answer should include a coherent account of the following measurements and their use**

measurements

(use a metre rule to) measure the length of the spring (1)

when it supports a standard mass (or known) mass (*m*) and when it supports the rock sample

repeat for different (standard) masses

accuracy – use a set square or other suitable method to measure the position of the lower end of the spring against the (vertical) mm rule or method to reduce parallax

use of measurements

either

plot graph of mass against length (or extension) (1)

read off mass corresponding to length (or extension) dueto the sample (1)

or

the extension of the spring = length – unstretched length (1)

$$\text{mass of rock sample} = \frac{\text{extension of spring supporting rock sample}}{\text{extension of spring supporting known mass}} \times M \ (1)$$

(ii) use a (G) clamp (or suitable heavy weight) to fix/clamp the base of the stand to the table **(1)**

clamp (or weight) provides an anticlockwise moment (about the edge of the stand greater than the moment of the object on the spring)/ counterbalances (the load) **(1)**

or adjust the stand so the spring is nearer to it **(1)**

so the moment of the load is reduced (and is less likely to overcome the anticlockwise moment of the base of the stand about the edge of the stand) **(1)**

or turn the base of the stand/rotate the boss by 180° **(1)**

so the weight of the load acts through the base **(1)**

2

[10]

M8. (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**

applies up to the limit of proportionality or elastic limit **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length when the force is removed **(1)**
(or correct use of permanent deformation)

(ii) the Young modulus: ratio of tensile stress to tensile strain **(1)**

unit: Pa or Nm^{-2} **(1)**

5

(b) (i) length of wire **(1)**

diameter (of wire) (1)

(ii) graph of force vs. extension **(1)**

reference to gradient **(1)** gradient = EA/l **(1)**

(or graph of stress vs. strain, with both defined and gradient = E)

area under the line of F vs. e **(1)**

6

[11]

M9. (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]

(iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)**

5

(b) (i) length of wire **(1)**
diameter (of wire) **(1)**

(ii) graph of force vs extension **(1)**
reference to gradient **(1)**

gradient = $E\frac{A}{l}$ **(1)**

[or graph of stress vs strain, with both defined
reference to gradient
gradient = *E]*

area under the line of *F* vs *ΔL* **(1)**
[or energy per unit volume = area under graph of stress vs strain]

6

[11]

M10. (a) λ(=2 × 38) = 76(m)

$f\left(\frac{c}{\lambda} = \frac{3.0 \times 10^8}{76}\right) = 3.9(4)$ MHz **(1)**

1

(b) (i) angle between cable and horizontal = $\left(\sin^{-1}\frac{12}{14}\right) = 59°$ **(1)**

T= 110 cos59° = 57N • (56.7N) **(1)**

(allow C.E. for value of angle)

(ii) cross-sectional area (= $\pi(2.0 \times 10^{-3})^2$)

=1.3×10^{-5}(m^2) **(1)**

(1.26×10^{-5}(m^2))

stress $\left(= \frac{tension}{area}\right) = \frac{57}{1.3 \times 10^{-5}}$ **(1)**

= 4.4×10^6Pa **(1)**

(4.38×10^6Pa)
(use of 56.7 and 1.26 gives 4.5×10^6 Pa)
(allow C.E. for values of T and area)

(iii) breaking stress is ≈ 65 × stress
copper is ductile
copper wire could extend much more before breaking
because of plastic deformation
extension to breaking point unlikely

any three **(1)(1)(1)**

7

[8]

M11. (a) tensile stress: (normal) force per unit cross-sectional area **(1)**

tensile strain: ratio of extension to original length **(1)**

2

(b) (i) loading: obeys Hooke's law from A to B **(1)**
B is limit of proportionality **(1)**
beyond/at B elastic limit reached **(1)**
beyond elastic limit, undergoes plastic deformation **(1)**

unloading: at C load is removed
linear relation between stress and strain **(1)**
does not return to original length **(1)**

(ii) ductile **(1)**
permanently stretched **(1)**
[or undergoes plastic deformation or does not break]

(iii) AD: permanent strain (or extension) **(1)**

(iv) gradient of the (straight) line AB (or DC) **(1)**

(v) area under the graph ABC **(1)**

Max 9

(c) $E = \frac{Fl}{Ae}$ **(1)**

$e = \frac{75 \times 3.0}{2.8 \times 10^{-7} \times 2.1 \times 10^{11}}$ = 3.8(3) mm**(1)**

2

[13]

M12. (a) Hooke's law: the extension is proportional to the force applied **(1)**
up to the limit of proportionality or elastic limit
[or for small extensions] **(1)**

2

(b) (i) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $\Delta L_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ **(1)**

$= 1.3 \times 10^{-4}$ (m) **(1)** (1.33×10^{-4} (m))

$\Delta L_b = \dfrac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ = 4.7 × 10^{-4} (m) **(1)** (4.66 × 10^{-4} (m))

total extension = 6.0 × 10^{-4} m **(1)**

(ii) $m = \rho \times V$ **(1)**
m_s = 7.9 × 10^3 × 2.4 × 10^{-6} × 0.8 = 15.2 × 10^{-3} (kg) **(1)**
m_b = 8.5 × 10^3 × 2.4 × 10^{-6} × 1.4 = 28.6 × 10^{-3} (kg) **(1)**
(to give total mass of 44 or 43.8 × 10^{-3} kg)

7

(c) (use of $m = \rho Al$ gives) $l = \dfrac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ **(1)**

= 2.2 m **(1)** (2.16 m)

(use of mass = 43.8 × 10^{-3} kg gives 2.14 m)

2

[11]

M13. (a) tensile stress: force/tension per unit cross-sectional area or $\dfrac{F}{A}$ with F and A defined **(1)**

tensile strain: extension per unit length or $\dfrac{\Delta L}{l}$ with e and l defined **(1)**

the Young modulus: $\dfrac{\text{tensile stress}}{\text{tensile strain}}$ **(1)**

3

(b) (i) $E_S = \dfrac{F_s}{A}\dfrac{l}{\Delta L}$ **(1)** and $E_B = \dfrac{F_B}{A}\dfrac{l}{\Delta L}$ **(1)** hence $\dfrac{E_S}{E_B} = \dfrac{F_S}{F_B}$

(ii) $\dfrac{E_S}{E_B}$ = 2 **(1)**

$\therefore F = 2F_B$ **(1)**

$F_S + F_B$ = 15 N **(1)** gives F_S = 10 N

[or any alternative method]

(iii) $\left(E = \dfrac{F}{A}\dfrac{l}{\Delta L}\text{ gives}\right)$ $e = \left(\dfrac{F}{A}\dfrac{l}{E}\right) = \dfrac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ **(1)**

$= 5.36 \times 10^{-5}$ m **(1)**

6

[9]

M14. (a) extension proportional to the applied force **(1)**
up to the limit of proportionality
[or provided the extension is small] **(1)**

2

(b) (i) 8 × 9.81 = 78 (5) N **(1)**

(allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8 \times 10^{-7}} \times \frac{2.5}{\Delta L}$ **(1)**

$\Delta L = 3.5 \times 10^{-3}$ m **(1)**

(iii) similar calculation **(1)**
to give $A_S = 5.6 \times 10^{-7}$ m^2 **(1)**
[or $A_B = 2A_S$ **(1)** and correct answer **(1)**]

(iv) (use of energy stored = ½ *Fe* gives) energy stored
$= ½ \times 78.5 \times 3.5 \times 10^{-3}$ **(1)**
= 0.14 J **(1)**

7

(c) (i) end A is lower **(1)**

(ii) $= ½\ 3.5 \times 10^{-3} = 1.8 \times 10^{-3}$ m **(1)** (1.75×10^{-3} m)

2

[11]

M15. (a) maximum force (from graph) = 1840 (N) (±100 N) **(1)**

max stress $\left(= \frac{\text{force}}{\text{contact area}}\right) = \frac{1840(\text{N})}{550 \times 10^{-6}(\text{m}^2)}$ **(1)**

(for correct denominator) **(1)**

$= 3.3 \times 10^{6}$ N m^{-2} **(1)**

4

(b) using shoes without cushioning:
impact time would be less **(1)**
maximum impact force would be greater **(1)**
area under the curve the same **(1)**

3

[7]

M16. (a) tensile stress: (stretching) force (applied) per unit <u>cross-sectional</u> area **(1)**
tensile strain: extension (produced) per unit length **(1)**

2

(b) Hooke's law (or stress $\propto$ strain) obeyed up to point A **(1)**A is limit of proportionality **(1)**elastic limit between A and region B **(1)**region C shows plastic behaviour or wire is ductile **(1)**region B to C wire will not regain original length **(1)**beyond region C necking occurs (and wire breaks) **(1)**

max 5
QWC

[7]

M17. (a) density = $\frac{\text{mass}}{\text{volume}}$ **(1)**

1

(b) (i) volume of copper = $\frac{70}{100} \times 0.8 \times 10^{-3}$ (= 0.56×10^{-3} m^3)

(volume of zinc = 0.24×10^{-3} m^3)

m_c (= $\rho_c V_c$) = $8.9 \times 10^3 \times 0.56 \times 10^{-3}$ = 5.0 kg **(1)** (4.98 kg)

$m_z = \frac{30}{100} \times 0.8 \times 10^{-3} \times 7.1 \times 10^3$ = 1.7 (kg) **(1)**

(allow C.E. for incorrect volumes)

(ii) m_b (= 5.0 +1.7) = 6.7 (kg) **(1)**
(allow C.E. for values of m_c and m_z)

$\rho_b = \frac{6.7}{0.8 \times 10^{-3}}$ = 8.4×10^3 kg m^{-3} **(1)**

(allow C.E. for value of m_b)
[or ρ_b = (0.7 × 8900) + (0.3 × 7100) **(1)** = 8.4 × 10^3 kg m^{-3} **(1)**]

max 4

[5]

M18. (a) correct plotting of points **(1)** **(1)**
increasing load graph **(1)**
decreasing load graph **(1)**

4

(b) (initially) the material/wire obeys Hooke's law [or behaves elastically] **(1)**up to the limit of proportionality **(1)**(beyond this), elastic limit is reached **(1)**undergoes plastic deformation **(1)**undergoes permanent change **(1)**reference to Hooke's law obeyed as load decreases **(1)**

max 4
QWC 2

(c) ($E = \frac{Fl}{A\Delta L}$ gives $E = \frac{F}{\Delta L} \times \frac{l}{A}$)

gradient = (e.g.) $\frac{46}{4.2 \times 10^{-3}}$ **(1)** (= 1.095 × 10^4)

E = 1.095 × 10^4 × $\frac{3}{2.8 \times 10^{-7}}$ = 1.2 × 10^{11} **(1)** Pa **(1)** (1.17 ×10^{11} Pa)

3

(d) area under the graph at any given point

1

[12]

M19. (a) (i) (35 × 9.81) = 343 N

(ii) tension in each cable $\left(= \frac{mg}{2}\right)$ = 172 N **(1)**

2

(b) area of cross-section (= $\frac{\pi d^2}{4}$) = $\frac{\pi(8.26 \times 10^{-3})^2}{4}$ = 5.36 × 10^{-5} (m^2)

$e = \frac{Fl}{EA}$ **(1)**

$= \frac{172 \times 2.5}{5.36 \times 10^{-5} \times 2.1 \times 10^{11}}$

$= 3.8 \times 10^{-5}$ m **(1)**

4

(c) (i) moments about T_2, (cable B) gives

5.52 T_1 **(1)** = 343 × 2.76 **(1)** + 196 × 4.52 **(1)**

$T_1 = \left(\frac{1833}{5.52}\right)$ **(1)** (= 332 N)

(ii) $T_1 + T_2$ = 343 + 196 = 539 (N) **(1)**T_2 = 539 – 332 = 207 N **(1)**

(allow C.E. for. value of T_1, from (i))

[or moments about T_1 gives 5.52 T_2 = (343 × 2.76) + (196 × 1.) **(1)**

T_2 =1143/5.52 = 207 N **(1)**

6

[12]

E1.(a) This question was well answered. Some left out ‘up to limit of *proportionality*’ and some put *‘elastic limit’* - though this was forgiven. Some gave the equation only in symbols, and this was not sufficient.

Again, with recall questions, not enough students are learning definitions and laws, producing instead vague descriptions rather than precisely memorised statements. E.g. *‘Hooke’s law is the extension of a spring when a force is applied.’*

(b) There were quite a few mistakes with units here; ‘Nm’, ‘Nm^{-2} ’and ‘Pa’ were all common incorrect units. In calculating the gradient, the point labelled ‘**A**’ was often used. However, at this point, the line had clearly ceased to be straight and thus the answer fell outside the range of tolerance.

(c) For calculating the work done up to point **B**, there was much use of ½ FL = ½ × 38 × 0.045, and sometimes simply 38 × 0.045, rather than an attempt to sum up the area under the line. Many estimates of the area were wildly inaccurate due to the approach being too approximate, counting some areas twice or missing bits out.

Summing the area under a curve is a technique that students must practise.

(d) Most candidates got this correct. A few said words to the effect of *'no longer obeys Hooke's law'*, which was not sufficient.

(e) There were many careless graphs drawn here, with the line not drawn exactly parallel, and this lost a mark. This means that some very straightforward marks are needlessly dropped by many candidates. In order to ensure that a line is parallel, students should be encouraged to make a quick measurement of the distance between the lines at a couple of points.

It would also appear that many students elect to sketch with a pen and are then reluctant to scribble out their line and replace it with a more accurate one. For diagrams only, please encourage students to use an HB pencil; this will show up perfectly well on the scans that are seen by the examiners.

(f) The majority of candidates understood that the area underneath the unloading line was less than for the loading. However, a significant number of candidates thought that the work done would be the same since *'energy is conserved'*.

E2.(a) Most were successful but a significant number did not multiply by g, perhaps not understanding the difference between weight and mass.

(b) A common error was to not half the force (or double the area). However, a high percentage did realise that you had to do more than simply substitute the numbers given.

(c) (i) Most correctly calculated the load on one of the cables but many did not realise they needed to double their result to get the complete load.

(ii) A lot of rounding errors were evident. 0.06 recurring was often rounded to 0.06 rather than 0.067. Many used their value for weight but did not halve it. Some candidates therefore lost a mark because even though they got the correct answer, they had not halved that weight and this was a physics error.

(iii) Many did not understand that they should use the weight and the extension previously calculated. Many thought that the total load divided by the extension of one cable would give only half of the total stiffness constant. This is not the case because the extension of each cable is the same.

E3. The 6 mark extended answer for part (a) included a quality of written communication assessment. The question seemed familiar to the majority of students of all abilities and many gained 5 or 6 marks. Nearly all mentioned the use of a rule to measure the extension which was essential to gain 4 or more marks and the majority described a correct graphical method which allowed access to 5 or 6 marks. It is still the case, however, that not enough students make suggestions about the range and number of readings they would aim to record. Some who do suggest a number of readings seem to believe that the ideal number is 5. However, one would always aim for more unless it was impossible to do so – ten to twenty readings would be sufficient here. It was surprising how many students believed it was necessary to verify the elastic limit by increasing the load beyond 20 N – that was not the question.

For part (b)(i) some students did not know how the parallel arrangement changed the spring constant. In part (b)(ii) many did not double the extension (or half the spring constant) here and got no marks. Those who understood that the spring constant would be halved tended to get both marks. Some thought the spring constant would double with two springs in series. In part (b)(iii) it was necessary to use $W=½F\Delta L$ with the extension from (b)(i). Many did this successfully but some then felt the need to then double the answer due to there being two springs. In part (b)(iv) many students did realise that the extension was greater for the series arrangement but they failed to point out that the load was the same for both series and parallel.

E4. In part (a), many students confused strain with stress and there were many vague descriptions rather than definitions, for example 'amount of extension due to a force applied'. The definition has to describe how a correct strain would be calculated. Therefore, it is essential that the 'original' length is specified and the phrase 'divided by' rather than 'compared to' needs to be used. Some students used the word 'from' to convey 'divided by' for example, 'the extension from the original length'. This was not accepted. 'The ratio of the extension from the original length' was acceptable.

Only 1.9×10^8 was accepted as an answer to part (b). Few students strayed from 1.9. However, many lost the mark by missing out the power of ten.

Most students did very well on part (c). Nearly all put the point in a sensible place just beyond the linear section but a few did not include a suitable label and therefore they did not get the mark.

Most students were very successful in part (d). Most chose the straight section for the gradient calculation and most chose a large enough section of it. Some went to a stress of 1.3 or more where the line was clearly curving. The unit was usually correct but a few had capital M or m^{-1}. Surprisingly, a significant number missed the unit out altogether.

Part (e)(i) should have been a straightforward question. Most students identified the correct area to evaluate but either did not use an accurate method or did not recognise the value of each square they counted. A very common answer was 38 rather than 38×10^5. Many divided the area into two triangles and a rectangle, leaving out a significant area from their calculation. With a number of similar examples of area approximation on past papers, it was surprising that very few were able to score both marks here. Many students do not know how to find the area under a curve to a sufficient accuracy.

Many students obtained the volume in answer to part (e) (i) but did not realise that they then needed the value they calculated from part (e) (i).

In part (f), many students did not recognise that a higher Young Modulus would give a steeper line and many who did realise this did not stop their line at 176 MPa. Many showed excessive curvature not characteristic of a brittle material.

E5. In part (a), suitable scales were chosen by nearly all candidates and points were plotted very accurately by all but a few. From knowledge of material properties, it is sensible to assume that the first section of the graph should be a straight line. However, many candidates drew a curve for the first part. After this, any suitable best fit line was accepted if it was smooth.

Part (b) was generally done very well, with most choosing points on their line correctly and using suitably large values. A few candidates wrongly used the ultimate tensile stress divided by the corresponding strain.

Most candidates were very successful on the calculation in part (c). The main problem was arithmetic errors and mistakes on powers on ten. It is a good idea to make even high ability students practice plenty of these questions when revising.

E6. Part (a) assessed the candidates' quality of written communication. Most responses were lacking in detail and there was a general lack of awareness of what is required in a question such as this. The question asked how the **data** to determine the Young modulus could be obtained accurately. A good response would mention the quantities needed and the measuring instruments required with an indication of how the apparatus is arranged.

Many candidates did not list all the measurements (original length, extended length, diameter) or the quantities derived from these (extension and cross sectional area) that would be needed for the calculation of Young modulus. Failure to state that diameter or cross-sectional area would be measured limited the candidate to two marks out of six.

Candidates were also expected to make a comment about accuracy and to get beyond two marks they needed to mention some form of repeat or the use of a range of masses or the use of a wire of 1.0 m or more.

The specification states that candidates should know a simple method for the determination of the Young modulus. This implies that they do not need to be familiar with Searle's apparatus. Some candidates scored well when giving a detailed account of Searle's. However, those who seen Seale's apparatus but only partially understood how to use it, tended to fare less well than those who described stretching a wire along a bench. It should be noted that the phrase 'simple method' does not imply that a non-graphical method will suffice. Many candidates described substituting one-off measurements into the Young modulus equation. An accurate method, at least in a school laboratory, should involve using a range of loads and extensions. We would recommend that centres who have Searle's apparatus do demonstrate it and give students the opportunity to use it. However, the simpler method of stretching horizontally on a bench can be presented as the preferred option for a descriptive question such as this for all but the most able and meticulous students.

Diagrams produced by candidates here tended to lack detail and labelling and many did not go on to state that the load or force had to be found from the mass.

In part (b) (i), the line of best fit was drawn well by 55%. Some drew a straight line but did not produce a curved section at the top. Some did not draw the line going through the origin. However, it was felt that in this case candidates should expect a stress-strain graph to go through the origin and should have extended to the origin. Best fit lines are taught extensively at KS3 and KS4. However, the evidence suggests that candidates continue to lose marks on these at AS level so a lot of practice is needed.

For part (b) (ii) most candidates did very well and picked up three or four marks. A significant percentage of candidates who had drawn an incorrect best fit line did pick up full marks for the gradient calculation. Of those who did not, many chose the wrong unit eg Nm^{-1}, Nm or 'pa' rather than Pa. Some candidates could have been awarded a method mark if they had drawn a triangle as evidence that they where calculating the gradient. Many candidates could have set out their answer in a much clearer manner.

E7. Half of the candidates gained both marks for part (a). Nearly all pointed out that force is proportional to extension but half did not mention the 'limit of proportionality'. Candidates need to 'look for a second mark'.

Candidates had to apply their knowledge of Hooke's law in part (b) (i). A significant number of candidates did not have a workable method and scored zero on this question. Many candidates picked up two marks by describing a simple comparison between extensions due to standard masses and the rock sample. A correct graphical approach and a point about accuracy were required for full marks. This question could perhaps form the basis of a practical activity to illustrate the significance of Hooke's law in measuring mass or weight. A large number of candidates believed that the Young modulus of the spring should be found.

In part (b) (ii) most candidates knew how to stop the apparatus toppling over but a significant number could not describe this well enough to get the first mark, i.e. 'put a weight on the stand' did not gain marks but 'put a weight on the base of the stand' did. For the second mark, it was expected that candidates would give a correct explanation in terms of moments but hardly any candidates spotted this.

E9. Few candidates gained the maximum mark of five for part (a). In part (i), the necessary condition that the wire had not been stretched beyond the elastic limit or beyond the limit of proportionality was usually omitted. In part (iii) the Young modulus was often defined as stress/strain, which was not acceptable, and finally a large number of candidates failed to give the unit of the Young modulus, many going for the easy option of stating that it had no units.

Candidates who took the trouble to read the stem of the question carefully usually gave good answers, but those who thought that part (b) required a description of the experiment failed miserably. In part (i) the usual answer of measuring the cross-sectional area was not accepted. The only answers that gained both allocated marks were the diameter and the length of the wire. In part (ii) a graph of force vs extension, or stress vs strain (provided both were defined) were acceptable, but many who opted for the stress vs strain graph then went on in part (iii) to give the answer as the area under the graph, which, of course, is wrong, unless they referred to the energy per unit volume.

E10. Most candidates gave a correct frequency calculation in part (a), although unfortunately some made a significant figure error in their final answer.

In part (b) (i), many candidates correctly calculated the angle between cable P and the ground or the mast. Many were then able to calculate the tension correctly, although some lost the final mark because they mistakenly doubled their answer, presumably on the grounds that the copper wire pulled on each mast. In part (ii), most candidates knew the correct expression for the stress but a significant number of candidates lost a mark through making an arithmetical error in the calculation of the cross-sectional area of the wire, or lost the final two marks as a result of using the expression for the surface area of the wire instead of the cross-sectional area. Other candidates lost the final mark as a result of a unit error in the final answer or an arithmetical error in the final calculation.

Many candidates scored two marks in part (iii) by comparing the breaking stress with their own calculated value and reaching a valid conclusion. Some candidates gained these marks by calculating the breaking force and comparing that with the tension in the wire. Very few candidates considered other relevant points such as the ductile nature of copper.

E11. The definitions of tensile stress and tensile strain in part (a) were usually correct, the most notable omission being not defining *A* as the area of cross-section rather than just the 'area of the wire'.

There were some very good descriptions given in part (b) (i), but many candidates used the question as an opportunity to write everything they knew about stretching a wire, with elastic limit, yield point, break point etc. thrown around at random. For some reason, many candidates assumed the wire broke at the point C, but then went on quite happily to describe what happened as the masses were unloaded. The remainder of part (b) met with mixed success. The fact that the wire was ductile was usually well known and also what AD represented, although phrases such as 'wire was deformed' were not accepted, neither were the shape or size of the wire. It is quite obvious, and candidates should be made to realise it also, that the shape of the wire does not change when it is permanently extended. Parts (iv) and (v) in (b), suffered due to candidates not being precise, for example, the gradient of the graph was not sufficient; the line AB had to be specified. Likewise the area under the graph in (v) had to be the area under the graph ABC.

The calculation in part (c) was usually correctly performed.

E12. Hooke's law, in part (a), was generally known to candidates although many did not state the condition under which it applied. Many introduced temperature into the argument.

The calculation in part (b) was usually correct with comparatively few candidates adding the two lengths or adding the values of the Young moduli to perform just one calculation. Questions on density, similar to those in part (b) (ii), are usually done well, and this question was no exception. Full marks were quite common in part (b).

Part (c) also proved to be relatively easy with the large majority of candidates obtaining the correct answer. Those who failed were usually those who tried to tackle it from a Young modulus point of view.

E13. Normally, the question on elasticity realizes high marks. Not so this time, although there were many completely correct answers. The three definitions were usually correct although, as in past papers, the Young modulus was defined in terms of stress and strain, rather than tensile stress and tensile strain. There also appeared this year, references to the *stiffness constant* of the wire. It should be pointed out that the stiffness constant is not the same as the Young modulus.

The algebra involved in parts (i) and (ii) of (b) caused problems and a significant number of candidates failed on this section. However, part (iii) proved to be a straightforward calculation for the majority of candidates.

E14. Responses to part (a) were extremely disappointing. The impression gained by examiners was that many candidates had not heard of Hooke's Law because they attempted to state it in terms of current and voltage. Others, realising that it had something to do with solids, attempted an answer in terms of a wire returning to its original shape and length when the force was removed. It should be pointed out that merely stating $F \propto e$ gained no credit unless the symbols were defined. Of those candidates who gave the correct version of Hooke's Law, most failed to gain the second mark by not giving the condition under which it was valid, i.e. up to the limit of proportionality. Validity up to the elastic limit was not accepted.

The calculation in part (b) was carried out quite successfully and many completely correct answers were obtained. The usual error occurred in part (i) in not realising that the tension due to the 16 kg was shared equally between the two wires. Others did not multiply by g, or used g = 10 m s^{-2}, which was not acceptable. The data sheet gives g = 9.81 m s^{-2} and this is the value which was required. Incorrect answers to part (i) were allowed to be carried forward into the remaining parts of the section. However, if the force in part (ii) was given as 16 kg or 8 kg, without conversion into a force (i.e. Newtons), then it was considered as a Physics error and both marks were lost.

The majority of candidates deduced (or guessed) that end A of the bar would be lower than end B, although some of the convoluted answers required significant interpretation to know which end of the bar candidates were talking about. The calculation in part (ii) was usually carried out correctly.

E15. In part (a), most candidates read off the maximum force correctly from the graph and also knew how to use this maximum force to calculate the stress. Some candidates were unable to convert the contact area successfully into m^2. Again, in part (b), most candidates correctly sketched the second curve higher and narrower than the first, although few candidates showed or stated that the area under the second curve was the same as that under the first curve.

E16. In part (a) the definitions of tensile stress and tensile strain were usually correct although some candidates were penalised for not stating that the area involved was the cross-sectional area. A definition of tensile stress as force per unit area was not accepted.

Part (b) gave candidates the opportunity to write at length on what they knew about stressstrain curves. Most accounts started off well with the easily recognisable linear region obeying Hooke's law. A linear region given in terms of a constant *y*oung modulus was not accepted. The point A on the graph was not always defined as the limit of proportionality.

After this initial section the descriptions became more vague. There seems to be some confusion as to where the elastic limit occurs and this is not helped by some textbooks. In this question the examiners were prepared to accept that the elastic limit occurred from A to the region B. A phrase which occurred regularly was 'plastic deformation' without any attempt being made at explaining what it meant. It would have been worthwhile for the candidates to extend their sentence by stating that the wire did not regain its original length or shape once the applied force was removed. Many candidates thought that because the graph became reasonably straight around section C that Hooke's law was obeyed again. The impression gained by the examiners was that the topic was, on the whole, loosely taught and that candidates memorised terms such as elastic limit without fully realising what happened to the wire.

E17. This is the first time since this Specification was introduced that a question on density has been set. The examiners were pleased to find that the majority of candidates seemed to understand the topic very well and gained full marks. Unfortunately, candidates who gave density as $\rho = mass \times volume$ were, because of the nature of the question, penalised quite heavily, but they could however earn marks for calculating the volume in part (b)(i) and adding the masses together in part (ii).

E18. Plotting the graph in part (a) was not as successful as most examiners had hoped for. Many candidates omitted the (0,0) point, which incurred a penalty. Very often, the lines were drawn free-hand and looked untidy and messy. This would incur another penalty. Several candidates, by using a small scale, drew the loading curve and then continued in the same direction along the axis to draw the unloading curve. They had obviously not come across the required graph before.

The explanation in part (b) was quite well done and the majority of candidates gained significant marks. Terms such as elastic limit, limit of proportionality, and plastic region were used with a sort of cavalier attitude with no reference to where one ended or the other started. This part also carried the quality of written communication marks and in general the candidates wrote very well.

The calculation in part (c) suffered from two failures. First, from using data in the table when the question required data from the graph to be used and then using the incorrect unit or omitting an unit altogether. Many candidates, when calculating the gradient, omitted the mm factor in the extension, but the subsequent answer was allowed as a consequential error and credit given when appropriate.

How to estimate the energy in the wire in part (d) was usually known, although a significant number of candidates thought that the area involved was that between the loading and unloading curves.

E19. In part (a) some candidates did not gain both marks as a result of a significant figure penalty. The calculation in part (b) was generally done well but some candidates calculated the area of cross-section incorrectly or used the weight of the beam instead of the tension in each cable.

Only a minority of candidates made progress in part (c)(i). The majority were unable to give the correct equation using the Principle of Moments. Some candidates worked out the correct answer without providing a satisfactory explanation, using little more than knowledge of the answer to guide them. However, a large number of candidates knew how to proceed in part (ii) and were able to gain full credit.