Q1. (a) Define the *density* of a material.

....

....

(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 = 8.9×10^3 kg m^{-3}
density of zinc = 7.1×10^3 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.

....

....

....

....

(ii) Calculate the density of brass.

....

....

(4)
(Total 5 marks)

Q2. (a) State Hooke's law.

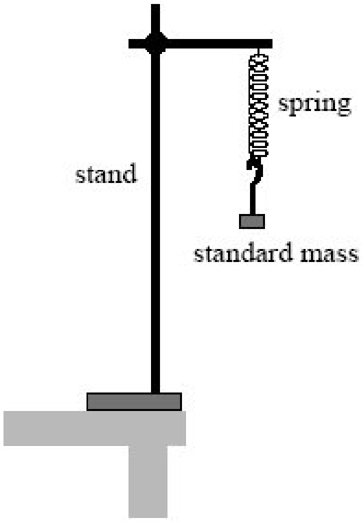
....

....

....

(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.

....

....

....

....

(2)
(Total 10 marks)

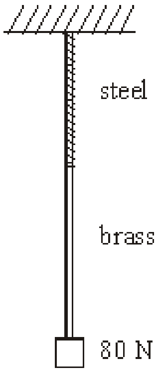
Q3. (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

....

....

(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 m
length of the brass wire = 1.40 m
the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

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

....

....

....

....

....

....

(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}

....

....

....

....

....

(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.

....

....

....

....

....

(2)
(Total 11 marks)

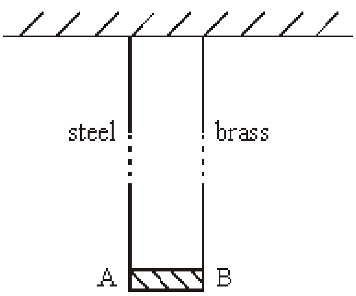
Q4. (a) State *Hooke's law* for a material in the form of a wire.

....

....

(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?

....

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

....

....

....

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

....

....

....

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

....

....

(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.

....

....

(2)
(Total 11 marks)

Q5. (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

....

....

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

....

....

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

....

....

(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?

....

....

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

....

....

....

....

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

....

....

(6)

(Total 11 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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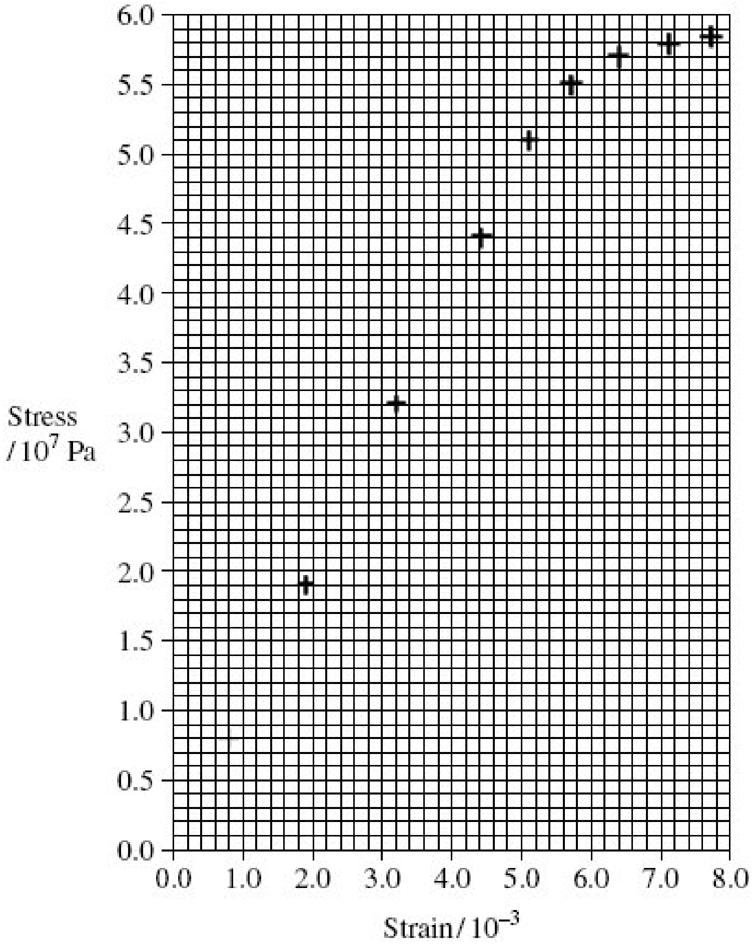
....

(6)

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



(i) Draw a be t fit line u ing the data point

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

tensile stress, ...

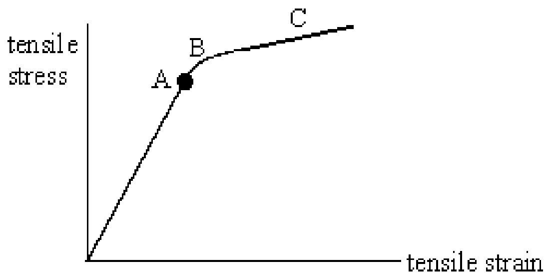
....

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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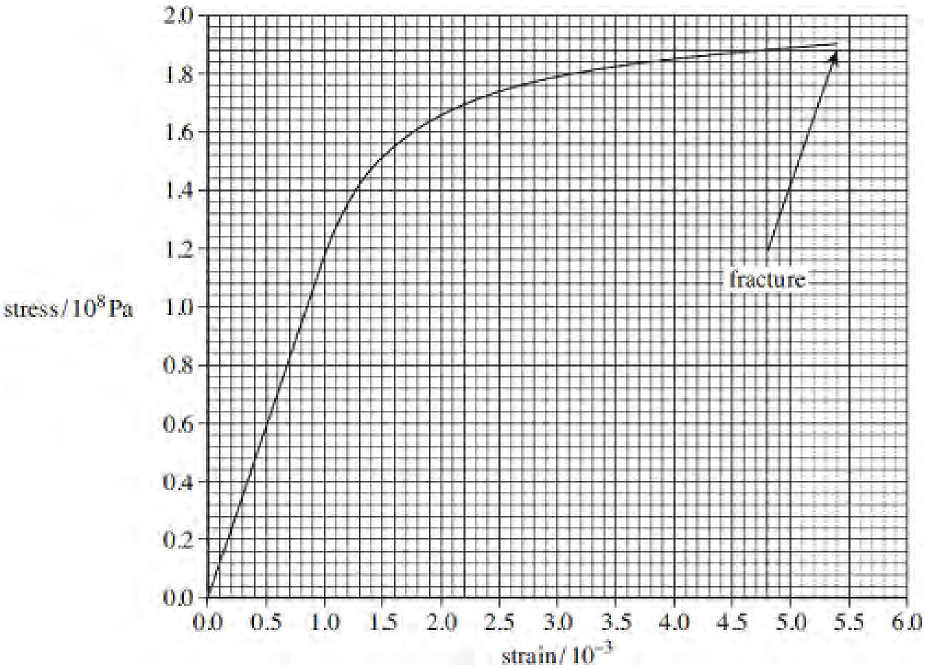
....

....

(5)
(Total 7 marks)

Q8. The figure below shows a stress-strain graph for a copper wire.



(a) Define tensile strain.

....

....

(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)

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

....

....

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

....

....

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

....

....

(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?

....

....

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

....

....

....

....

....

....

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

....

....

(6)
(Total 11 marks)

Q10. (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire.
State the meaning of

tensile stress, …..

....

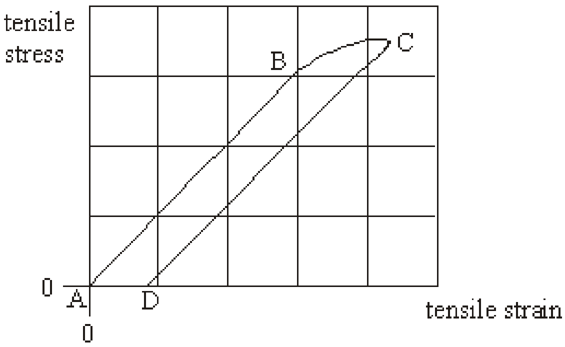
tensile strain. ....

....

(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.

....

....

(iii) What does AD represent?

....

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

....

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

....

(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

....

....

....

....

(2)

(Total 13 marks)

M1. (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)

$\rho_b = \frac{6.7}{0.8 \times 10^{-3}} = 8.4 \times 10^3$ 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]

M2. (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) due to 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]

M3. (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))

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

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

(ii) $m = \rho \times V$ **(1)**

$m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) **(1)**

$m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (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]

M4. (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 $E = \dfrac{F}{A}\dfrac{l}{\Delta L}$ gives) $2.0 \times 10^{11} = \dfrac{78.5}{2.8 \times 10^{-7}} \times \dfrac{2.5}{\Delta L}$ **(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 × 78.5 × 3.5×10^{-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]

M5. (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]

M6. (a) the mark scheme for this part of the question includes an overall assessment 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 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.	**3-4**
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 (× 10^{-3}) for correct gradient calculation **(1)**

1.0 ± 0.05 × 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) 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 ∝ 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]

M8. (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 ≥ 0.6 × 10^8 Pa** ✓ allow range 116 − 120 GPa

Pa or Nm^{-2} or N/m^2 ✓

(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) ✓

$380\,000 \times 1.674 \times 10^{-6} = 0.64$ (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]

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 = $E\dfrac{A}{l}$ **(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) 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]