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) $8 \times 9.81 = 78$ (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 <u>></u> 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 = $E\frac{A}{l}$ **(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) 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]