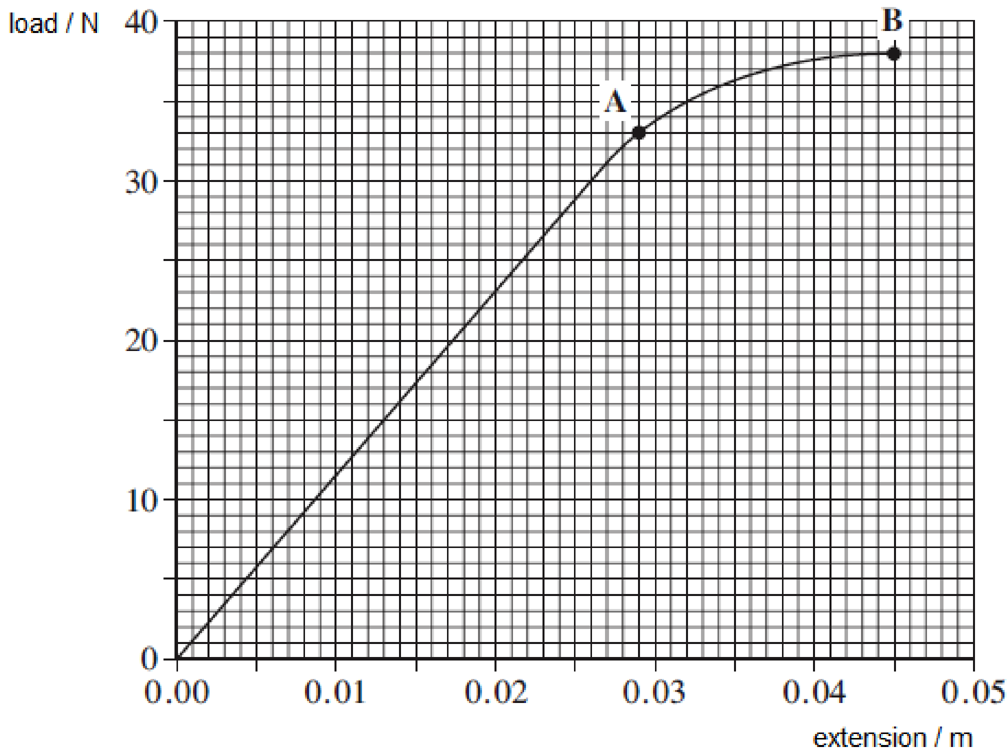
Q1. A manufacturer of springs tests the properties of a spring by measuring the load applied each time the extension is increased. The graph of load against extension is shown below.



(a) State Hooke's law.

....

....

....

(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.

....

....

(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.

....

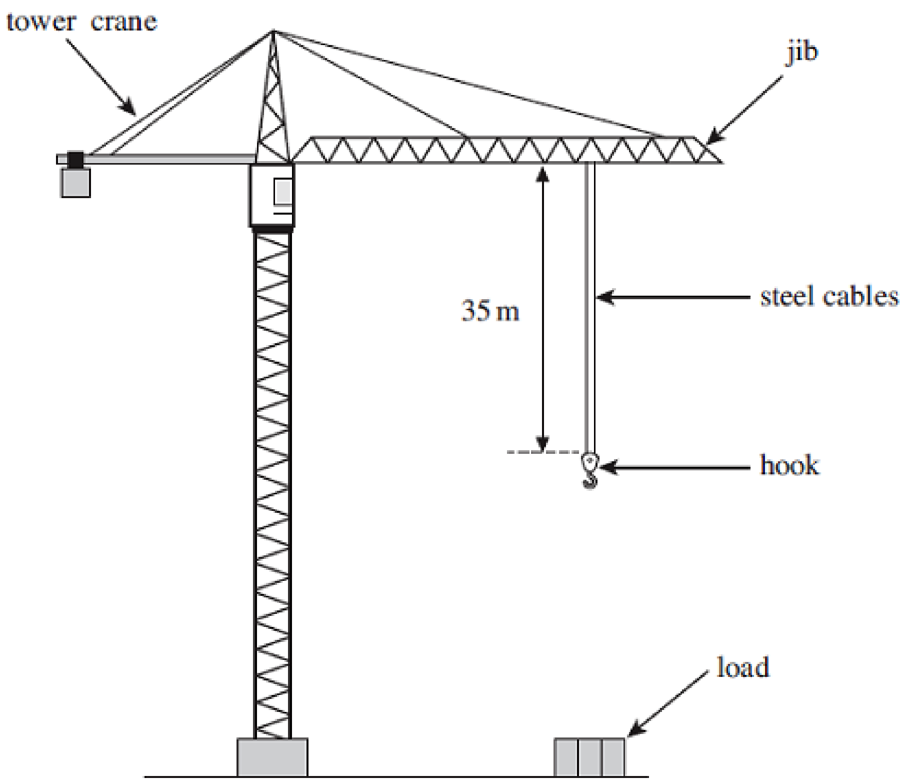
....

....

(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.

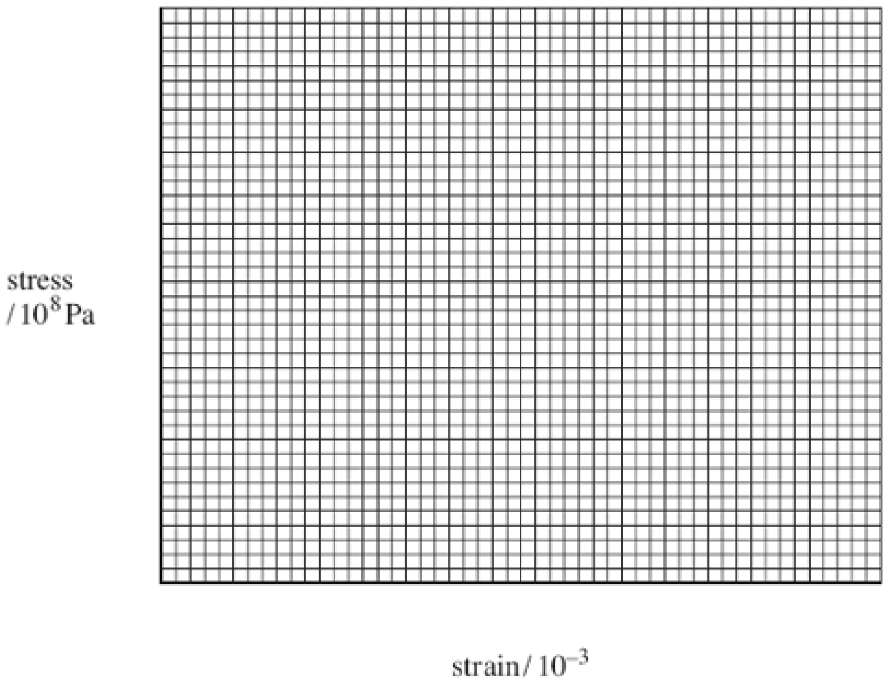
energy stored = ... J

(2)
(Total 13 marks)

Q3. 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 / 10^{-3}	0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00
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)

Q4. (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 ....

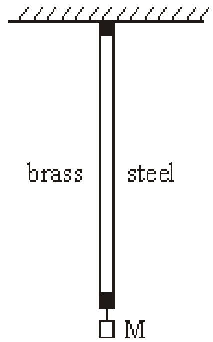
....

(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 the same 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.

....

....

....

(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

....

....

....

....

(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.

....

....

....

....

(6)
(Total 9 marks)

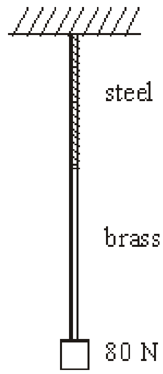
Q5. (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

....

....

(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)

M1. (a) Force proportional to extension ✓

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

Symbols must be defined
Accept word equation
allow '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

(× 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

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

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

$\left(= \frac{(4.96 \times 10^5/2) \times 35}{6.2 \times 10^{-4} \times 2.1 \times 10^{11}} = \right)$ 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)

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

$= \frac{2 \times 248\,000}{6.667 \times 10^{-2}}$ 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) $(E = \frac{1}{2}F\Delta L$ or $E = \frac{1}{2}k\Delta L^2)$

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

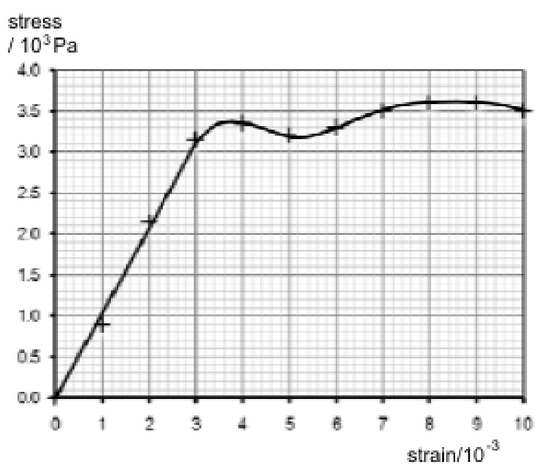
$= 1.6(5) \times 10^{4}$ (J) ✓

Forgive incorrect prefix if correct answer seen.
Doubling the force gets zero.

2

[13]

M3. (a)



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 (= $\Delta y/\Delta x$) ✓

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]

M4. (a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$ with *F* and *A* defined **(1)**

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

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

3

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

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

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

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

[or any alternative method]

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

= 5.36×10^{-5} m **(1)**

6

[9]

M5. (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)**

= 1.3×10^{-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]