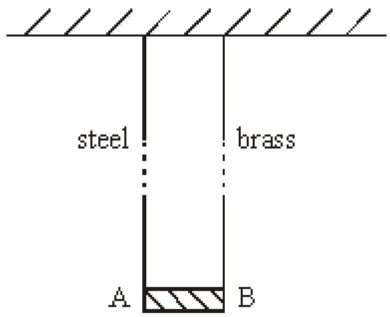
1 (a) State *Hooke's law* for a material in the form of a wire.

___

___

(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)

2 (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 $= 8.9 \times 10^3$ 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.

___

___

___

___

(ii) Calculate the density of brass.

___

___

(4)

(Total 5 marks)

3 (a) The Young modulus is defined as the ratio of *tensile stress* to *tensile strain*. Explain what is meant by each of the terms in italics.

tensile stress ____

____

____

tensile strain ____

____

(3)

(b) A long wire is suspended vertically and a load of 10 N is attached to its lower end. The extension of the wire is measured accurately. In order to obtain a value for the Young modulus of the material of the wire, two more quantities must be measured. State what these are and in each case indicate how an accurate measurement might be made.

quantity 1 ____

method of measurement ____

____

quantity 2 ____

method of measurement ____

____

(4)

(c) Sketch below a graph showing how stress and strain are related for a ductile substance and label important features.

(2)

(Total 9 marks)

4 (a) Explain why an engineer needs to consider *the yield stress* of a metal such as steel when deciding on its suitability for use in the construction of a building or a bridge.

____

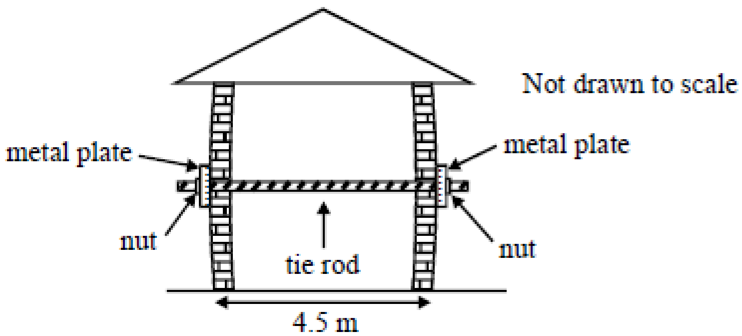
____

____

____

(2)

(b) In order to prevent the collapse of walls of old buildings a metal rod is often used to tie opposite walls together, as shown below.



In one case a steel tie rod of diameter 19 mm is used as shown above. When the nuts are tightened, the rod extends by 1.5 mm. The Young modulus of steel is 2.1×10^{11} Pa.

Calculate:

(i) the force exerted on the walls by the rod;

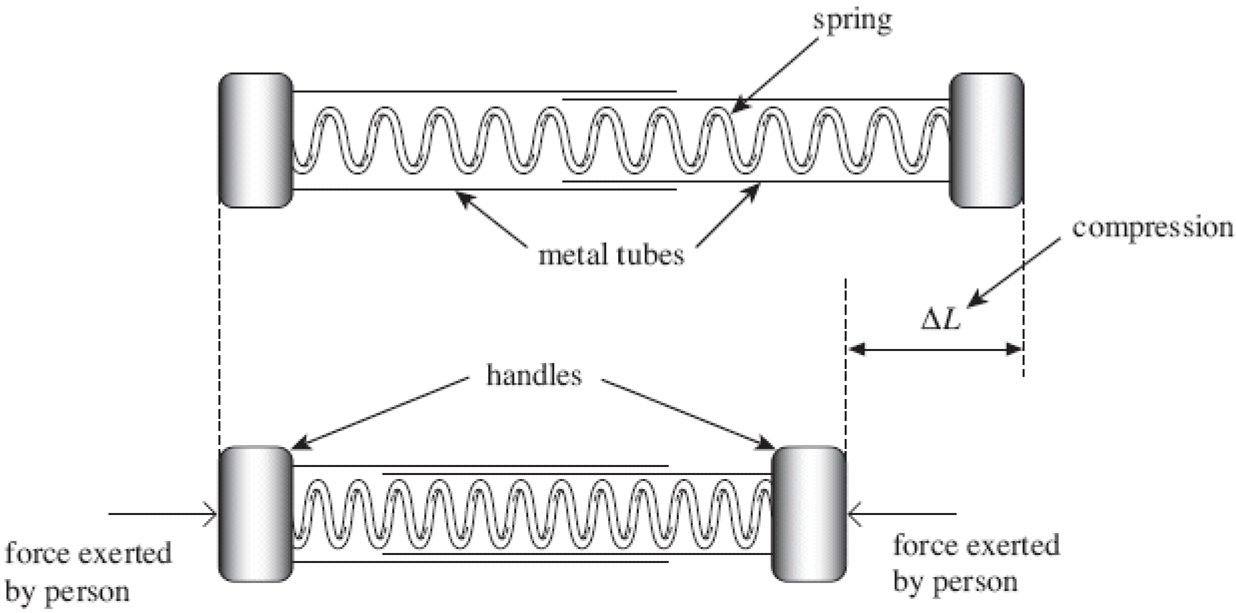
(3)

(ii) the elastic strain energy in the rod when it is extended by 1.5 mm.

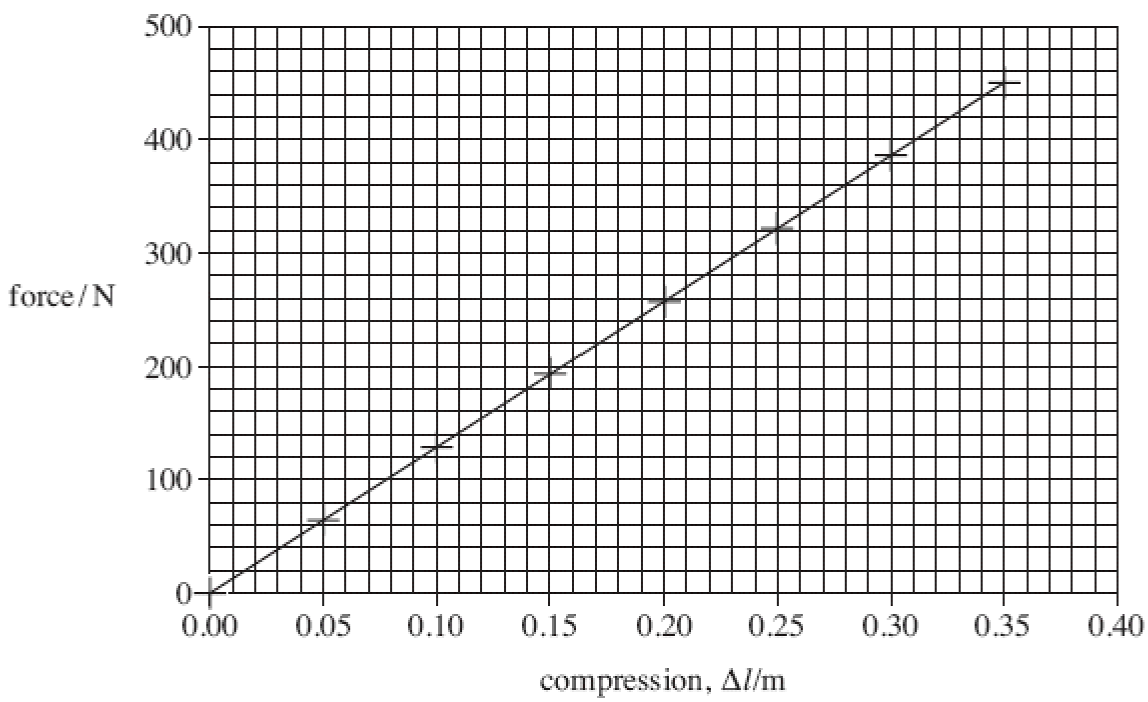
(2)

(Total 7 marks)

5 A type of exercise device is used to provide resistive forces when a person applies compressive forces to its handles. The stiff spring inside the device compresses as shown in the figure below.



(a) The force exerted by the spring over a range of compressions was measured. The results are plotted on the grid below.



(i) State Hooke's law.

____

____

(2)

(ii) State which two features of the graph confirm that the spring obeys Hooke’s law over the range of values tested.

____

____

(2)

(iii) Use the graph to calculate the spring constant, stating an appropriate unit.

answer = ______________________

(3)

(b) (i) The formula for the energy stored by the spring is

$$E = \frac{1}{2} F \Delta L$$

Explain how this formula can be derived from a graph of force against extension.

____

____

____

____

____

____

(3)

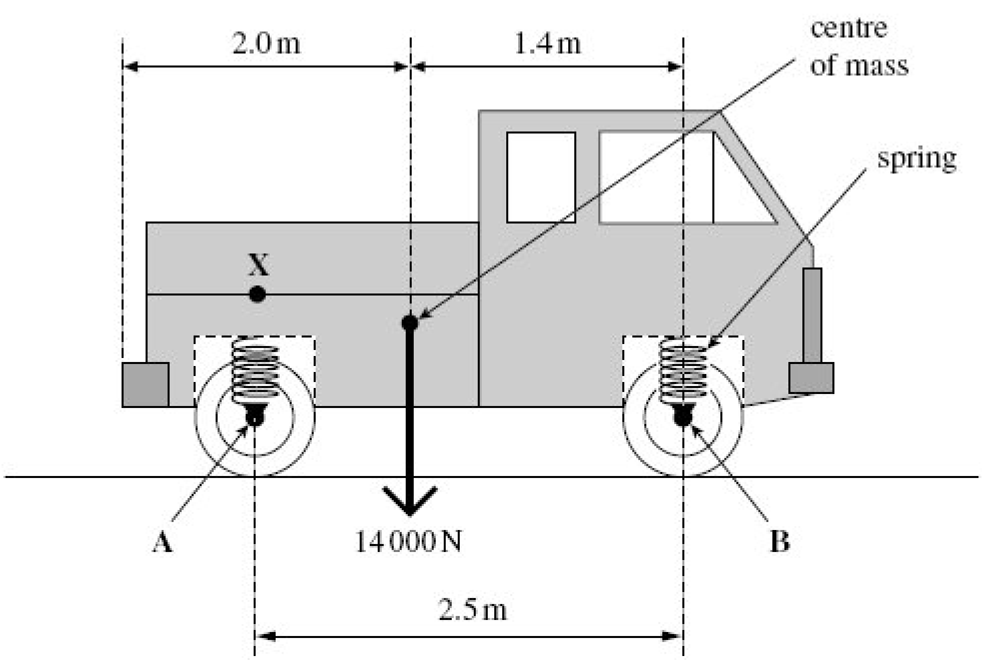
(ii) The person causes a compression of 0.28 m in a time of 1.5 s. Use the graph in part (a) to calculate the average power developed.

answer = ______________________ W

(3)

(Total 13 marks)

6 Heavy duty coil springs are used in vehicle suspensions. The pick-up truck shown in the diagram below has a weight of 14 000 N and length of 4.5 m. When carrying no load, the centre of mass is 2.0 m from the rear end. The part of the vehicle shown shaded in grey is supported by four identical springs, one near each wheel.



(a) (i) Define the moment of a force about a point.

____

____

____

____

(2)

(ii) State and explain which pair of springs, front or rear, will be compressed the most.

____

____

____

____

(2)

(iii) By taking moments about axle **B**, calculate the force exerted on the truck by each rear spring.

answer = ____________________ N

(4)

(b) The spring constant for each of these springs is 100 000 N m^{-1}.

Calculate the distance that each of these rear springs is compressed by this vehicle as shown in the diagram above.

answer = ____________________ m

(2)

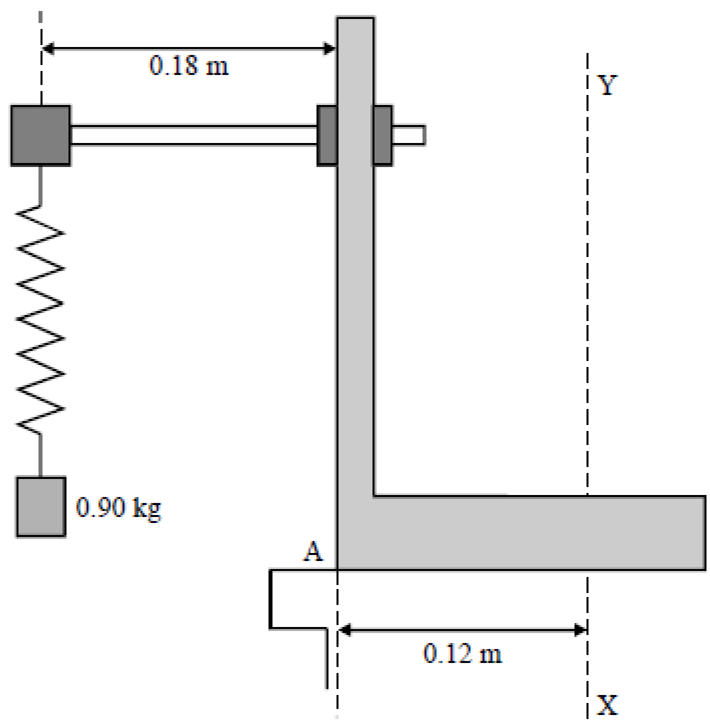
(c) The springs must not be compressed by more than an additional 0.065 m. Calculate the maximum load that could be placed at point **X**, which is directly above the centre of the rear axle **A**, as shown in the diagram above.

answer = ____________________ N

(2)

(Total 12 marks)

7



The mass of a retort stand and clamp is 1.6 kg and their combined centre of mass lies along the line XY. A spring which has a negligible mass is attached to the clamp and supports a mass of 0.90 kg, as shown in the diagram. The spring requires a force of 6.0 N to stretch it 100 mm.

(a) Calculate the extension of the spring.

____

____

(2)

(b) Show that this arrangement will not tip (i.e. will not rotate about A) when the 0.90 kg mass is at rest in its equilibrium position.

(2)

(c) If the mass is lifted up and released, it will vibrate about the equilibrium position. Explain, without calculation, why the stand will tip if the amplitude exceeds a certain value.

(3)

(Total 7 marks)

8 **Figure 1** and **Figure 2** both show the side view of a steel bolt.

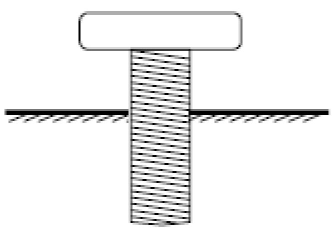


Figure 1

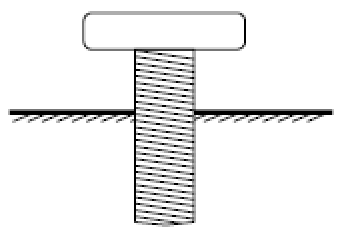


Figure 2

(a) Show on **Figure 1** forces acting on the bolt which would produce a tensile strain.

(1)

(b) The ultimate tensile stress of steel is 5.0×10^8 Pa, the elastic limit is 2.5×10^8 Pa and the Young modulus of steel is 2.0×10^{11} Pa.

Defining any terms used, state what is meant by:

(i) *tensile stress;*

(1)

(ii) *tensile strain;*

(1)

(iii) *the elastic limit.*

(1)

(c) When the main engines of a space shuttle are fired, they develop a total thrust of 4.5×10^6 N. In a test firing the shuttle is held to the launch pad by 8 steel bolts each of diameter 9.0×10^{-2} m. Using data given in (b):

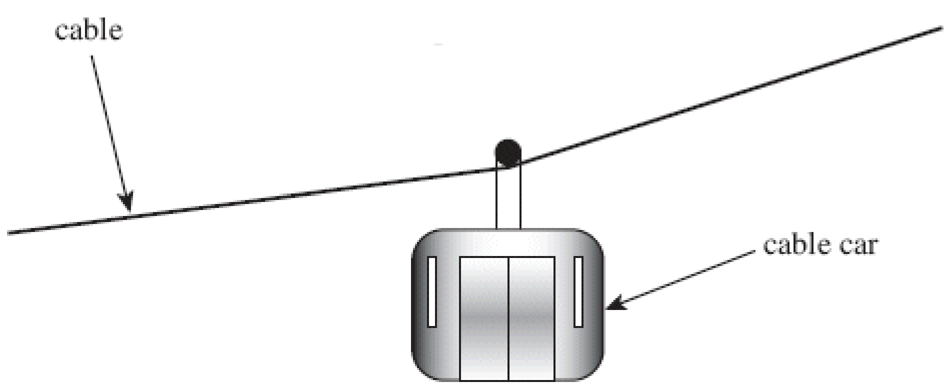
(i) calculate the strain for each bolt during the test;

(4)

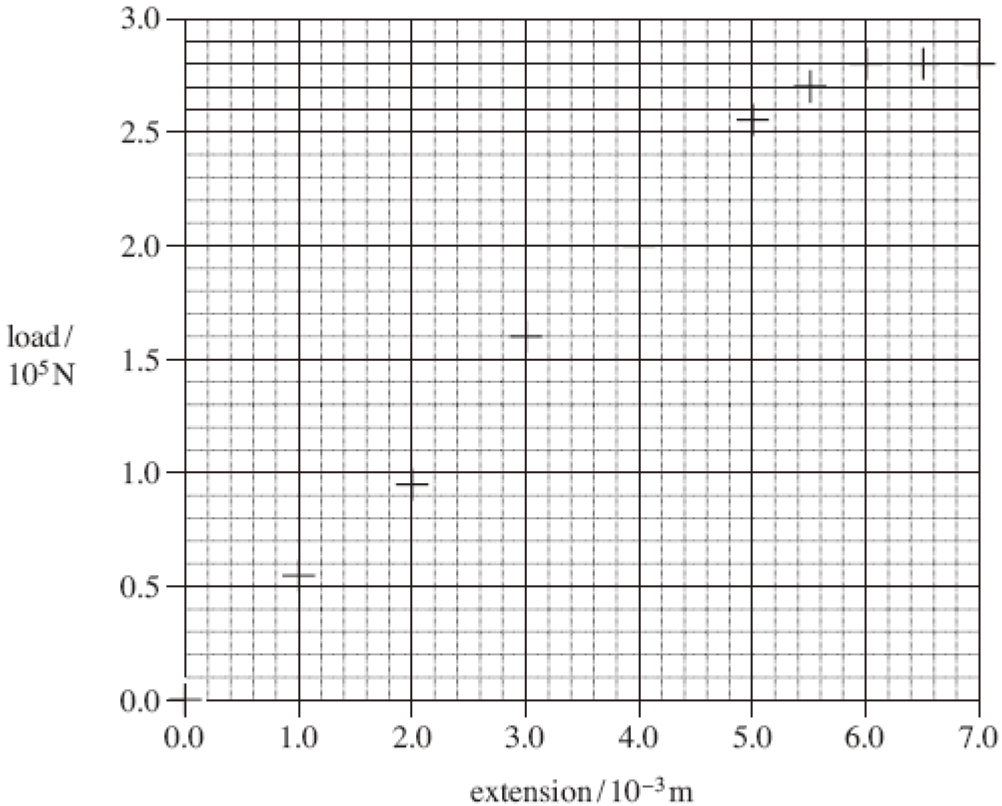
(ii) determine the minimum number of bolts that could have been used when carrying out the test.

(3)
(Total 11 marks)

9 A cable car system is used to transport people up a hill. The figure below shows a stationary cable car suspended from a steel cable of cross-sectional area 2.5×10^{-3} m^2.



(a) The graph below is for a 10 m length of this steel cable.



(i) Draw a line of best fit on the graph.

(2)

(ii) Use the graph to calculate the initial gradient, *k,* for this sample of the cable.

answer = ______________________ N m^{-1}

(2)

(b) The cable breaks when the extension of the sample reaches 7.0 mm. Calculate the breaking stress, stating an appropriate unit.

answer = ______________________

(3)

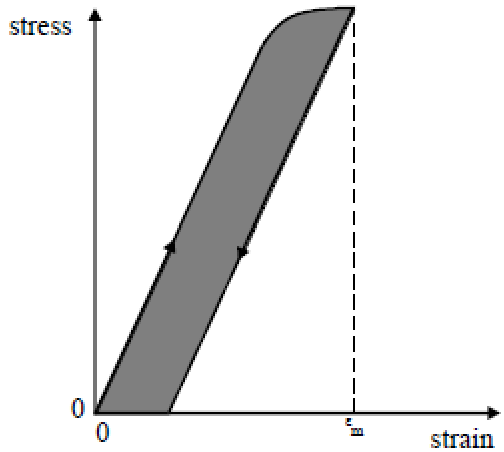
(c) In a cable car system a 1000 m length of this cable is used. Calculate the extension of this cable when the tension is 150 kN.

answer = ______________________ m

(2)

(Total 9 marks)

10 The graph shows the variation of stress with strain for a ductile alloy when a specimen is slowly stretched to a maximum strain of ε_m and the stress is then slowly reduced to zero.



The shaded area

A represents the work done per unit volume when stretching the specimen

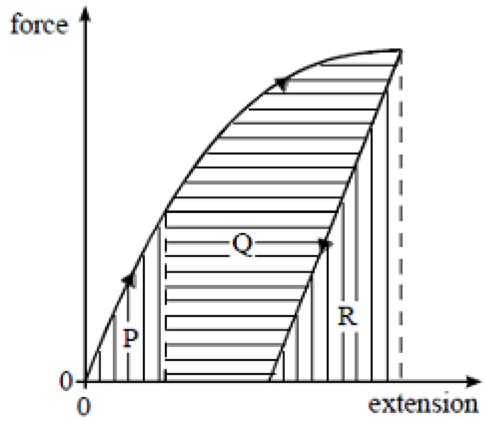
B represents the energy per unit volume recovered when the stress is removed

C represents the energy per unit volume which cannot be recovered

D has units of J m^{-1}

(Total 1 mark)

11 The force on a sample of a material is gradually increased and then decreased. The graph of force against extension is shown in the diagram.



The increase in thermal energy in the sample is represented by area

A R

B $P + Q$

C $P + Q + R$

D $P + Q - R$

(Total 1 mark)

12 A stone is projected horizontally by a catapult consisting of two rubber cords. The cords, which obey Hooke's law, are stretched and released. When each cord is extended by x, the stone is projected with a speed v. Assuming that all the strain energy in the rubber is transferred to the stone, what is the speed of the stone when each cord is extended by $2x$?

A v

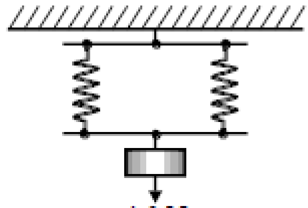
B $\sqrt{2v}$

C $2v$

D $4v$

(Total 1 mark)

13 A load of 4.0 N is suspended from a parallel two-spring system as shown in the diagram.



The spring constant of each spring is 20 N m^{-1}. The elastic energy, in J, stored in the system is

A 0.1

B 0.2

C 0.4

D 0.8

(Total 1 mark)

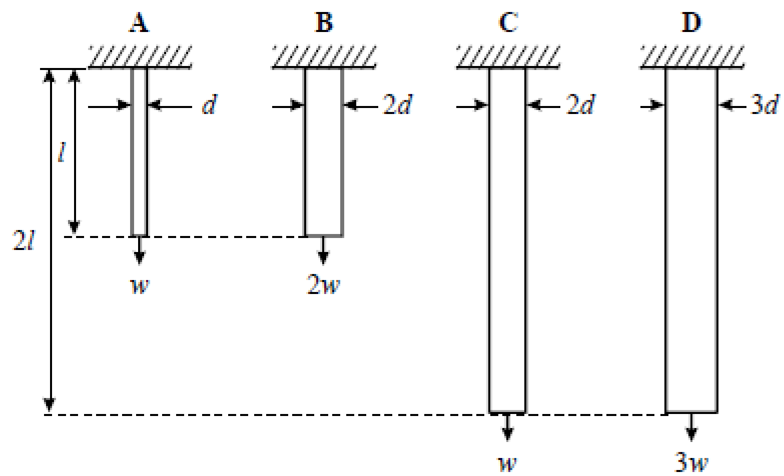
14 For which of the following relationships is the quantity y related to the quantity x by the relationship $x \propto \frac{1}{y}$?

	x	y
A	energy stored in a spring	extension of the spring
B	gravitational field strength	distance from a point mass
C	de Broglie wavelength of an electron	momentum of the electron
D	period of a mass-spring system	spring constant (stiffness) of the spring

(Total 1 mark)

15 The four bars **A**, **B**, **C** and **D** have diameters, lengths and loads as shown. They are all made of the same material.

Which bar has the greatest extension?



(Total 1 mark)

Mark schemes

1

(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 × 78.5 × 3.5 × 10^{-3} **(1)**
= 0.14 J **(1)**

7

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

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

2

[11]

2

(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 × 10^3 × 0.56 × 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]

3

(a) tensile stress = $\frac{\text{(tensile) force}}{\text{cross - sectional area}}$ **(1)**

tensile strain = $\frac{\text{extension}}{\text{original length}}$ **(1)**

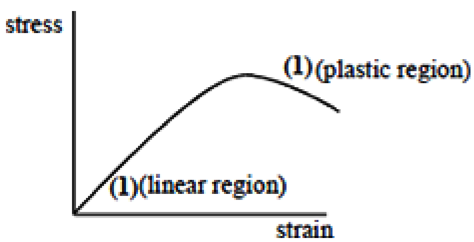
mention of tensile **and** original **(1)**

(3)

(b) diameter of wire **(1)**
in several *places* [or repeated] **(1)**
using a micrometer **(1)**
(original) length of wire **(1)**
using a metre rule (or tape measure) **(1)**

(max 4)

(c)



(2)

[9]

4

(a) below yield stress material behaves elastically
or returns to original length when forces are removed

B1

above the yield stress: (condone 'at the yield stress')
material behaves plastically/is permanently deformed / is ductile

B1

extends considerably / has large strain / extension

B1

for very small increases in stress / force

B1
Max 2

(b) (i) Strain = 3.33×10^{-4} or $\frac{1.5 \times 10^{-3}}{4.5}$ seen **C1**

$E = stress / strain$ **and** $stress = F / A$;
or $E = Fl / A\Delta l$ **C1**

$A = 2.8 \times 10^{-4}$ m^2 **or** $\frac{\pi(0.0019)^2}{4}$ or $\pi(9.5 \times 10^{-3})^2$ seen **C1**

Stress = 7.0×10^7 Pa **C1**

2 max for C marks

Force = 19.6 to 19.8 (20) kN **A1**

(3)

(ii) Strain energy = $\frac{1}{2}F\Delta l$ or ½ their (b)(i) × (1.5×10^{-3}) **C1**

condone incorrect power or no 10^{-3} for C mark
or $\frac{1}{2}\sigma\varepsilon \times volume$
14.6 to 14.9 (15) J (e.c.f.) **A1**

(2)

[7]

5 (a) (i) $F \propto \Delta L$ **(1)** up to limit of proportionality **(1)**
accept 'elastic limit'

$F = k\Delta L$ with terms defined gets first mark **2**

(ii) straight line **(1)** through origin **(1)** **2**

(iii) working shown and F ≥ 200 N **(1)** (500/0.385) = **1290** ± 20 **(1)**

N m^{-1} or N/m kg s^{-2} **(1)** **3**

(b) (i) ($\Delta W = F\Delta s$) so area (beneath line from origin to ΔL) represents (work done or) energy (to compress/extend) **(1)**

work done (on or by the spring) linked to energy stored **(1)**

(area of triangle) = $\frac{1}{2} b \times h$ (therefore $E = \frac{1}{2} F\Delta L$) **(1)** **3**

(ii) F = **360** (N) used **(1)** $P = \dfrac{\frac{1}{2} \times (360) \times 0.28}{1.5} = \dfrac{50.4}{1.5}$ **(1)** = **34**

(33.6) (W) **(1)**

ecf from wrong force

3

[13]

6 (a) (i) force × perpendicular distance **(1)**

between line of action of force and the point **(1)**

2

(ii) rear **(1)**

at rear + idea that centre of mass is closer to the rear wheel
(than to the front wheel) **(1)**

2

(iii) 14000 × 1.4 = F × 2.5 **(1)**

F = 7840 (N) **(1)**

divides their final answer by 2 **(1)**

= 3900 (N) **(1)** (3922)

4

(b) ($F = k\Delta l$) $\dfrac{F}{k}$ or (Δl =) $\dfrac{\text{(a)(iii)}}{100000}$ **(1)**

= 0.039 (m) **(1)** ecf

2

(c) F = (100000 × 0.065 =) 6500 (N) **(1)**

F = (2 × 6500) = 13000 (N) **(1)**

2

[12]

7 (a) use of $mg = k\Delta l$ (or 0.90 × 9.81 = 60Δl)**(1)**
Δl = 0.15 m **(1)**

(2)

(b) no tipping if moment of weight of clamp about A > moment of 0.90 kg **(1)**
moment of 0.90 kg about A = 0.90 g × 0.18 = 0.16 g
moment of weight of clamp about A = 1.60 g × 0.12 = 0.19 g
∴ no tipping **(1)**

(2)

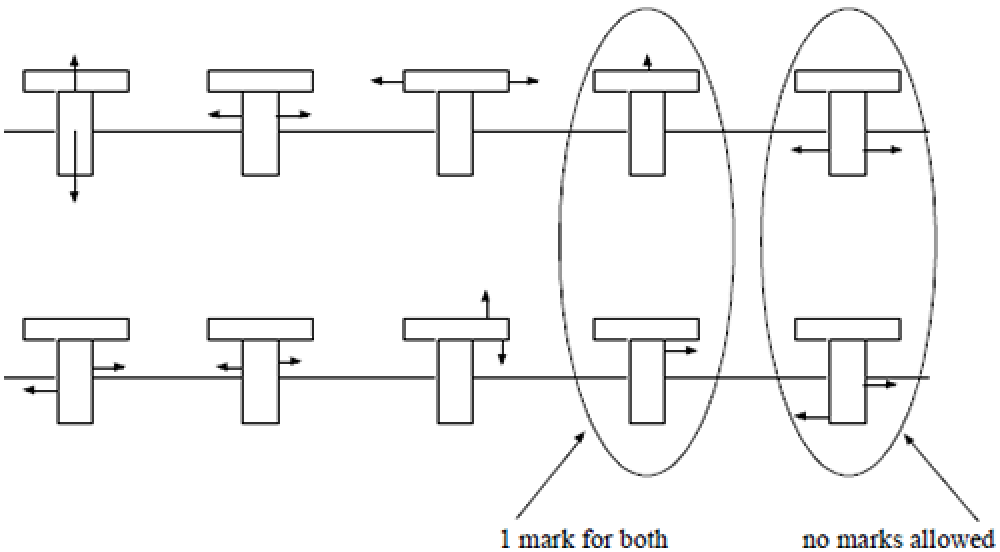
(c) as mass vibrates tension changes **(1)**
maximum tension increases as amplitude increases because maximum length increases **(1)**
tipping when moment of tension exceeds moment of weight of clamp **(1)**

(3)

[7]

8 (a) two forces shown producing tension (see examples below)

B1



(2)

(b) (i) tension / area

or force / area (perpendicular to the surface on which the force acts)

or F / A with terms defined (condone loose definition of area)

B1

(2)

(ii) extension / original length

or extension per unit length

B1

(2)

(iii) the point / stress / strain / force or extension up to which

either all energy supplied in stretching is returned when (deforming) forces are removed

or the object returns to its original shape when (deforming forces) are removed

or beyond which further stress causes plastic deformation or permanent deformation

B1

(2)

(c) (i) force on each bolt = 0.56 MN (ie total force divided by 8)

or

cross-sectional area each bolt = πr^2 plus correct substitution 6.4×10^{-3} m^2

C1

stress = 8.8×10^7 or $\frac{0.56}{6.4 \times 10^{-3}}$

stress / strain = Young modulus

C1

strain = 4.4×10^{-4}

A1

(4)

(ii) area of steel needed = maximum force / UTS

or maximum force / elastic limit

C1

$4.5 \times 10^6 / 5.0 \times 10^8 = 9.0 \times 10^{-3}$ m^2

or $4.5 \times 10^6 / 2.5 \times 10^8 = 18.0 \times 10^{-3}$ m^2

C1

number of bolts = 9.0×10^{-3} / area of a bolt (allow e.c.f.)

= 1.4 bolts

or = 2.8 bolts

A1

answer = 2 bolts (c.a.o.)

or answer = 3 bolts (c.a.o.)

B1

(3)

[11]

9 (a) (i) straight best fit line from 0 → (at least) extension of 4.0×10^{-3} m **(1)**

smooth curve near points after 5.0×10^{-3} m **(1)**

2

(ii) $\left(k = \frac{\Delta F}{\Delta l} = \frac{2.55(\times 10^5)}{5.0(\times 10^{-8})}\right)$ their $\frac{\Delta F}{\Delta l}$ (ignore powers of ten) **(1)**

= 5.1×10^7

and x axis interval ≥ 3.0 **(1)** (5.06 to 5.14×10^7 N m^{-1}) ecf from graph

allow error in calculation ± 2%

2

(b) load = 2.8×10^5 or $\left(\text{stress} = \frac{F}{A}\right) = \frac{2.8(\times 10^5)}{2.5 \times 10^{-3}}$ **(1)** 2.8 only

$= 1.1 \times 10^8$ (Pa) 110 (MPa) **(1)** (1.12×10^8)

(M)Pa, pascals, N m^{-2} **(1)**

3

(c) ($\Delta l = \frac{F}{k}$) $= \frac{150000}{5.1 \times 10^7}$ **(1)** (= 2.94×10^{-3} m for 10 m)

gives 0.29(4) (m) **(1)** ecf

or reads a reasonable extension for 150 kN from the graph **(1)**

and multiples by 100 (= 0.29) (ecf) **(1)**

2

[9]

10 C

[1]

11 B

[1]

12 C

[1]

13 B

[1]

14 C

[1]

15 A

[1]

Examiner reports

1 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 $g = 10\ \text{m s}^{-2}$, which was not acceptable. The data sheet gives $g = 9.81\ \text{m s}^{-2}$ 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.

2 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 ρ = *mass* × *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).

4 (a) Although there were many good answers this was not well understood by the majority of the candidates. Many candidates seemed unaware of the term and wrote only of breaking or bending. Weak answers implied that for stresses below the yield stress the material (bridge or building) would not 'deform' at all.

(b) (i) Most candidates were able to gain one or two marks here by making some progress toward the answer. Common errors were use of the diameter value in πr^2 or failure to convert the mm dimensions to m. Weak candidates often related the 'original length' to 19 mm.

(ii) Allowing the error carried forward there were many correct answers. A minority simply calculated the strain and some thought that ½ *stress* × *strain* gave the energy stored. Using ½ *stress* × *strain* × *volume* made it hard going but those using it usually succeeded. Some following this route used the increase in volume rather than the total volume of the rod.

5 The definition of Hooke's law in part (a) (i) was done very well. Some missed the second mark by not mentioning the *limit of proportionality*.

Most candidates pointed out that the line was straight in part (a) (ii), but many did not score the second mark for saying that the line passed through the origin.

In part (a) (iii) many candidates either gave incorrect units, including Pa, J, Nm, or no units at all. Most correctly calculated the gradient, though some did not use a wide enough range to score full marks.

For part (b) (i), most candidates pointed out that energy stored is found from the area and that area is half base times height for a triangle. For the third mark, it was necessary to relate the area to the work done and this response was rarely seen. Work has been done on the spring to compress it (or work is done by the spring if it is being released) and the area represents the work done and therefore also the energy stored. Some lost marks because they explained how to calculate energy from the graph rather than how to derive the equation.

Surprisingly, only a relatively small number of candidates got full marks on part (b) (ii). Many used $P = Fv$ or $P = W/t$ and did not realise they would need to half their answer. A surprising number misread the force from the graph as 340 N, 370 N or 380 N rather than 360 N for instance. Another common error was to divide force by time (360/1.5) believing 360 to be the work done.

6 In part (a) (i), the majority of candidates stated 'force × perpendicular' distance but only 16% stated the full definition. Many did not recall the definition accurately or did not say the distance was between the line of action of the force and the point. Many said 'force × perpendicular distance from the line of action' or 'force × perpendicular distance to the point'. These candidates were only awarded one mark. A significant number of candidates stated the Law of moments rather than the definition of a moment and some produced a vague description of a turning effect rather than a definition. Students should be encouraged to learn the full definition off by heart.

In part (a) (ii) 57% scored two marks very easily. However, a surprising number selected the front springs rather than the rear due to 'a larger distance from the pivot causing a greater moment on the front'; confusing the *centre of mass* with the 'pivot'. Some candidates assumed the *centre of mass* is always closer to the front of a truck. However, the question shows a rear-engined pick-up. Some candidates thought that the rear springs were 2.0 m from the *centre of mass* having incorrectly interpreting the dimensions on the diagram. Some felt that since the truck was in equilibrium, both sets of springs would be equally compressed.

For such a simple moments question, part (a) (iii) was done poorly by the majority. Perhaps the context made it seem more difficult than it really was, but many chose the wrong distances and equated a moment with a force rather than another moment. Common incorrect answers were 14000 × 1.4 = 19600 and 14000 × 1.4 = 14000 × 1.1. Many common answers given were greater than the weight of the truck. Most of those who couldn't pick up any marks for the moments calculation did realise that it would be necessary to divide by two at the end and so most scored at least one mark.

In part (b) most gained two marks with the error carried forward from their previous answer.

The poor response to part (c) was very surprising. Only 5% gained two marks with 47% getting zero and 18% not attempting the question. Perhaps those who had struggled on previous parts of this question made the assumption that this would be difficult as it was the final part of the question. However, it was perhaps the easiest part of the question and was independent of the previous parts.

8

(a) The question asked for the forces required. Many showed only one force. Some showed only arrows below the surface. Many candidates appeared to have had little experience of drawing force diagrams.

(b) There was frequently a lack of precision in stating the meaning of the terms. Although definition of any terms used was asked in the question, many simply quoted, for example, F / A. In (ii) the 'length' involved was often not defined clearly. In part (iii) many candidates wrote that the elastic limit is 'the point at which the material would not return to its original length when the force is removed'. This should have been expressed as the maximum force for which the material would return to its original length when the force is removed. The phrase 'when the force is removed' was often omitted from otherwise good answers.

(c) (i) Working was often hard to follow in many responses. Candidates should be encouraged to state briefly what they are trying to determine when they use a formula as often there seemed no logic to what was being attempted. With some explanation it might have been possible to gain some credit. The 'divide by 8' aspect of the problem often appeared in odd places in the process and lack of analysis of the problem often led to this being done twice. Many failed because they did not know how to calculate area of cross section and others did not read data accurately and used the diameter given as the radius. Obtaining a strain as if one bolt had been used and then dividing by 8 was an unconvincing approach used by many.

(ii) The best answers showed that candidates had good problem solving ability and that they could set out a sensible argument. The obvious approach is to determine the cross sectional area of steel required and divide by the area of one bolt to determine the number of bolts (rounding up). The use of elastic limit or breaking stress was acceptable.

9 In part (a) (i), the line of best fit had to start very near to the origin and go between the fifth and sixth points on the graph. Most candidates did this very well. Very few candidates who attempted a freehand line made their line smooth or straight enough to gain the first mark. A smooth curve was expected for the last few points on the graph. Most candidates knew that this is how a spring is likely to behave and assumed a curve would be more appropriate than another straight section.

Many candidates did not get the powers of ten correct or simply ignored them when calculating the gradient in part (a) (ii). There was a general lack of care with the precision of the gradient measurement. Often a line would not go exactly through the origin and this would not be taken into account by the candidate. Gradients were often calculated from less than half of the available length of the line.

Part (b) was done well. However, a surprising number of candidates misread the force as 2.6 or 2.7 or 2.85×10^5 N. Marks were often lost on the unit. The unit (Pa or N m^{-2}) needed to have a capital 'N' or 'P' and a lowercase 'm' or 'a'.

For part (c), many candidates successfully used Hooke's law to find the extension of a 10 m length of the cable with a force of 150 kN. Many did not realise that they then needed to multiply by 100 to get the extension of a 1000 m section. Some multiplied by 1000 instead of 100. A considerable number thought they needed to divide by 1000. Surprisingly, very few realised they simply could read off the extension from the graph for a 10 m length at 150 kN and then multiply by 100. It was also common to see the Young modulus equation used, but this was unnecessarily complicated and rarely yielded the correct answer. The suspicion is that this question caught many candidates out, because a certain amount of manipulation of numbers was necessary, in addition to substitution into an equation. This is a skill that will be essential for those continuing to A2.