Solids

Q1.

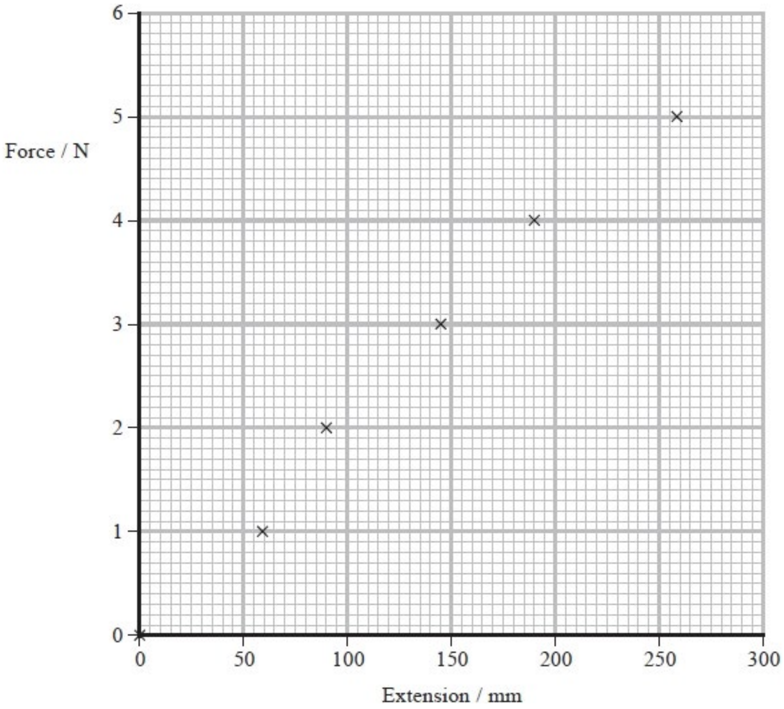
A manufacturer gives the following information about a spring.

1. Follows Hooke's law up to loads of 5 N
2. Maximum extension without permanent deformation 0.4 m
3. Stiffness 21 N m^{-1} ±5%
4. Stores up to 1.6 J

A student carried out an investigation on the spring to test this information.

She applied a range of forces from 0 N to 5 N to the spring. She measured the length of the spring and recorded the extension for each force.

She plotted a graph of force against extension.



Determine the stiffness of the spring.

(3)

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Stiffness = ...

(Total for question = 3 marks)

Q2.

A manufacturer gives the following information about a spring.

1. Follows Hooke's law up to loads of 5 N
2. Maximum extension without permanent deformation 0.4 m
3. Stiffness 21 N m^{-1} ±5%
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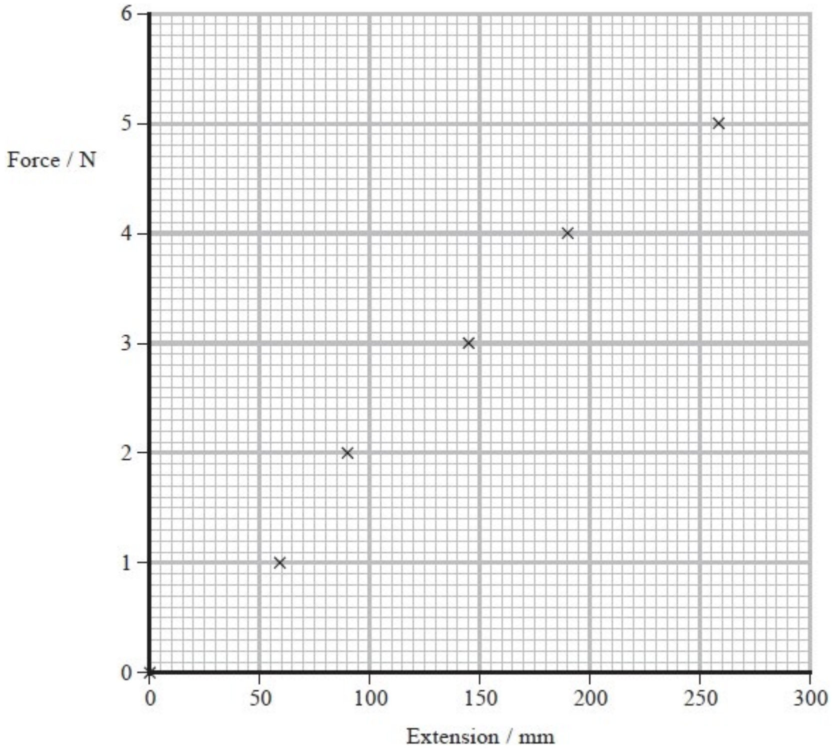

Discuss the extent to which the student's results are consistent with the information given by the manufacturer.

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(Total for question = 6 marks)

Q3.

The student then found a value of μ for a brass wire, using a different method.

(i) He measured the diameter *d* of the wire using a micrometer.

Explain one technique the student should use when measuring *d*.

(2)

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(ii) The student obtained the following data.

d / mm			
0.55	0.59	0.57	0.58

The stated value of μ for the brass wire used by the student was 2.14×10^{-3} kg m^{-1}.

Deduce whether the student's data supports this value for μ.

density of brass = 8700 kg m^{-3} ± 200 kg m^{-3}

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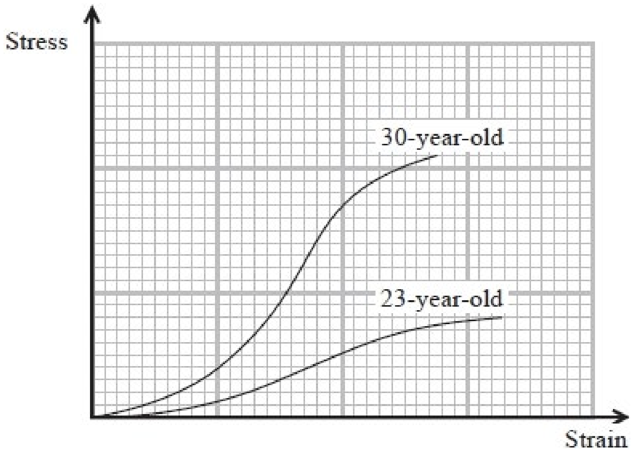
(Total for question = 8 marks)

Q4.

The power of the lens in the human eye changes as the lens changes shape. This enables a person to see objects at different distances clearly. To change the shape, muscles in the eye put the lens under stress.

A stress-strain graph for the eye lens for people of different ages is shown.



(i) State one difference between the lens of a 23-year-old and the lens of a 30-year-old.

(1)

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(ii) Give a reason for your answer, making reference to the graph.

(1)

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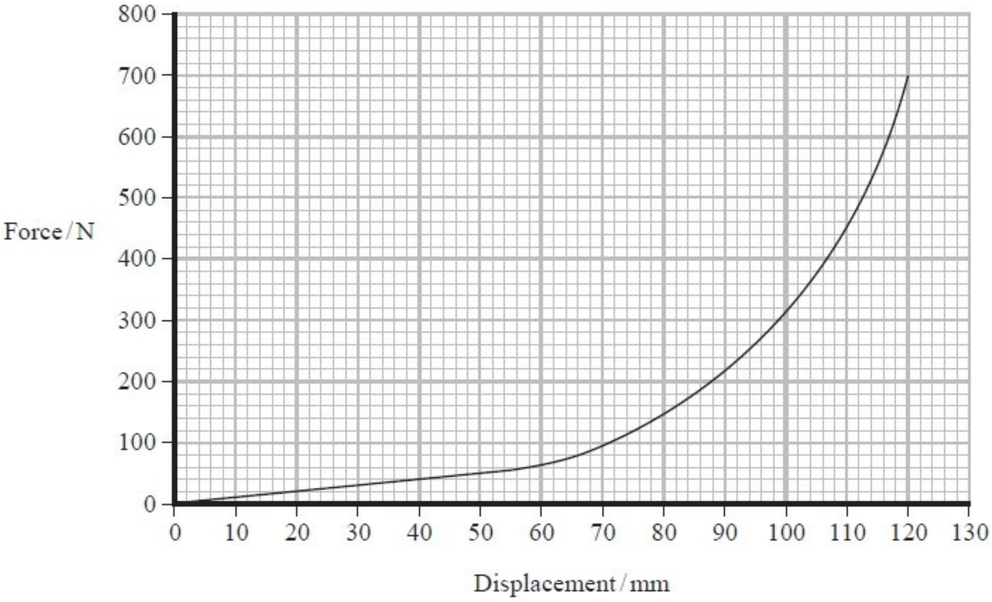
(Total for question = 2 marks)

Q5.

In a conical spring the diameter of the coils increases over its length. The spring can be designed so that each coil fits into the inner diameter of the next coil so they take up minimal space when fully compressed.

(Source: © Anatolii Riabokon/Alamy Stock Vector)

A conical spring is compressed against a flat surface. The graph shows the force-displacement graph for the spring as the compression force increases from 0 N to the point when the spring is fully compressed.



The spring obeys Hooke's law for small compression forces.

The compression force is increased from 60 N to 220 N.

Determine a value for the additional energy stored in the spring due to this increase in force.

(3)

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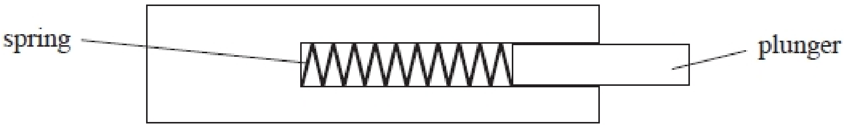
Additional energy = ...

(Total for question = 3 marks)

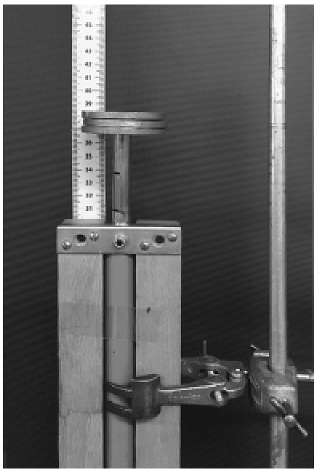
Q6.

A school dynamics trolley has a plunger attached to a spring. When the plunger is pushed in, the spring is compressed. When the plunger is released, it is pushed back out by the spring.



(a) A student investigated the spring to determine whether it obeys Hooke's law in compression.

The trolley was placed vertically in front of a scale and weights were added in turn to the top of the plunger, as shown. The position of the end of the plunger was recorded each time.



The recorded results are shown in the table.

Weight / N	Position of plunger / cm	
0.00	37.3	
2.00	37.0	
4.00	36.6	
6.00	36.2	
8.00	35.9	
10.00	35.5	

(i) Use the results to plot a graph of weight against compression. You may use the additional column for your processed data.

(5)

(ii) The student concluded that the spring obeys Hooke's law with a spring constant of about 600 N m^{-1}.

Determine whether the student's conclusion is justified.

(4)

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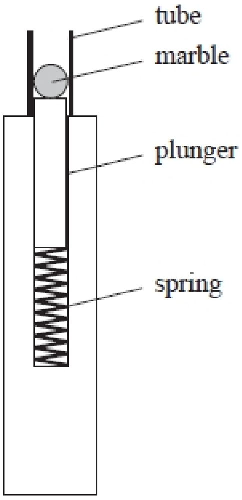
(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



Determine the maximum possible launch velocity of the marble when the spring is compressed by 5.4 cm.
spring constant = 610 N m^{-1}
mass of marble = 4.1 g
mass of plunger = 35.4 g

(4)

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Maximum launch velocity = ...

(c) The launch velocity was measured using a light gate and data logger. This produced a smaller value for the launch velocity than that calculated in (b).

Give a reason why this method produced a smaller value for the launch velocity.

(1)

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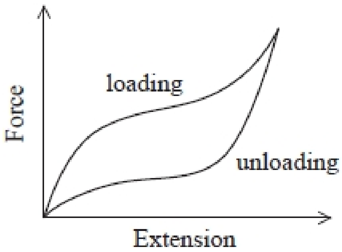
(Total for question = 14 marks)

Q7.

* A resistance band is a length of an elastic material that can be used for exercise. The user repeatedly applies an increasing tensile force (loading) and then releases the force (unloading).

The force-extension graph for the resistance band is shown.



The user finds that the band gets warm during use.

Describe, with reference to the graph, the behaviour of the resistance band when it is repeatedly loaded and unloaded.

(6)

(Total for question = 6 marks)

Q8.

In an investigation to determine the Young modulus of a material in the form of a wire, a tensile force of 14 N was applied to the wire. The length of the wire was 2.0 m. The diameter of the wire was 2.5 mm. The length of the wire increased by 0.20%.

Explain why the wire chosen should be as long as possible.

(2)

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(Total for question = 2 marks)

Q9.

The photograph shows an example of a Foucault pendulum.

This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

During refurbishment, the pendulum is taken down and the wire is replaced.

Steel wires of the following diameters are available:

0.71 mm 0.91 mm 1.22 mm 1.63 mm 2.03 mm

(i) Explain which of these wires is the thinnest that could be used to support the sphere safely.

breaking stress of steel = 3.10×10^8 N m^{-2}

(3)

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(ii) The wire identified in part (i) is used for the pendulum, the unstretched length of the new wire is 11.2 m.

Calculate the extension of the new wire when the sphere is attached.
Young Modulus for steel = 200 GPa

(3)

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Extension = ...

(Total for question = 6 marks)

Q10.

Genuine crystal balls are made from clarified quartz rather than glass.
A student was given a small crystal ball and wanted to know whether it was genuine.

The mean diameter of the crystal ball was measured to be 5.06 cm and the mass of the crystal ball was measured to be 175 g.

Show that the density of the material of the crystal ball is about 2600 kg m^{-3}.

(3)

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(Total for question = 3 marks)

Q11.

Genuine crystal balls are made from clarified quartz rather than glass. A student was given a small crystal ball and wanted to know whether it was genuine.

The student measured the diameter of the crystal ball using vernier calipers with a resolution of 0.01 cm.
She measured the mass of the crystal ball using a balance with a resolution of 1 g.

The table gives the densities of clarified quartz and glass.

Material	Density / kg m^{-3}
Clarified quartz	2650
Glass	2590

Determine whether the crystal ball was genuine.

(6)

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(Total for question = 6 marks)

Q12.

Concrete is a material used in buildings due to its high compressive strength.

Another concrete post is reinforced with steel rods, to increase its tensile strength.
A steel rod is under a tensile load of 130 N and extends by 4.0×10^{-4} m.
The steel has not reached its elastic limit.

Calculate the elastic strain energy in the steel rod.

(2)

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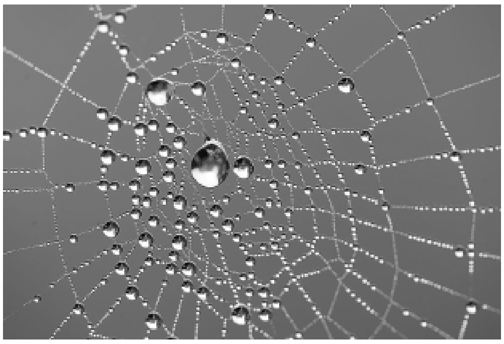
Elastic strain energy = ...

(Total for question = 2 marks)

Q13.

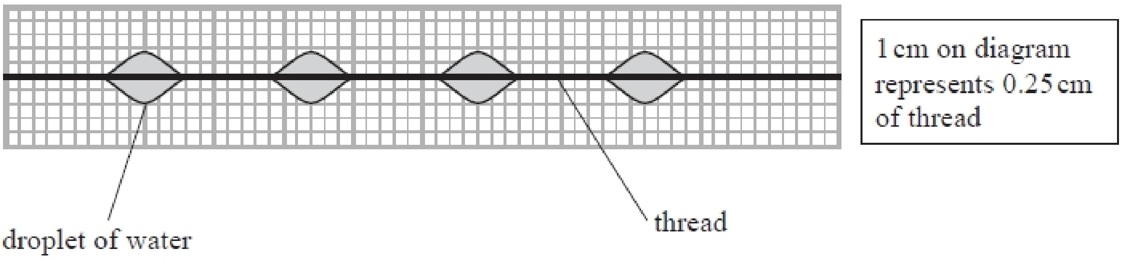
The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



Spiders are almost completely dependent on vibrations transmitted through their web for receiving information about the location of trapped insects. When the threads are disturbed by the insects, progressive waves are transmitted along sections of the silk.

It has been suggested that the droplets of water collect at certain points on the web because stationary waves are formed.

The diagram shows water droplets on a single thread of spider silk when the frequency of waves is 7.9 Hz.



Further measurements are taken to test whether the observations are consistent with the presence of stationary waves in the threads.

diameter of the thread = 3.6×10^{-6} m

mass per unit length of the thread = 1.32×10^{-8} kg m^{-1}

Young modulus of spider silk = 1.2×10^{9} N m^{-2}

strain in the thread = 9.7×10^{-9}

Determine, by considering wave speed, whether the measurements are consistent with this suggestion.

(7)

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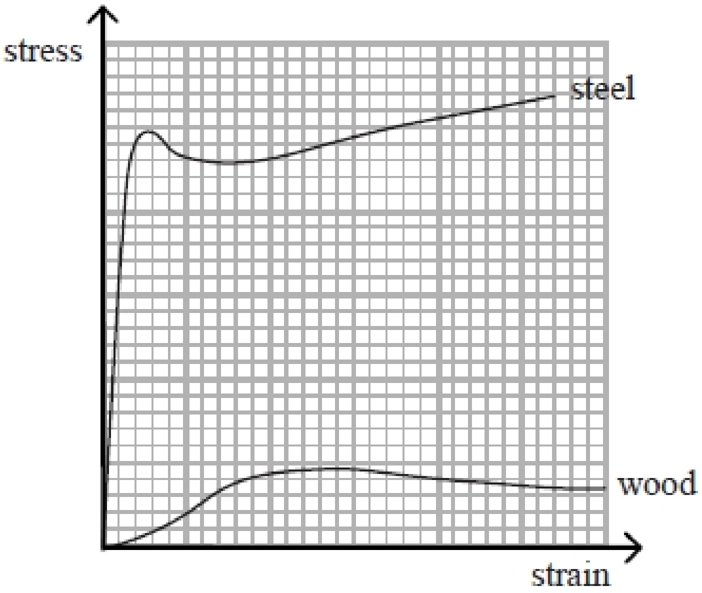
Q14.

Read the following article and then answer the questions that follow.

> "The fastest, tallest and longest dive coaster, on which amusement park thrill seekers can experience free fall, is set to open next summer at Cedar Point in Sandusky, Ohio. Valravn is designed to take riders up to a 66 m peak from which they plummet vertically with an acceleration g and feel weightless.
>
> The advent of steel-frame roller coasters in 1959 made taller structures possible.
>
> Whereas height remains one of the best ways to attain intense speeds, a coaster car can also be shot from its starting point via electromagnetic propulsion or a catapult. Cars on these launched coasters have the potential to go from zero to 130 km h^{-1} in two seconds.
>
> Although coasters can definitely go faster, they're limited by the acceleration those higher speeds would require. Roller coasters reach their peak speeds in a matter of seconds. The achieved acceleration is what causes *g*-forces, which allows riders to feel an increased or decreased sense of their mass. These *g*-forces can be dangerous but they are also well understood by physicists, so roller coasters are built according to strict standards that keep them well within safe levels.
>
> Coasters are only permitted to accelerate up to 6g."
>
> (Source: *Shriek Science: Simple Physics Powers Extreme Roller Coasters Hackett Jennifer, Oct 14, 2015*)

The graph shows typical stress-strain curves for wood and steel.



Discuss how the use of steel, rather than wood, has made the construction of faster and taller roller coasters possible.

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(Total for question = 5 marks)

Q15.

A deforming force is applied to a sample of material.

Which row of the table shows the axes of a graph for which the gradient is stiffness *k*?

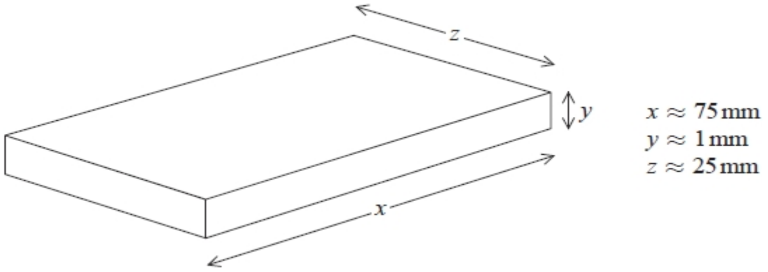
	y-axis	*x*-axis
☒ **A**	extension	force
☒ **B**	force	length
☒ **C**	stress	strain
☒ **D**	strain	length

(Total for question = 1 mark)

Q16.

A student carries out measurements to determine the density of glass. The student has 20 glass microscope slides available.

The approximate dimensions of one slide are shown.



(a) The density is calculated using the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

Describe how the student can determine an accurate value for the density of the glass. Your answer should include the measuring instruments required.

(4)

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(b) State one precaution that the student should take to ensure the measurements are accurate.

(1)

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(Total for question = 5 marks)

Q17.

A sample of steel in the form of a wire is subjected to an increasing load.

Which of the following is the best description of the elastic limit of the steel?

☐ **A** The stress at which the steel undergoes an increase in strain with no increase in stress.

☐ **B** The stress beyond which the stress and strain are no longer proportional.

☐ **C** The stress beyond which the steel becomes permanently deformed.

☐ **D** The stress at which the steel breaks.

(Total for question = 1 mark)

Q18.

When a force *F* is applied to a spring with stiffness *k*, the elastic potential energy stored is *E*.

What is the elastic potential energy stored when a force 2*F* is applied to a spring with stiffness 2*k*?

☐ **A** $\frac{E}{2}$

☐ **B** E

☐ **C** $2E$

☐ **D** $8E$

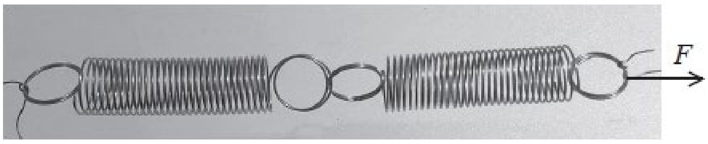
(Total for question = 1 mark)

Q19.

A horizontal force *F* is applied to a horizontal spring, fixed at one end.

The stiffness of the spring is *k* and the elastic strain energy stored is *E*.

A second, identical spring is added and the same force is applied to the combination of springs, as shown.



What is the elastic strain energy stored for the combination of springs?

☒ **A** $\frac{E}{2}$

☒ **B** E

☒ **C** $2E$

☒ **D** $8E$

(Total for question = 1 mark)

Q20.

In an investigation to determine the Young modulus of a material in the form of a wire, a tensile force of 14 N was applied to the wire. The length of the wire was 2.0 m. The diameter of the wire was 2.5 mm. The length of the wire increased by 0.20%.

Calculate the energy stored in the stretched wire.

(2)

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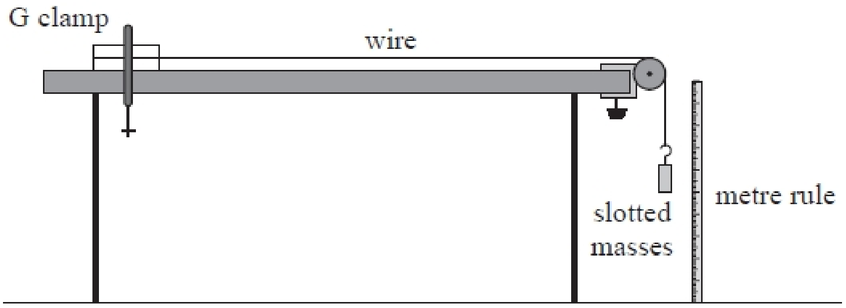
Energy stored = ...

(Total for question = 2 marks)

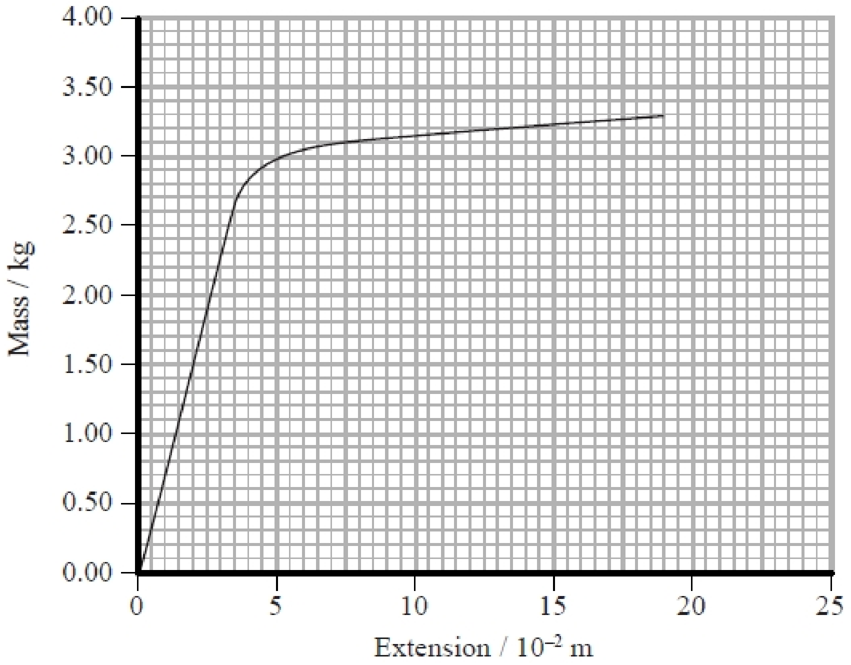
Q21.

The diagram shows the equipment a student used to investigate the behaviour of a material in the form of a wire under an increasing tension.



Masses were added up to a maximum of 3.30 kg. Each time a mass was added the extension of the wire was calculated.

(a) The following mass-extension graph was obtained.



(i) Initially the extension increased linearly.
State what is meant by 'increased linearly' in relation to this graph and what can be concluded about the wire from this observation.

(2)

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(ii) Use the graph to calculate the maximum energy that the wire could store while behaving linearly.

(3)

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Maximum energy = ...

(iii) Describe the behaviour of the wire when the added mass was greater than 2.9 kg.

(2)

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(b) The student modifies the investigation.

(i) Suggest **one** modification that would produce a greater extension for a given mass.

(1)

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(ii) Suggest **two** measuring techniques that could be used to ensure the accuracy of the measured extensions.

(2)

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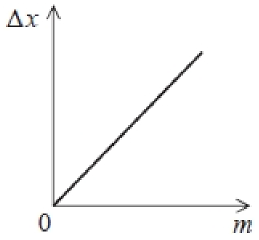
(Total for question = 10 marks)

Q22.

A spring is hung vertically and masses are added to the lower end.
The graph shows how the extension Δ*x* of the spring varies with the mass *m* added.



The work done in extending the spring can be expressed as

(1)

☒ **A** $mg\Delta x$

☒ **B** $\frac{mg}{\Delta x}$

☒ **C** $\frac{1}{2}mg\Delta x$

☒ **D** $\frac{mg}{2\Delta x}$

(Total for question = 1 mark)

Q23.

A student is investigating the extension of a spring.

A force of 29 N is applied to the spring and it extends by 32 cm. The spring obeys Hooke's law.

Calculate the extension of the spring when a force of 27 N is applied.

(2)

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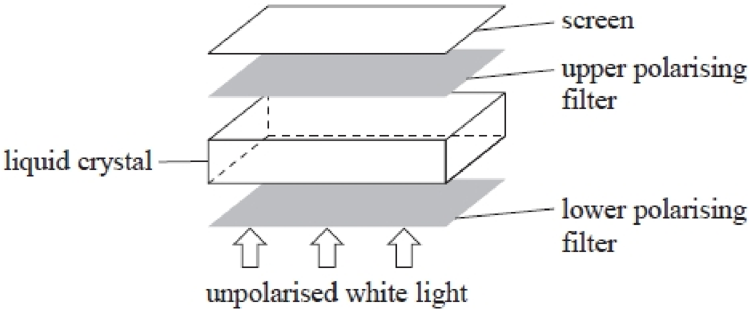
Extension = ...

(Total for question = 2 marks)

Q24.

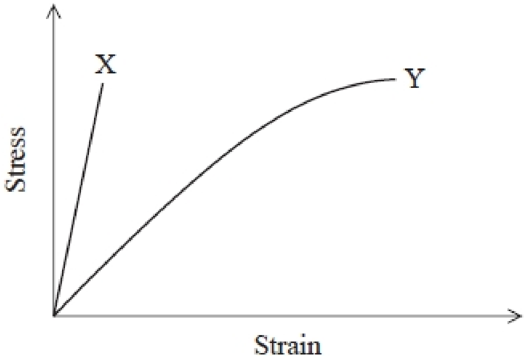
A liquid-crystal display uses a series of segments to form letters and numbers on a screen.

The construction of a display segment is shown.



- Unpolarised white light passes through the lower polarising filter and becomes plane polarised.
- When there is no potential difference (p.d.) across the liquid crystal, the molecules in the liquid crystal rotate the plane of polarisation by 90°.
- Light then passes through the upper polarising filter and appears on the screen.
- When a p.d. is applied across the liquid crystal, the molecules no longer rotate the plane of polarisation. The light will not pass through the upper polarising filter and the screen appears dark.

Manufacturers are developing new materials for flexible screens for liquid-crystal displays. The graph shows how stress varies with strain for two materials X and Y up to typical stresses that would be applied to the screens in normal use. Both materials behave elastically over the ranges shown.



Deduce which material would be more suitable to use for the flexible screen in liquid-crystal displays.

(4)

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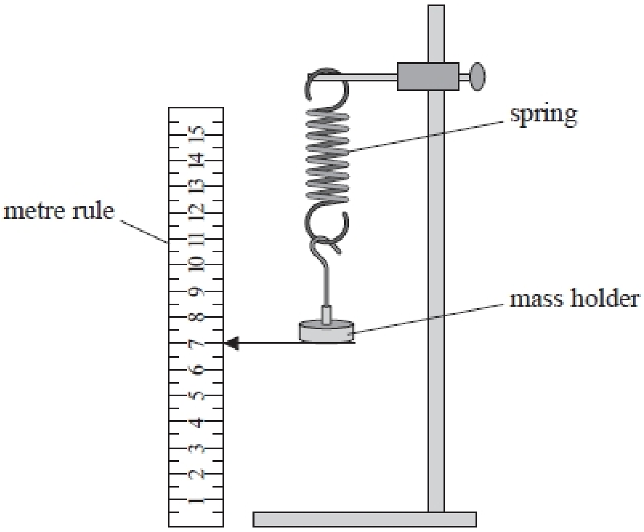
(Total for question = 4 marks)

Q25.

A student investigated the behaviour of a spring under tension. The spring was hung vertically with a mass holder attached.

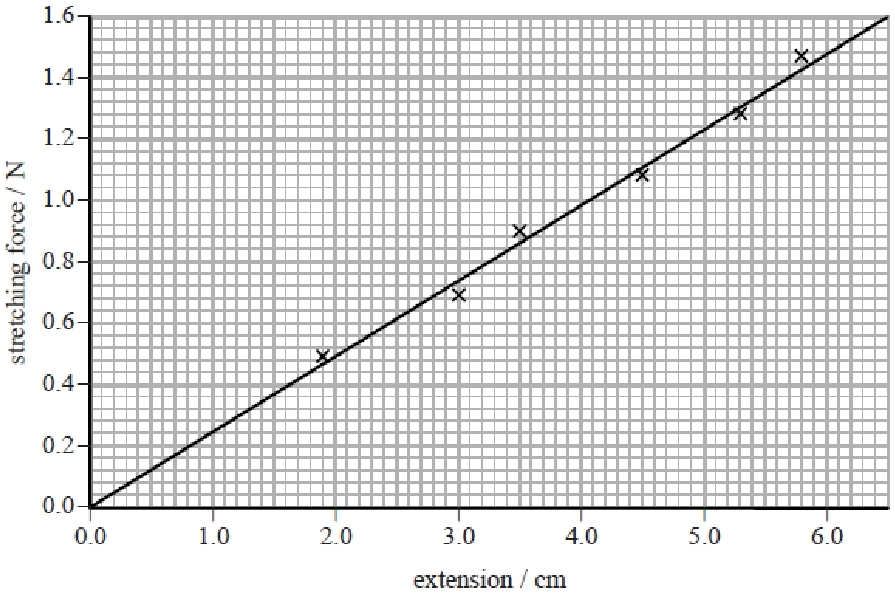


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

The student produced the following table.

Mass added / g	Extension / cm	Stretching force / N
50	1.9	0.49
70	3	0.69
90	3.5	0.9
110	4.5	1.08
130	5.3	1.28
150	5.8	1.47

The student used her data to plot a graph as shown.



Determine a value for the force constant *k* of the spring.

(2)

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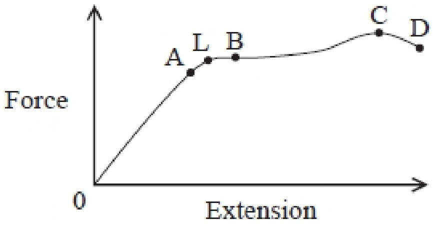
k = ...

(Total for question = 2 marks)

Q26.

The diagram shows a force-extension graph for a wire.



L is the elastic limit.

Which point represents the yield point?

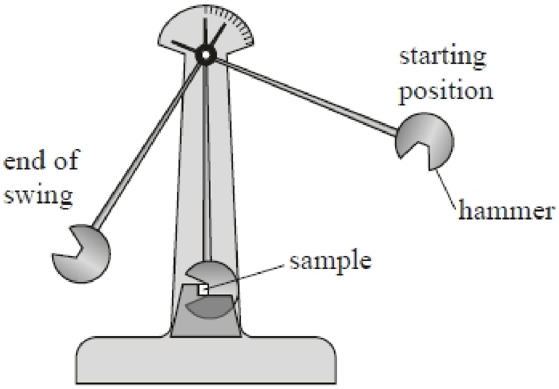
(1)

☐ **A**
☐ **B**
☐ **C**
☐ **D**

(Total for question = 1 mark)

Q27.

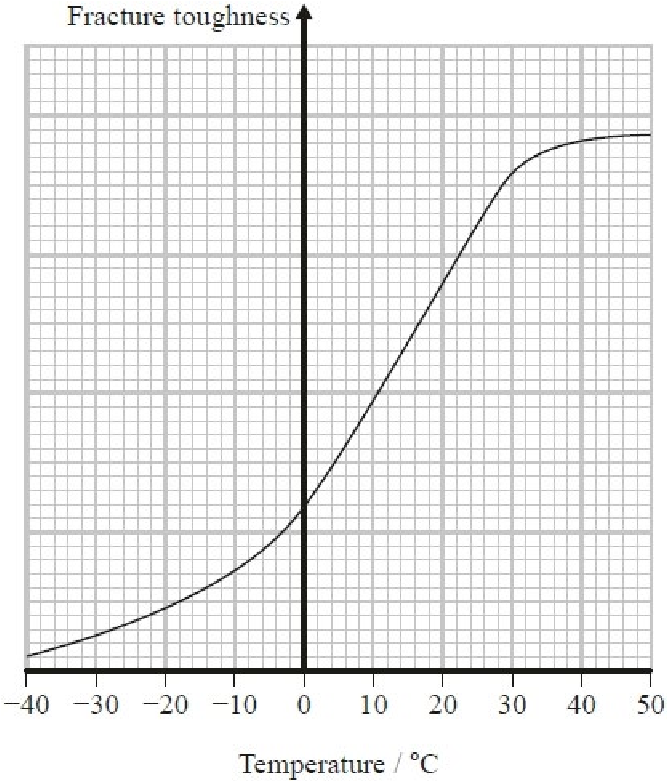
Read the passage and answer the questions below.



(ref: Physics Review April 2015 p22)

The Charpy test is used by scientists to measure the fracture toughness of a material. A simple pendulum, with a hammer on the end, is held high and released so that it swings down and strikes the sample. The height from which the hammer is released is increased until the sample fractures. Some energy is absorbed by the sample in the impact but the hammer continues to move until it comes to rest at the top of its swing. Due to the law of conservation of energy the hammer will not swing up as high as its starting position. The difference in height between the start and end is proportional to the energy absorbed in the impact – the fracture toughness.

The sketch graph shows how the fracture toughness of a sample of steel varies with temperature.



A material with a low fracture toughness can absorb less energy before fracture than a material with high fracture toughness.

The ship *Titanic* sank in 1912 following a collision with an iceberg in the icy waters of the Atlantic. The steel hull of the ship was fractured by the impact.

Deduce why the steel was likely to have been fractured by the impact.

(3)

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(Total for question = 3 marks)

Q28.

The Hooke's law equation is:

$$\Delta F = k\Delta x$$

Which of the following gives the base units of *k*?

☒ **A** kg s^{-2}

☒ **B** kg m s^{-2}

☒ **C** N m

☒ **D** N m^{-1}

(Total for question = 1 mark)

Q29.

A force meter measures force by making use of Hooke's Law.

The extension of a spring inside the force meter allows the magnitude of the force applied to be read from a scale.

The spring in one type of force meter extends by 5.5 cm when a force of 2.5 N is applied.

(i) Show that the stiffness of the spring is about 50 N m^{-1}.

(2)

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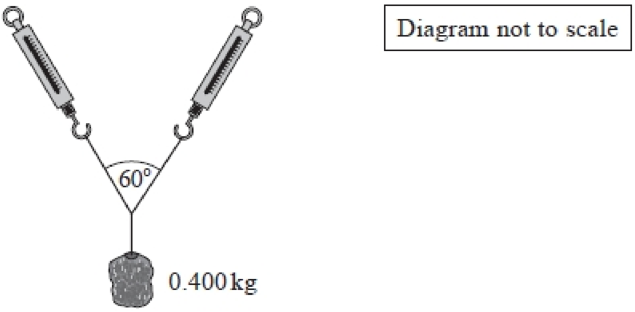
(ii) Two identical force meters of this type support a mass of 0.400 kg as shown.



(Source: adapted from https://image.slidesharecdn.com/balancedunbalancedgravityfriction-170509114658/95/balanced-unbalanced-gravity-friction-14-638.jpg?cb=1494330595)

Calculate the extension Δ *x* of each spring.

(4)

....

....

....

....

....

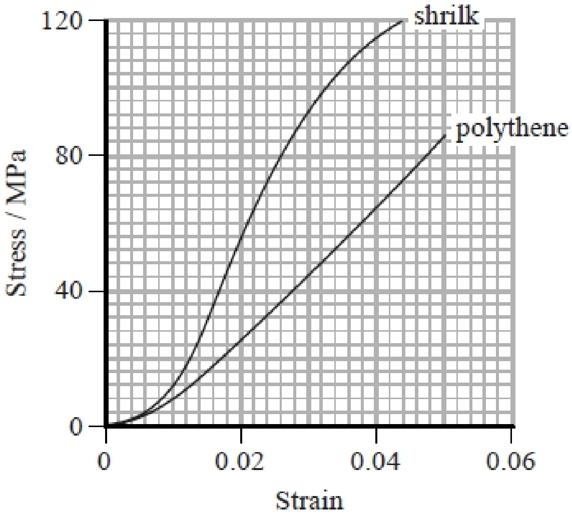
Δ *x* = ...

(Total for question = 6 marks)

Q30.

Shrilk is a new material made from discarded shrimp shells. It is biodegradable and is easily moulded into different shapes. Shrilk is an alternative to polythene and could be used to make waste bags in the future.

The graph shows a stress-strain curve for a 25.0 cm length of shrilk and for a similar length of polythene, up to breaking point.



(a) (i) Calculate the force applied to the shrilk at a strain of 0.02

cross-sectional area = 1.2×10^{-6} m^2

(3)

....

....

....

....

Force = ...

(ii) Determine the extension of the shrilk at a strain of 0.04

(2)

....

....

....

....

....

Extension = ...

(b) Deduce whether shrilk or polythene is better for making waste bags.

(3)

....

....

....

....

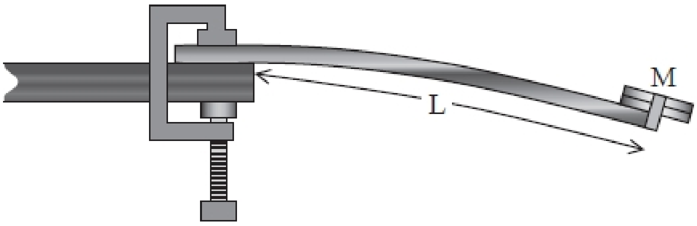
....

....

(Total for question = 8 marks)

Q31.

A metre rule clamped at one end is an example of a cantilever. The diagram shows an arrangement of a cantilever where a mass *M* is attached to the end of a metre rule and the rule clamped with a free length *L*.



When *M* is displaced, the period of oscillation *T* of the cantilever is related to *L* and the Young modulus *E* of the material of the metre rule by the following equation:

$$T^2 = \frac{KML^3}{E}$$

where *K* is a constant.

A student uses this arrangement to compare the Young modulus values for two metre rules. The metre rules have identical dimensions, but are made from different types of wood.

(a) One of the metre rules is set into oscillation, and the time for 20 oscillations is measured with an electronic stopwatch. This is repeated twice with the same metre rule. The same procedure is carried out for the second metre rule, using an identical mass and free length.

(i) Explain why a pointer placed at the equilibrium position of the end of the metre rule would help the student to obtain repeatable data.

(2)

....

....

....

....

(ii) The student collects the following data.

	Time for 20 oscillations t_1 / s	**Time for 20 oscillations t_2 / s**	**Time for 20 oscillations t_3 / s**
Metre rule 1	19.3	19.1	19.3
Metre rule 2	21.3	21.5	21.5

Use this data to calculate a value for the ratio E_2/E_1 of the Young modulus values of the two metre rules.

(3)

....

....

....

....

....

....

E_2/E_1 = ...

(b) The student intends to use a graphical method to determine a value for the Young modulus of one of the metre rules. She decides that she will vary the free length *L* and measure the time period for each length.

(i) State what variables she should plot.

(1)

y-axis ....

x-axis ....

(ii) Explain how the student can use her graph to determine the Young modulus of the rule.
You may assume that she has been provided with the value of *K*.

(2)

....

....

....

....

(c) Explain what the student could do to reduce the uncertainty in her measurement of the time period.

(2)

....

....

....

....

(Total for question = 10 marks)

Q32.

A mass is supported by a single spring as shown.

The strain energy stored by the spring is *E*.

The mass is then supported by two springs, each identical to the first spring, as shown.

What is the total strain energy stored with two springs arranged in this way?

☒ **A** ¼ *E*

☒ **B** ½ *E*

☒ **C** *E*

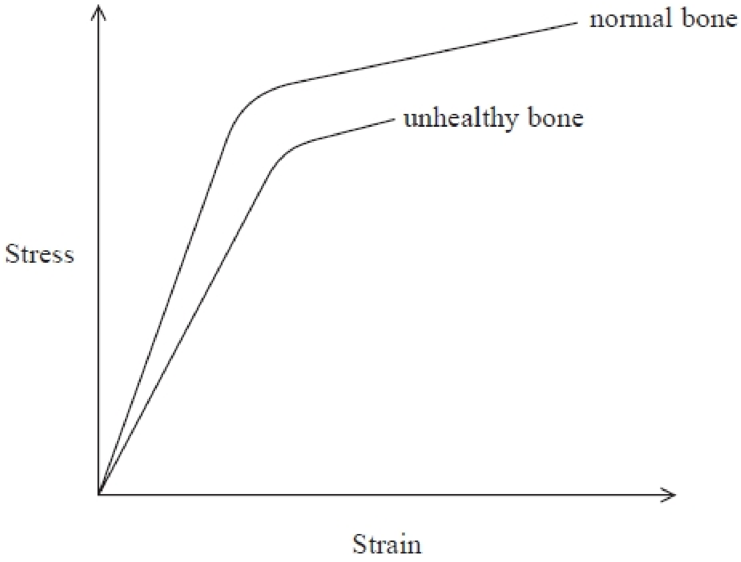
☒ **D** 2*E*

(Total for question = 1 mark)

Q33.

Some sports place high stresses on the bones in the body, which can result in injury.

The graph shows how stress varies with strain for normal bone and for unhealthy bone.



Describe how the graph shows that unhealthy bone under stress is more likely to break than normal bone.

(3)

....

....

....

....

....

....

(Total for question = 3 marks)

Q34.

The diagram shows a rock climber of mass 55 kg. She is hanging on a rope with one foot in contact with a rock face. She uses this foot to push herself horizontally away from the rock face. The rope is inclined at 20° to the vertical.

(a) Complete the free-body force diagram below to represent the forces acting on the climber.

(3)

(b) (i) Show that the tension in the rope is about 600 N.

(3)

....

....

....

....

....

....

(ii) The rope extends by 2.5 cm when used as shown.
Calculate the energy stored within the rope.

(2)

....

....

....

....

Energy stored = ...

(iii) State one assumption made in this calculation.

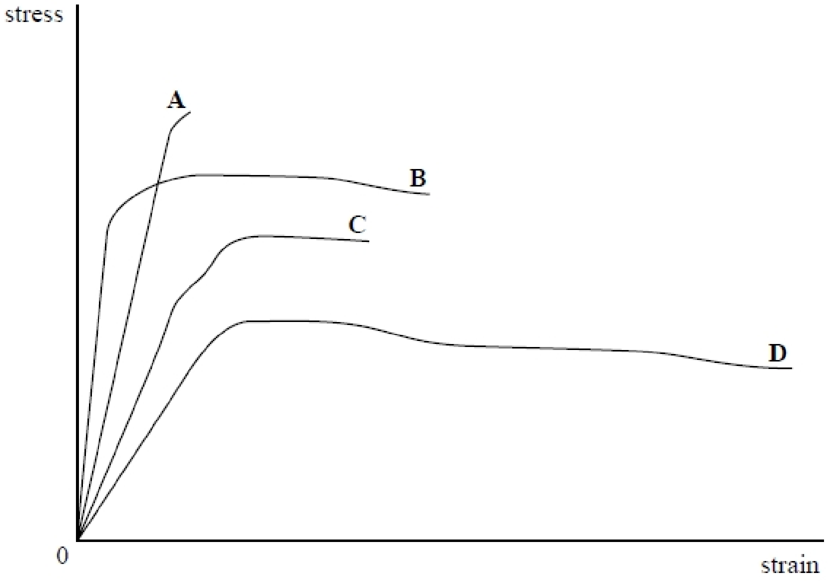
(1)

....

....

(Total for question = 9 marks)

Q35.



Which of the materials represented in the graph has the largest value of the Young Modulus?

☐ **A**

☐ **B**

☐ **C**

☐ **D**

(Total for question = 1 mark)

Q36.

In an investigation to determine the Young modulus of steel in the form of a wire, a student plots a straight line graph. The Young modulus is numerically equal to the gradient of the graph.

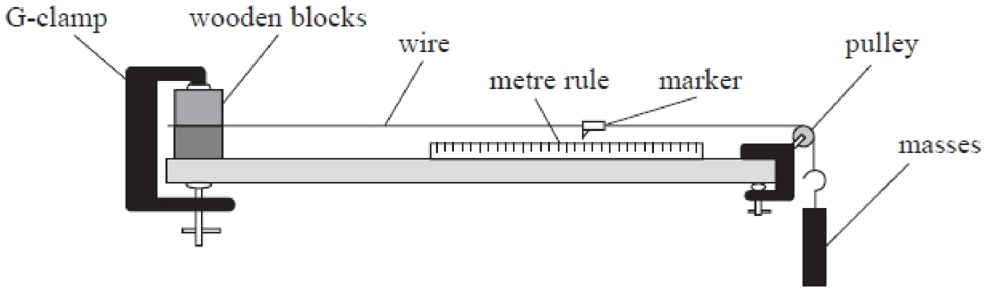
What quantities did the student plot on each axis on the graph?

		y-axis	*x*-axis
☒	**A**	strain	stress
☒	**B**	stress	strain
☒	**C**	$\frac{1}{\text{strain}}$	stress
☒	**D**	$\frac{1}{\text{stress}}$	strain

(Total for question = 1 mark)

Q37.

A student carries out an investigation to measure the Young modulus of the material of a wire. He clamps one end of the wire and passes the other end over a pulley as shown.



The student measures the length and diameter of the wire. He hangs masses from the free end of the wire and completes a table with values of mass and extension.

Describe how the data collected should be used to determine the Young modulus using a graphical method. Your answer should include a sketch of the expected graph.

(4)

....

....

....

....

....

....

....

....

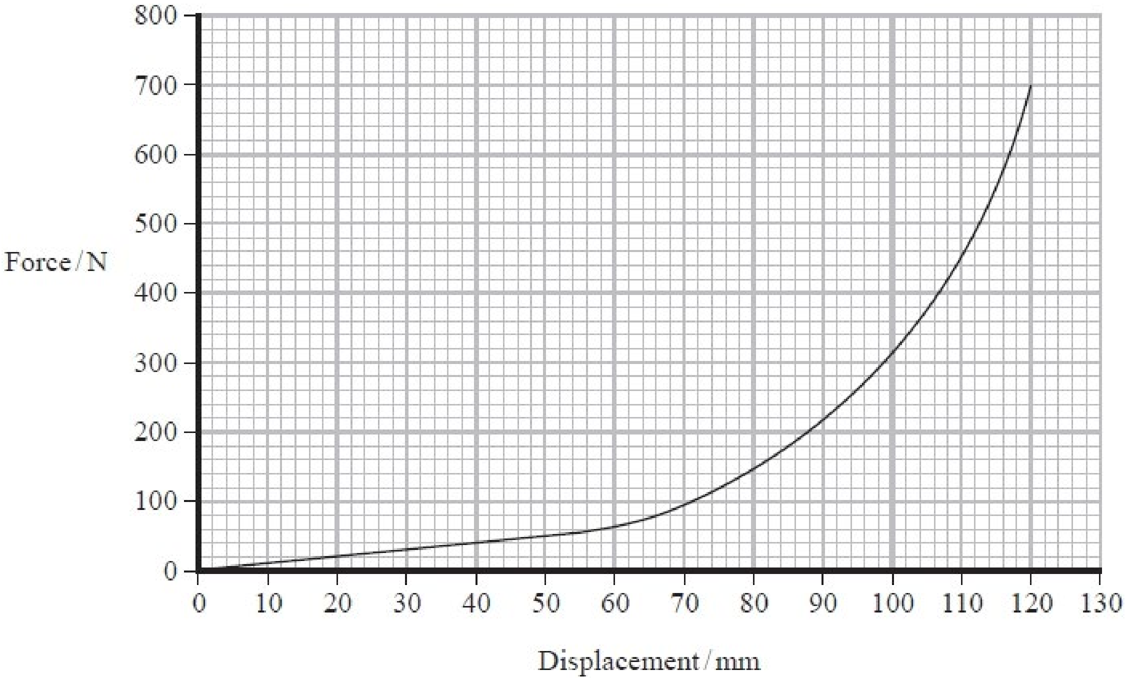
(Total for question = 4 marks)

Q38.

In a conical spring the diameter of the coils increases over its length. The spring can be designed so that each coil fits into the inner diameter of the next coil so they take up minimal space when fully compressed.

(Source: © Anatolii Riabokon/Alamy Stock Vector)

A conical spring is compressed against a flat surface. The graph shows the force-displacement graph for the spring as the compression force increases from 0 N to the point when the spring is fully compressed.



The spring obeys Hooke's law for small compression forces.

Determine a value for the spring constant of the spring for compression forces up to 60 N.

(2)

....

....

....

....

Spring constant = ...

(Total for question = 2 marks)

Q39.

The following measurements were made to determine the Young modulus of a metal bar.

original length of bar = 0.50 m
area of cross section = 4.5×10^{-4} m^2
tensile force applied to bar = 36 000 N
extension of bar = 2.0×10^{-4} m

Which of the following gives the Young modulus of the metal?

☐ **A** $\frac{36000 \times 0.50}{4.5 \times 10^{-4} \times 2.0 \times 10^{-4}}$

☐ **B** $\frac{4.5 \times 10^{-4} \times 2.0 \times 10^{-4}}{36000 \times 0.50}$

☐ **C** $\frac{36000 \times 2.0 \times 10^{-4}}{4.5 \times 10^{-4} \times 0.50}$

☐ **D** $\frac{4.5 \times 10^{-4} \times 0.50}{36000 \times 2.0 \times 10^{-4}}$

(Total for question = 1 mark)

Q40.

The Young Modulus of a material can be expressed by the formula $E = \frac{Fx}{A\Delta x}$.

The derivation of this formula is

$E = \frac{\sigma}{\varepsilon}$

So $E =$ ....

And $E = \frac{Fx}{A\Delta x}$

Which of the following completes the second line of the derivation?

☐ **A** $\dfrac{\frac{x}{\Delta x}}{\frac{F}{A}}$

☐ **B** $\dfrac{\frac{\Delta x}{x}}{\frac{F}{A}}$

☐ **C** $\dfrac{\frac{F}{A}}{\frac{\Delta x}{x}}$

☐ **D** $\dfrac{\frac{F}{A}}{\frac{x}{\Delta x}}$

(Total for question = 1 mark)

Q41.

In an investigation to determine the Young modulus of a material in the form of a wire, a tensile force of 14 N was applied to the wire. The length of the wire was 2.0 m. The diameter of the wire was 2.5 mm. The length of the wire increased by 0.20%.

Calculate the Young modulus of the material.

(3)

....

....

....

....

Young modulus = ...

(Total for question = 3 marks)

Mark Scheme - Solids

Q1.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Draws a line of best fit (1) • Calculates a gradient using at least half the graph (1) • 19.4 – 20.6 N m^{-1} (1)	<u>Example of calculation</u> Gradient = $\frac{5\text{ N}}{0.25\text{ m}}$ = 20 N m^{-1}	3

Q2.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Comment that a straight line graph through the origin (up to 5 N) is consistent with Hookes law / $F \propto x$ (1) • Comment that indicates that the max extended length 400 mm is not covered by the student's results (1) • Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ **and** $F = k\Delta x$ with $\Delta x = 0.4$ m **Or** Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ using extrapolated readings from graph (1) • Candidate's calculated energy value compared with 1.6 J and valid conclusion given (1) **Either** • Use of %U to determine the range in *k* (manufacturer's) (1) • Comparison of values for *k* with conclusion consistent with candidates calculated value (1) **Or** • Calculates % difference between candidate's calculated value for *k* and 21 N m^{-1} (1) • Comparison of calculated % difference with 5% and conclusion made (1)	<u>Example of calculation</u> $k = 21 \pm 1.05 = 19.95 - 22.05$ N m^{-1} $F = k\Delta x = 20$ N m^{-1} × 0.4 m = 8.0 N $\Delta E_{el}(\text{max}) = \frac{1}{2} \times 8.0$ N × 0.4 m = 1.6 J	6

Q3.

Question Number	Acceptable Answer	Additional Guidance	
(i)	An explanation that makes reference to the following points: **Either** • Take readings in different positions/orientations along the wire (and calculate a mean) (1) • As wire diameter may not be uniform (1) OR • Check (and correct for) for zero error (1) • Zero error reduces the accuracy of the measurement (1) Or Zero error moves the value away from the true value	**Accept:** use ratchet to close up micrometer to avoid squashing the wire MP2 accept cross section for diameter MP2: accept to reduce the effect of random error MP2 accept systematic error not changed by repeat measurements	2

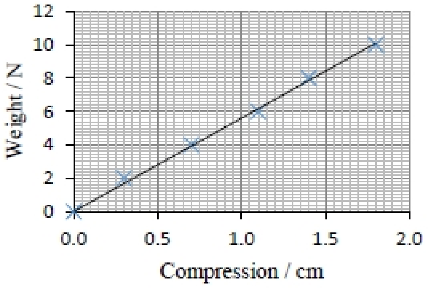
Q4.

Question Number	Acceptable Answers	Additional guidance	Mark
i	For the 30-year-old • greater stress for a given strain **Or** greater Young Modulus **Or** stiffer **Or** max deformation of the 23-year-old lens is greater **Or** breaking stress of 30-year-old lens is greater (1)	Accept answers for the 23-year-old	1
ii	• Reference to the graph consistent with their answer to (i) (1)		1

Q5.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• attempt to determine an area under the graph or use of $\Delta E_{el} = \frac{1}{2} F \Delta x$ (1) • area between $F =$ 60 and 220 used or average value for F used (1) • Ans 3.75J to 4.2 J (1)	For example: trapezium calculation or counting squares	3

Q6.

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>(a)(i)</td><td>Processing of data to calculate change in length (1)
Axes with labels & units (accept force for weight) (1)
Scales (1)
Plots (1)
Line of best fit (1)
<table>
<tr><th>Weight/ N</th><th>Compression/ cm</th></tr>
<tr><td>0.00</td><td>0.0</td></tr>
<tr><td>2.00</td><td>0.3</td></tr>
<tr><td>4.00</td><td>0.7</td></tr>
<tr><td>6.00</td><td>1.1</td></tr>
<tr><td>8.00</td><td>1.4</td></tr>
<tr><td>10.00</td><td>1.8</td></tr>
</table>
</td><td>

MP2: only award for a graph of weight against compression. Units may be in m or cm for compression. Allow paper to be landscape
MP3: scales only in 1,2,4,5 and must cover at least half of paper
MP4: a 2 mm square tolerance, check all points</td><td>5</td></tr>
</table>

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	• States that best fit line is through the origin (1) • So it fits Hooke's law because extension is proportional to force (1) • Uses corresponding values from best fit line from (a)(i) to determine gradient (1) • Spring constant = 10.0 N / 0.0176 m = 568 (N m^{-1}) (which, 1 s.f., is the stated answer) (1)	If plunger position plotted in (a)(i) then only MP2 may be awarded for attempt at gradient MP3: values selected from at least half way along line or a triangle using over half the line is used MP4: conditional on MP3 and allow any value that rounds to 1 sf as 600	4

Question Number	Acceptable answers	Additional guidance	Mark
(b)	• Use of $\Delta F = k\Delta x$ (1) • Use of $\Delta E_{el} = ½ F\Delta x$ (1) • Use of $E_k = ½ mv^2$ (1) • $v = 6.7$ m s^{-1} to 6.8 m s^{-1} (1)	Example of calculation $\Delta F = k\Delta x = 610$ N m^{-1} × 0.054 m = 32.94 N $\Delta E_{el} = ½ F\Delta x = ½ × 32.94$ N × 0.054 m = 0.90 J $E_k = ½ mv^2$ so 0.90 J = ½ × (0.0041 + 0.0354) kg × v^2 $v = 6.75$ m s^{-1}	4

Question Number	Acceptable answers	Additional guidance	Mark
(c)	Work may be done against friction (by the spring/marble) **Or** KE is gained by the spring **Or** GPE gained by the piston **and** marble **Or** the light gate must be above the launch position so the marble is already accelerating downwards **Or** statement of friction between two specified parts in launch system (1)		1

Q7.

Question Number	Acceptable Answers	Additional guidance	Mark
	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. **Indicative Content** • Band does **not** obey Hooke's law **Or** there is a non-linear relationship between force and extension (1) • (The band is elastic so) the extension returns to zero when the force is removed or size/shape is unchanged (1) • For a given force the extension when loading is less than when unloading **or** for the same extension more force required when loading (1) • Area under the loading curve is greater than the unloading curve **Or** Loading increases the elastic strain energy (of the band) (1) • The band absorbs more energy when being loaded than it releases when unloaded **Or** Unloading: some strain energy transferred by heating (1) • Energy released by heating represented by the area between the lines (1)	The following table shows how the marks should be awarded for structure and lines of reasoning <table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	6

Q8.

Question Number	Acceptable Answers	Additional guidance	Mark
	- (The longer the wire) the larger the extension (for a given force) (1) - (So) smaller percentage uncertainty (in measurement of extension) (1)		2

Q9.

Question Number	Acceptable answers	Additional guidance	Mark
(i)	- Use of (breaking) stress = F/A (1) - Use of $A = \pi r^2$ (1) - Diameter = 1.06 mm and choose 1.22 mm because it is the thinnest wire with stress lower than the breaking stress (1)	Example of calculation For max stress, $3.10 \times 10^8 \text{ N m}^{-2} = 28 \text{ kg} \times 9.81 \text{ N kg}^{-1}/A$ $A = 8.86 \times 10^{-7} \text{ m}^2$ $8.86 \times 10^{-7} \text{ m}^2 = \pi r^2$ $r = 5.3 \times 10^{-4}$ m diameter = 1.06 mm	3
(ii)	- Use of stress = F/A and $A = \pi r^2$ (ecf for radius from (b)(i)) (1) - Use of Young modulus = stress / strain and strain = $\Delta x/x$ (1) - Extension =1.3 cm (1)	Allow ecf for radius of wire chosen in part (b)(i), but not for the calculated radius or area Example of calculation stress = $28 \text{ kg} \times 9.81 \text{ N kg}^{-1}/ \pi (1.22 \times 10^{-3} \text{ m} / 2)^2$ strain = 2.34×10^8 Pa / 200 GPa = 0.00117 extension = 0.00117 × 11.2 m = 0.0132 m	3

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	- Use of $V = \frac{4}{3}\pi r^3$ (1) - Use of $\rho = \frac{m}{V}$ (1) - $\rho = 2580 \text{ (kg m}^{-3})$ (1)	Example of calculation $V = \frac{4}{3}\pi\left(\frac{5.06 \times 10^{-2} \text{ m}}{2}\right)^3 = 6.78 \times 10^{-5} \text{ m}^3$ $\rho = \frac{0.175 \text{ kg}}{6.78 \times 10^{-5} \text{ m}^3} = 2580 \text{ kg m}^{-3}$	3

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• Use of half resolution to calculate % uncertainty (1) (1) • % uncertainty in $V = 3 \times$ % uncertainty in r (1) • % uncertainty in ρ = (% uncertainty in m + % uncertainty in V) (1) (1) • Use of % uncertainty to calculate upper value of density (1) • Upper value of density 2596 (kg m^{-3}) [2616 (kg m^{-3}) if "show that" value used] • Glass is in the range and Quartz isn't, so it may not be genuine Allow use of half resolution in either r or m to calculate minimum V and maximum m and then calculate maximum ρ for MP1 → MP4 ECF from (a)	% uncertainty in $r = \frac{0.005\text{ cm}}{5.06\text{ cm}} \times 100\ \% = 0.10\ \%$ % uncertainty in $m = \frac{0.5\text{ g}}{175\text{ g}} \times 100\ \% = 0.29\ \%$ % uncertainty in $\rho = (3 \times 0.1\%) + 0.29\% = 0.59\%$ Range $= \pm\frac{0.6}{100} \times 2580\text{ kg m}^{-3} = \pm 15.5\text{ kg m}^{-3}$ Density range = 2565 → 2596 kg m^{-3}	6

Q12.

Question Number	Answer	Additional Guidance	Mark
	• Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ (1) • 0.026 J (1)	Example of calculation $\Delta E_{el} = \frac{1}{2} \times 130\text{ N} \times 4.0 \times 10^{-4}\text{ m} = 0.026\text{ J}$	2

Q13.

Question Number	Acceptable answers	Additional guidance	Mark
	• states wavelength = 1.2 cm (1) • use of E = stress / strain (1) • use of $A = \pi d^2/4$ (1) • use of stress = F/A (1) • use of $v = \sqrt{(T/\mu)}$ (1) • use of $v = f\lambda$ with any two of the stated / measured / calculated values of v, f or λ to calculate the other (1) • comparison of this calculated value of v, f or λ with the value obtained another way (1)	<u>Example of calculation:</u> $\lambda = 4.8 \times 0.25$ cm = 1.2 cm $A = \pi d^2 / 4$ $= \pi(3.6 \times 10^{-6}$ m$)^2 / 4$ $= 1.012 \times 10^{-11}$ m^2 stress = strain × $E = 9.7 \times 10^{-9} \times 1.2 \times 10^9$ N m^{-2} = 11.64 N m^{-2} $T = F$ = stress × A = 11.64 N m^{-2} × 1.012×10^{-11} m^2 = 1.18×10^{-10} N $v = \sqrt{(\quad \div \quad)} = \sqrt{8.92 \times 10^{-3}}$ = 0.094 m s^{-1} Using $v = f\lambda$, v = 7.9 Hz × 0.012 m = 0.0912 m s^{-1} Agree to within 3%, so suggests consistent	**7**

Q14.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Young modulus of steel > young modulus of wood **Or** steel is stiffer **Or** greater stress for a given strain **Or** less strain under the same stress (1) • So there are less changes in dimensions under a given force for steel (1) • Breaking stress of steel > breaking stress of wood **Or** steel is stronger **Or** steel withstands greater forces without breaking (1) • steel can withstand a larger force/weight than wood of the same (cross-sectional) area **Or** Under the same force/weight steel can have a smaller (cross-sectional) area than wood (1) • Steel coasters can be built that withstand the larger forces from faster cars **Or** (taller tracks can be built because) steel tracks can have smaller dimensions (1)	Answers must a comparison between steel and wood Accept deformation for changes in dimension MP3 accept UTS steel > UTS wood	5

Q15.

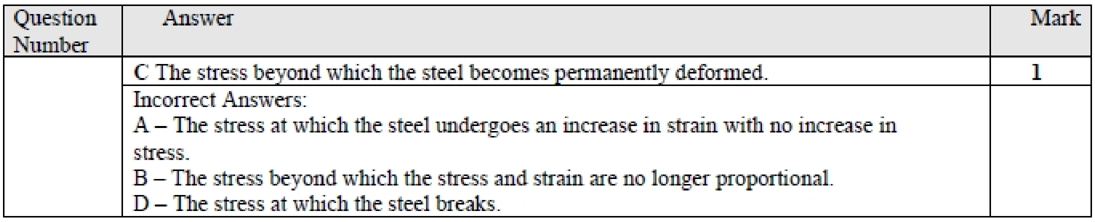
Question Number	Acceptable answers	Additional guidance	Mark
	The only correct answer is B because the gradient of this graph is change in length ÷ change in force and the change in length is the same as the change in extension, so the gradient is equal to stiffness A is not correct because a graph of extension against force will have a gradient of $1/k$ C is not correct because a graph of stress against strain will have a gradient equal to the Young modulus for the sample D is not correct because a graph of strain versus length is equivalent to a graph of extension versus $(\text{length})^2$, so it does not have a gradient equal to k		1

Q16.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	• Use a micrometer to measure y and/or z (1) • Use Vernier/digital calipers to measure x and/or (1) • Mass of slide(s) measured using (top pan) balance/scales (1) • Repeat and determine mean for at least one measurement (1)	**(Part (a) and (b) to be marked holistically** **MP1** accept digital calipers for a single slide Accept Vernier calipers if it is clear that the thickness of a number of slides is being measured. To award both MP1 & 2, x, y & z must all be referred to. MP4 can be awarded for a reference to averaging any of the measurements.	**4**

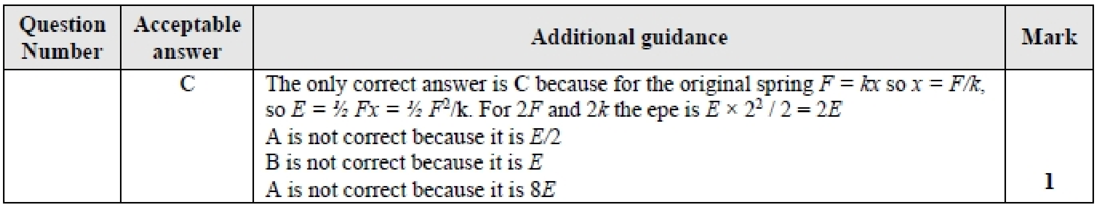
Question Number	Acceptable Answer	Additional Guidance	Mark
(b)	Check zero error on micrometer/callipers/balance **Or** measure $x/y/z$ of slide in different places **Or** measure thickness/mass of multiple slides (1)	Accept 'tare' for zero error check on balance	**1**

Q17.



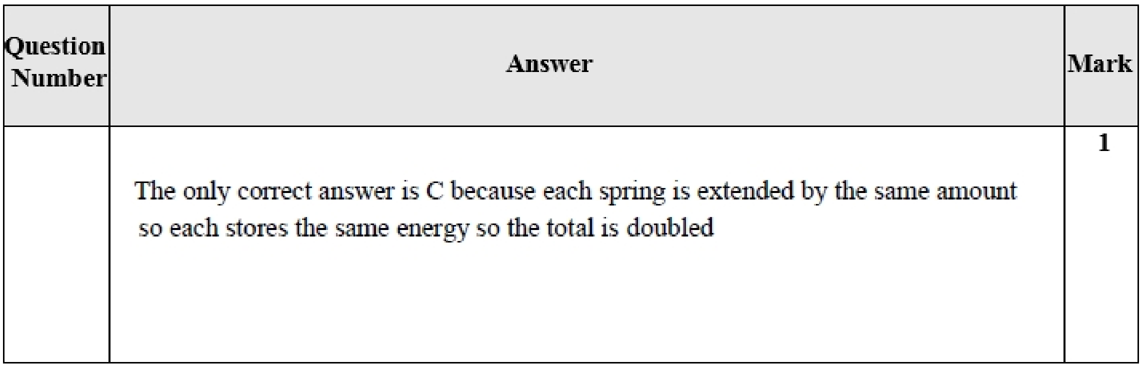
Question Number	Answer	Mark
	C The stress beyond which the steel becomes permanently deformed.	1
	Incorrect Answers: A – The stress at which the steel undergoes an increase in strain with no increase in stress. B – The stress beyond which the stress and strain are no longer proportional. D – The stress at which the steel breaks.	

Q18.



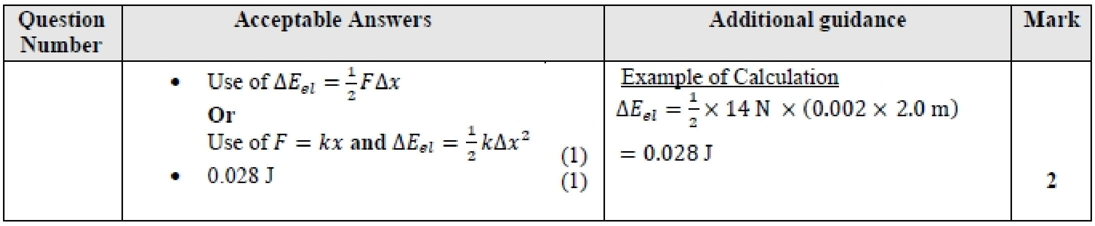
Question Number	Acceptable answer	Additional guidance	Mark
	C	The only correct answer is C because for the original spring $F = kx$ so $x = F/k$, so $E = ½ Fx = ½ F^2/\text{k}$. For $2F$ and $2k$ the epe is $E \times 2^2 / 2 = 2E$ A is not correct because it is $E/2$ B is not correct because it is E A is not correct because it is $8E$	1

Q19.



Question Number	Answer	Mark
	The only correct answer is C because each spring is extended by the same amount so each stores the same energy so the total is doubled	1

Q20.



Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\Delta E_{el} = \frac{1}{2}F\Delta x$ **Or** Use of $F = kx$ and $\Delta E_{el} = \frac{1}{2}k\Delta x^2$ (1) • 0.028 J (1)	Example of Calculation $\Delta E_{el} = \frac{1}{2} \times 14\text{ N} \times (0.002 \times 2.0\text{ m})$ $= 0.028\text{ J}$	2

Q21.

Question Number	Answer	Mark
(a)(i)	The increase in extension is constant for a fixed increase in mass **Or** mass is proportional to extension **Or** extension is proportional to mass **Or** graph is a rising/increasing straight line (1) The wire obeys Hooke's law (1)	2
(a)(ii)	Use of area under the graph **Or** use of ½ $F\Delta x$ (with m or F) (1) Identify that the limit of proportionality is at 2.6 ± 0.1 kg (1) Elastic potential energy = 0.5 J (1) (accept 0.40 J to 0.50 J) Example of calculation Area under the graph = ½ × 3.5×10^{-2} m × 2.6 kg = 0.046 kg m Area × g = 0.046 kg m × 9.81 N kg^{-1} Elastic potential energy = 0.45 J	3
(a)(iii)	The wire will experience a large (increase in) extension/strain for a small (increase in applied) force/stress/mass (1) The wire will not return to its original length/shape (once the force is removed) **Or** the wire will be permanently deformed **Or** the wire will exhibit plastic deformation/behaviour (1)	2
(b)(i)	Thinner wire **Or** smaller CSA/ diameter/radius **Or** longer wire **Or** wire with a lower stiffness/k/spring constant **Or** wire that is more ductile **Or** wire with a lower Young modulus (1) (comments must be comparative)	1
(b)(ii)	**Max 2** Use a pointer on the wire/masses (1) Sensible suggestion to reduce parallax e.g. read at eye level **Or** place the rule as near as possible to the mass/wire (1) Use a set square to ensure rule is vertical (1) Wait for the extension to finish (1) Add masses gently (1)	2
	Total for question	**10**

Q22.

Question Number	Answer	Mark
	C $\frac{1}{2}mg\Delta x$	1
	Incorrect Answers: A – no factor of $\frac{1}{2}$ B – incorrect equation and no factor of $\frac{1}{2}$ D – incorrect equation	

Q23.

Question Number	Acceptable Answers		Additional guidance	Mark
	- Use of $F = k\Delta x$ - 0.30 m	(1) (1)	Example of Calculation $\frac{29\ \text{N}}{0.32\ \text{m}} = \frac{27\ \text{N}}{\Delta x}$ $\Delta x = 0.30\ \text{m}$	2

Q24.

Question Number	Acceptable answers		Additional guidance	Mark
	- X is brittle at greater stresses/forces - Y will deform plastically at greater stresses/forces - The Young modulus for X is greater than Y - A screen made from material Y would be more suitable as it is more flexible	(1) (1) (1) (1)	Accept converse for MP3 and MP4 MP4: accept less stiff for flexible.	4

Q25.

Question Number	Acceptable Answer		Additional Guidance	Mark
	- Attempt to calculate gradient - $k = (24.0 \rightarrow 25.0)\ \text{N m}^{-1}$	(1) (1)	Accept $k = (0.24 \rightarrow 0.25)\ \text{N cm}^{-1}$ Example of calculation: gradient= $\frac{(1.6\text{-}0)\ \text{N}}{(6.5\text{-}0)\times 10^{-2}\text{m}} = 24.6\ \text{N m}^{-1}$	2

Q26.

Question Number	Acceptable answers	Additional guidance	Mark
	B		1

Q27.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Steel had a lower fracture toughness due to the low temperature (1) • at low temperatures less energy is absorbed before fracture (1) • the (absorbed) energy was sufficient to cause fracture (1)		3

Q28.

Question Number	Answer	Mark
	A kg s^{-2}	1
	Incorrect Answers: B – base units for N C – incorrect units and not base units D – correct units but not base units	

Q29.

Question Number	Answer	Additional Guidance	Mark
(i)	• Use of $\Delta F = k\Delta x$ (1) • 45 (N m^{-1}) [accept 0.45 N cm^{-1}] (1)	Example of calculation $k = \frac{2.5\ \text{N}}{5.5\ \times 10^{-2}\ \text{m}} = 45.45\ \text{N m}^{-1}$	2
(ii)	• Use of $w = mg$ (1) • Use of vertical component of spring forces (1) • Use of $\Delta F = k\Delta x$ (1) • $\Delta x = 0.050$ m [accept 5.0 cm] (1) (ECF from (a)(i))	Example of calculation $w = 0.400\ \text{kg} \times 9.8\ \text{N kg}^{-1} = 3.92\ \text{N}$ $2T \cos 30° = 3.92\ \text{N}\ \therefore$ $F = \frac{3.92\ \text{N}}{2 \cos 30°} = 2.26\ \text{N}$ $\Delta x = \frac{2.26\ \text{N}}{45.45\ \text{N m}^{-1}} = 0.0498\ \text{m}$	4

Q30.

Question Number	Acceptable answers	Additional guidance	Mark
(a)(i)	• σ= 54-56 (MPa) **(1)** • Use of $\sigma = \frac{F}{A}$ with their value of σ **(1)** • F = 64.5 N – 67.5 N **(1)**	do not penalise powers of 10 Example of calculation $F = 56 \times 10^6 \text{Nm}^{-2} \times 1.2 \times 10^{-6} \text{m}^2$ F = 67 N	**3**

Question Number	Acceptable answers	Additional guidance	Mark
(a)(ii)	• Use of $\varepsilon = \frac{\Delta x}{x}$ **(1)** • Extension = 1.0 cm **(1)**	Example of calculation 0.04 = Δx / 25 cm Δx = 0.04 × 25 cm = 1.0 cm Allow 1 cm, 0.01 m, 10 mm	**2**

Question Number	Acceptable answers	Additional guidance	Mark
(b)	An answer that makes reference to the following: • Shrilk has less strain for same stress **Or** Shrilk is stiffer **(1)** • Shrilk breaks at a higher stress (compared to polythene) **Or** Shrilk can withstand a greater stress/force/load/weight **Or** Shrilk is stronger **(1)** • Shrilk doesn't stretch as much (for a given force) **(1)**	It should be clear from the student's answer that shrilk is the better material Ignore references to Young modulus, renewable, biodegradable, cost Accept converse arguments for polythene	**3**

Q31.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)(i)	• reference point so that reliable timings can be made (1) • end of metre rule will be travelling fastest at its equilibrium position (so uncertainty is determining when rule is at this position is least) (1)		**(2)**
(a)(ii)	• calculate average time period for each ruler [T_1 = 0.962 s, T_2 = 1.072 s] (1) • use of $T^2 \propto \frac{ML^3}{E}$ (1) • $\frac{E_2}{E_1} = 0.80$ (1)	Example of calculation: $T_1 = \frac{19.3\text{s} + 19.1\text{s} + 19.3\text{s}}{60} = 0.962\text{s}$ $T_2 = \frac{21.3\text{s} + 21.5\text{s} + 21.5\text{s}}{60} = 1.07\text{s}$ $T^2 \propto \frac{ML^3}{E} \therefore \frac{E_1}{E_2} = \frac{T_2^2}{T_1^2}$ $\frac{E_2}{E_1} = \frac{T_1^2}{T_2^2} = \left(\frac{0.962\text{s}}{1.07\text{s}}\right)^2 = 0.804$	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	T^2 on y-axis and L^3on x-axis (or vice versa)		**(1)**
(b)(ii)	An explanation that makes reference to the following: • $T^2 = \frac{KML^3}{E}$, so gradient will be $\frac{KM}{E}$(if T^2 plotted against L^3) (1) • $\therefore E = \frac{KM}{\text{gradient}}$, if *K* is known *E* can be determined (1)	If axes reversed in (b)(i), gradient = *E*/*KM* for full credit	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An explanation that makes reference to the following: • time a larger number of oscillations (1) • as the greater the total time the smaller the % uncertainty (1)		**(2)**

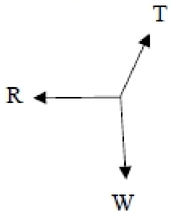
Q32.

Question Number	Acceptable answer	Additional guidance	Mark
	B	The only correct answer is **B**: for each spring, ½ force, so ½ extension, so ½ *Fx* gives ¼ *E*, so total is ½ *E* A is not correct because it is the energy for one spring with this extension C is not correct because it only applies the factor of ½ once D is not correct because it is the energy for two springs, each with the original extension	1

Q33.

Question Number	Answer	Additional Guidance	Mark
	Max three Elderly bone: • lower gradient showing the bone is under more strain for a given stress (1) • graph ends at a lower stress showing it has a lower breaking stress (1) • Area under graph is smaller as less energy is absorbed before fracture (1) • Graph is shorter showing less plasticity (1)	Accept answer with respect to healthy bone Accept more brittle	3

Q34.

Question Number	Acceptable answers	Additional guidance	Mark
(a)	• Arrow upwards and to the right at approximately 20° to the vertical labelled Tension/T (1) • Arrow to left and horizontal labelled Reaction/R (1) • Arrow vertically down labelled Weight/W/mg/540 N (1)	Accept Push (from rock) /Contact  Max 2 if any additional arrows drawn	3

Question Number	Acceptable answers	Additional guidance	Mark
(b)(i)	• Resolve tension vertically: $T\cos 20$ **Or** $T\sin 70$ (1) • Equate mg and their vertical component of T (1) • Tension = 570 (N) (1)	Example of calculation $55 \times 9.81 = T\cos 20$ $T = 574$ N	3

Question Number	Acceptable answers		Additional guidance	Mark
(b)(ii)	• Use of $\Delta E = ½ F \Delta x$ • Energy stored = 7.1 – 7.2 J	(1) (1)	(ecf from (b)(i)) show that value gives 7.5 J Example of calculation $\Delta E = \frac{1}{2} \times 570 \text{ N} \times 2.5 \times 10^{-2} \text{ m}$ $\Delta E = 7.1$ J	2

Question Number	Acceptable answers		Additional guidance	Mark
(b)(iii)	• Rope has extended linearly **Or** Hooke's law applies **Or** extension ∝ force **Or** has not exceeded limit of proportionality	(1)	Do not accept elastic limit	1

Q35.

Question Number	Acceptable Answers	Additional Guidance	Mark
	B		1

Q36.

Question Number	Answer	Mark
	B stress v strain	1
	Incorrect Answers: **A** – gradient ≠ Young modulus **C** – gradient ≠ Young modulus **D** – gradient ≠ Young modulus	

Q37.

Question Number	Acceptable Answers		Additional Guidance	Mark
	• Calculate force = mg • calculate the cross-sectional area $A = \pi \frac{d^2}{4}$ • x- and y- variables to produce a suitable straight-line graph • correct use of the gradient from their graph to determine E	(1) (1) (1) (1)	Accept $A = \pi r^2$ and $r = \frac{d}{2}$	4

Q38.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• Uses $\Delta F = k\Delta x$ with corresponding points up to F=60N (1) or calculates the gradient between F=0 and 60N (1) • 1000 -1100 N m^{-1}	Example of calculation $k = \frac{\Delta F}{\Delta x} = \frac{60\text{ N}}{0.06\text{ m}} = 1000\text{ N m}^{-1}$	2

Q39.

Question Number	Answer	Mark
	A $\frac{36000 \times 0.5}{4.5 \times 10^{-4} \times 2.0 \times 10^{-4}}$	1
	Incorrect Answers: B – incorrect arrangement of equation C– incorrect arrangement of equation D – incorrect arrangement of equation	

Q40.

Question Number	Answer	Mark
	C $\frac{F/A}{\Delta x/x}$ (stress/strain)	1
	Incorrect Answers: A incorrect arrangement B incorrect arrangement D incorrect arrangement for strain	

Q41.

Question Number	Acceptable Answers	Additional guidance	Mark
	• Use of $\sigma = \frac{F}{A}$ and $A = \frac{\pi d^2}{4}$ (1) • Use of $E = \frac{\text{stress}}{\text{strain}}$ with strain = 0.2 % (1) • $E = 1.4 \times 10^9$ Pa (1)	Example of Calculation Stress = $\frac{14\text{ N}}{\pi \times \left(\frac{2.5 \times 10^{-3}\text{m}}{2}\right)^2} = 2.85 \times 10^6\text{ N m}^{-2}$ $E = \frac{2.85 \times 10^6\text{ N m}^{-2}}{0.2/100} = 1.4 \times 10^9\text{ N m}^{-2}$	3