PEARSON EDEXCEL A-LEVEL PHYSICS · 9PH0

PHYSICS



EXAM QUESTION PACK

TOPIC 4: MATERIALS

SOLIDS

SCORE	PERCENTAGE
/444	%

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Q1.

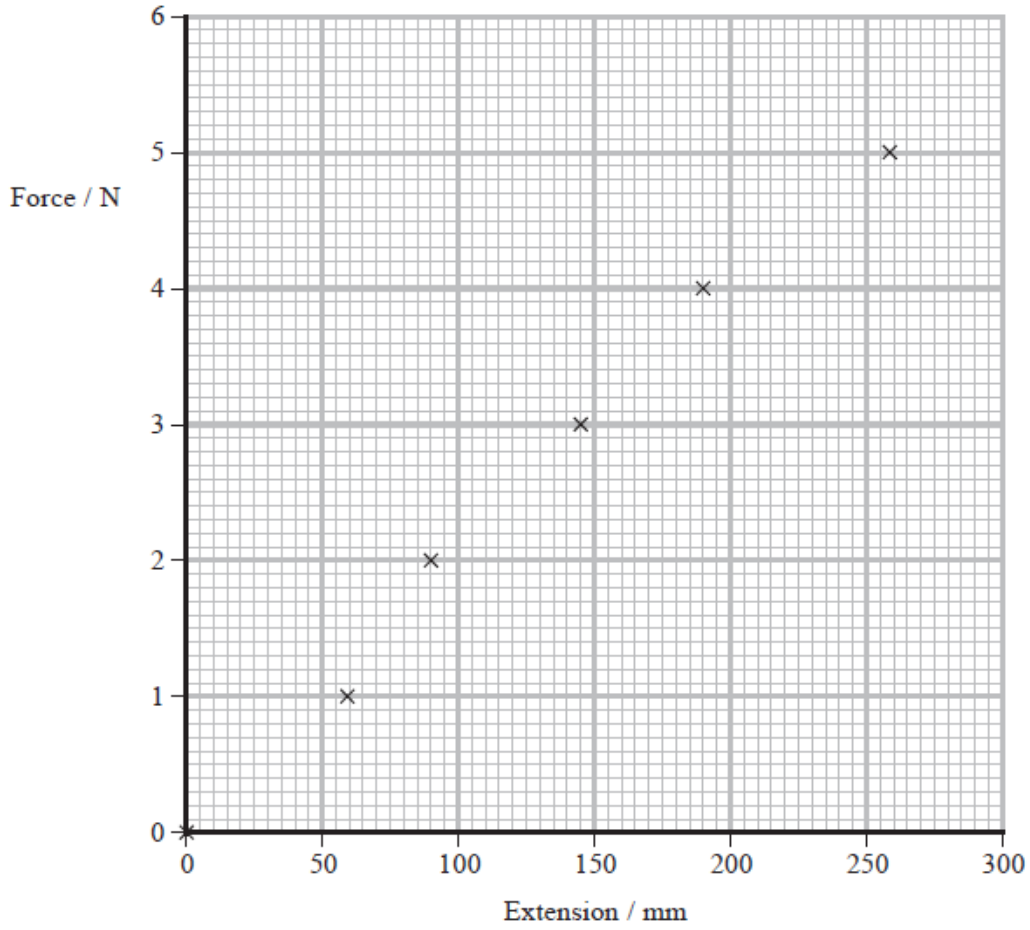
A manufacturer gives the following information about a spring.

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.

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Stiffness = ...

(Total for question = 3 marks)

Q2.

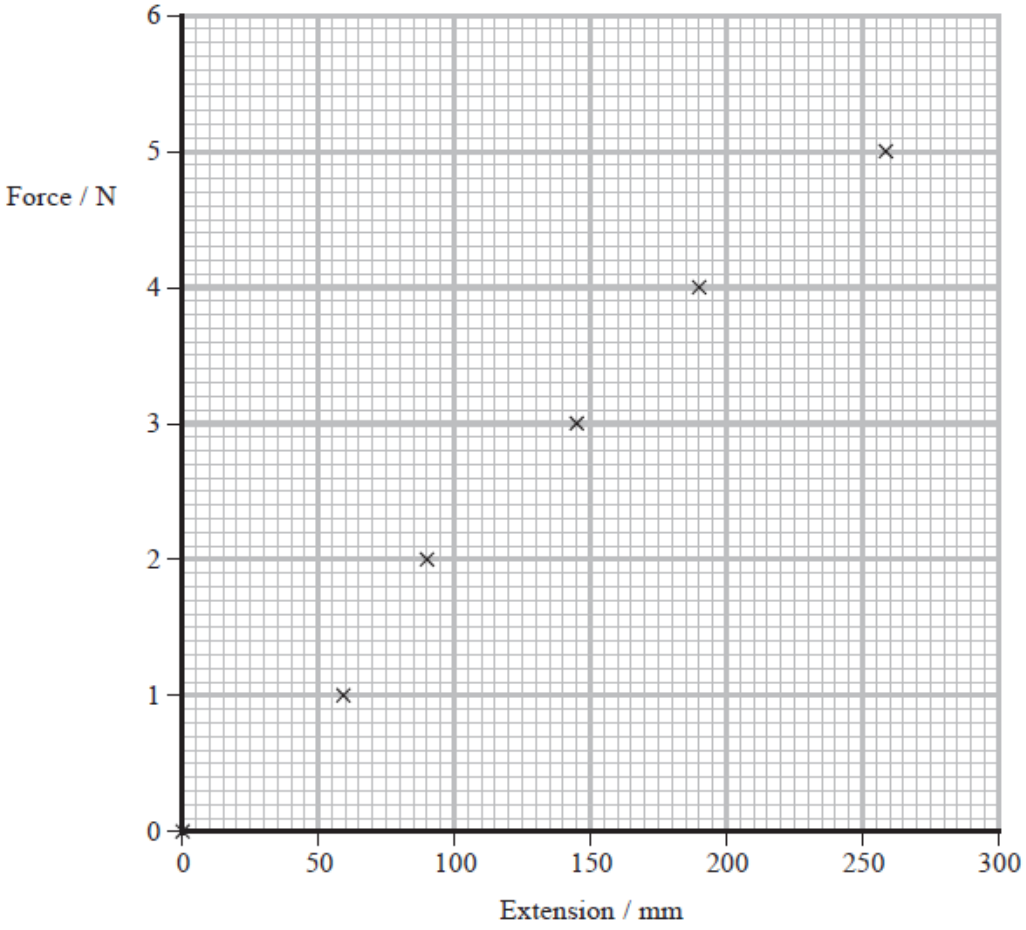
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A student carried out an investigation on the spring to test this information.

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.



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

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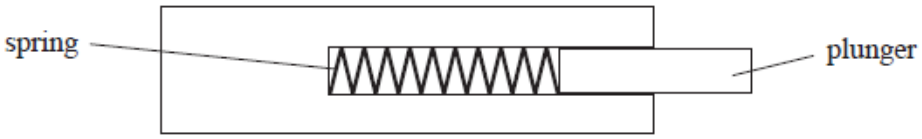
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(Total for question = 6 marks)

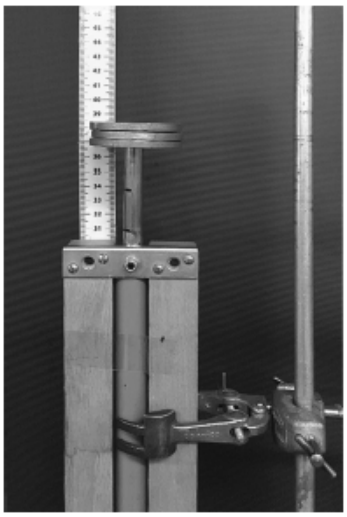
Q3.

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.

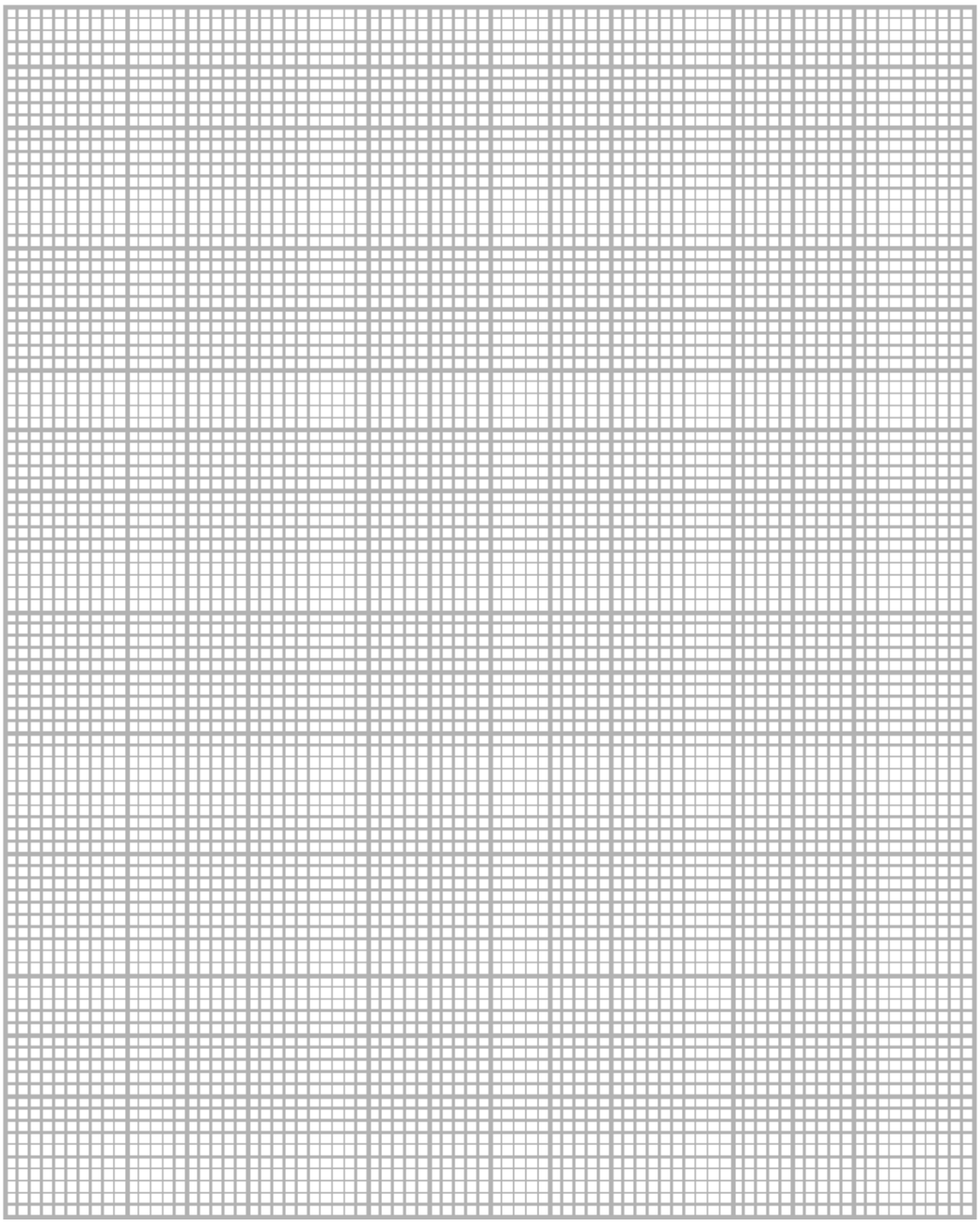


The recorded results are shown in the table.

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.

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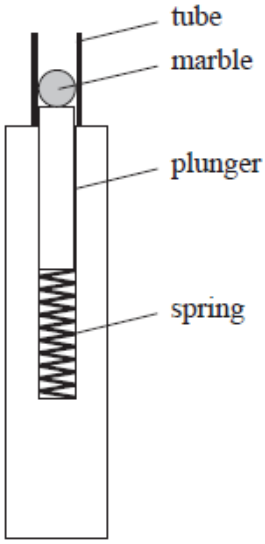
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(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



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)

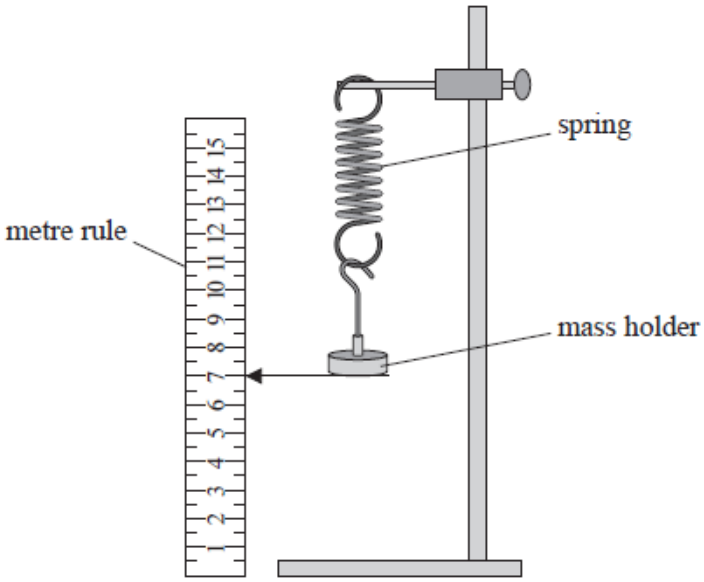
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(Total for question = 14 marks)

Q4.

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

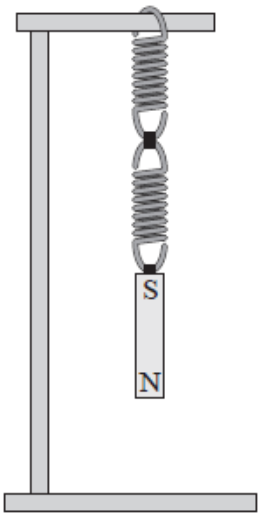


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

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

Two identical springs are joined in series and a bar magnet is hung from one end as shown.



The bar magnet is displaced a small distance vertically from its equilibrium position and released.

Calculate the frequency at which the system oscillates.

mass of magnet = 120 g
spring constant of each spring = 22 N m^{-1}

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Frequency = ...

(Total for question = 4 marks)

Q5.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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?

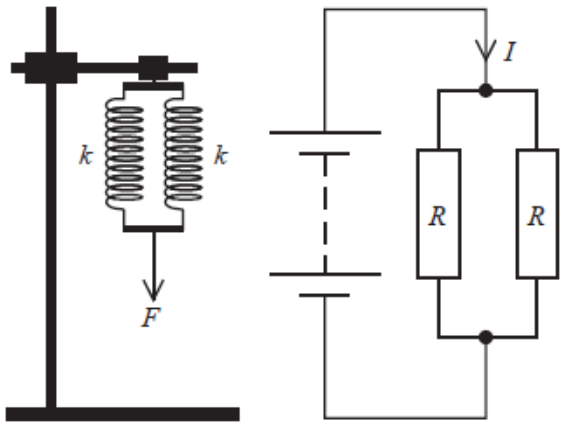
	y-axis	x-axis
☐ **A**	extension	force
☐ **B**	force	length
☐ **C**	stress	strain
☐ **D**	strain	length

(Total for question = 1 mark)

Q6.

A student is experimenting with different combinations of springs and recalls that in physics it is often possible to model different physical situations in similar ways.

The student suggests that a parallel combination of springs could be a model for a parallel combination of resistors in a circuit.



Assess the validity of the student's suggestion by considering the effective stiffness of two identical springs in parallel.

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(Total for question = 6 marks)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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 $2F$ is applied to a spring with stiffness $2k$?

☐ **A** $\frac{E}{2}$

☐ **B** E

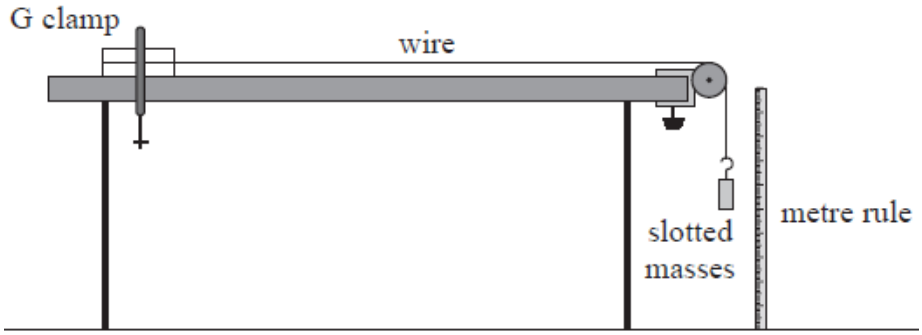
☐ **C** $2E$

☐ **D** $8E$

(Total for question = 1 mark)

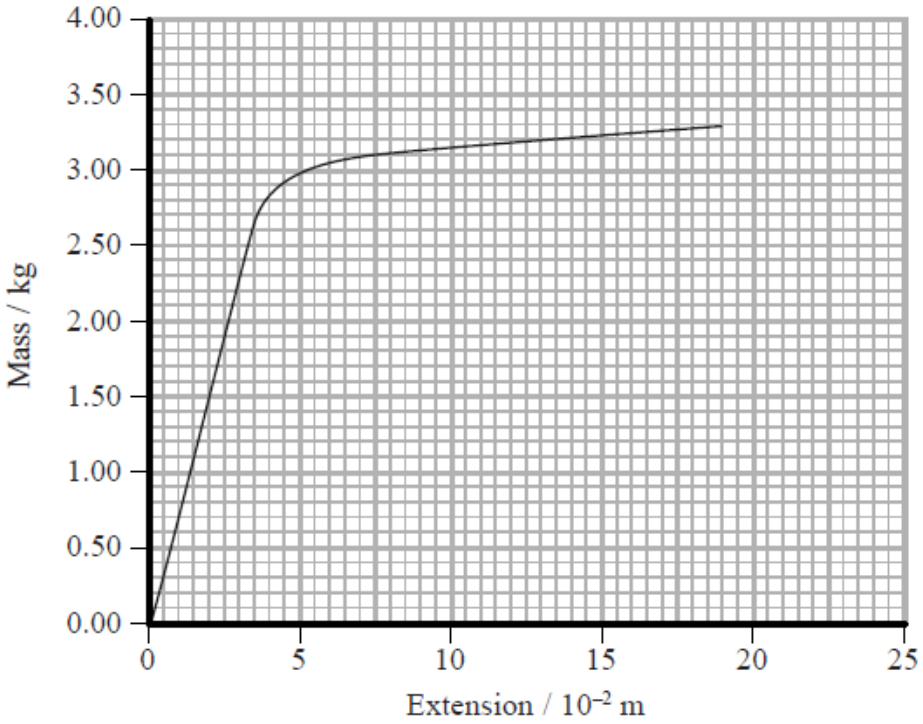
Q8.

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)

Q9.

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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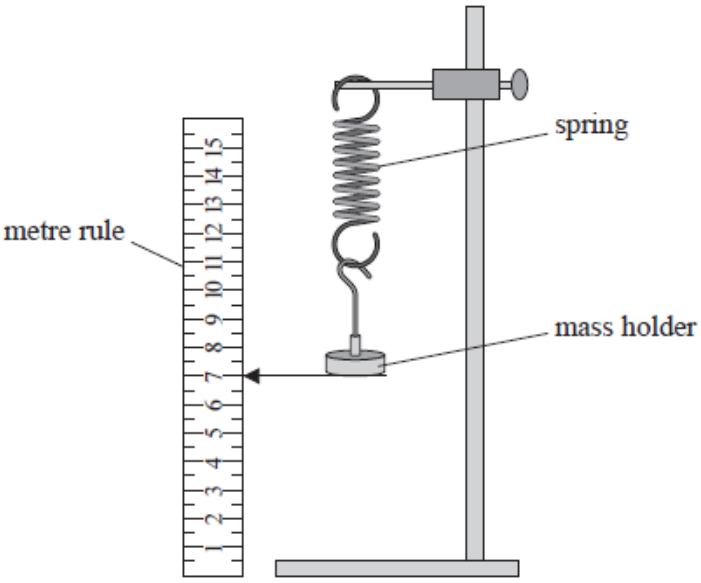
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Extension = ...

(Total for question = 2 marks)

Q10.

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

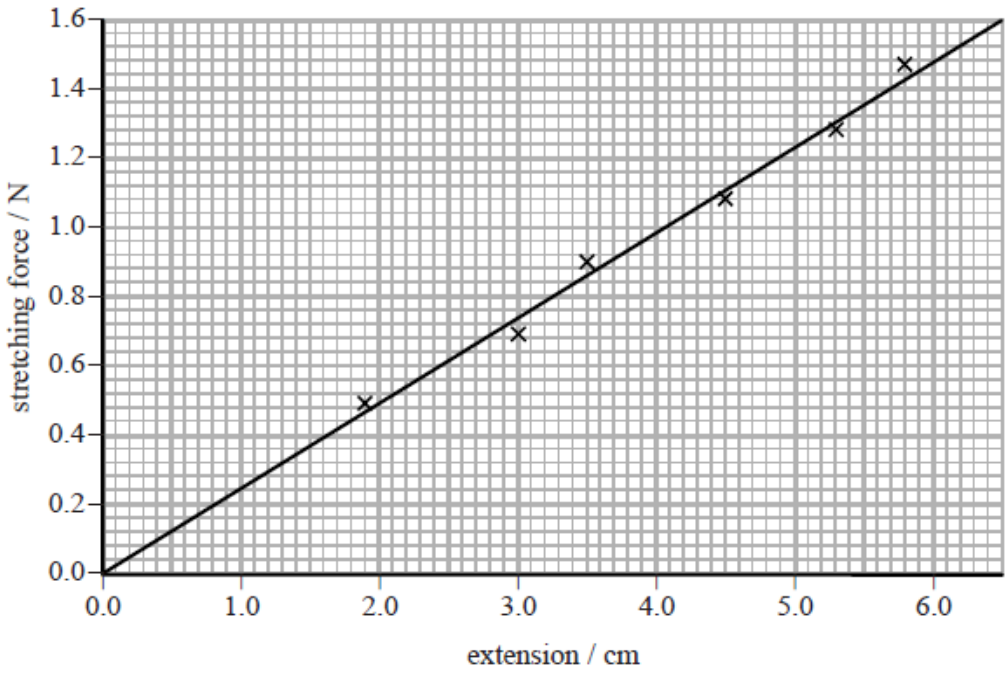


The position of the bottom of the mass holder was recorded. The spring was stretched by adding masses to the mass holder and the new positions were recorded. The extension of the spring each time was calculated.

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.

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k = ...

(Total for question = 2 marks)

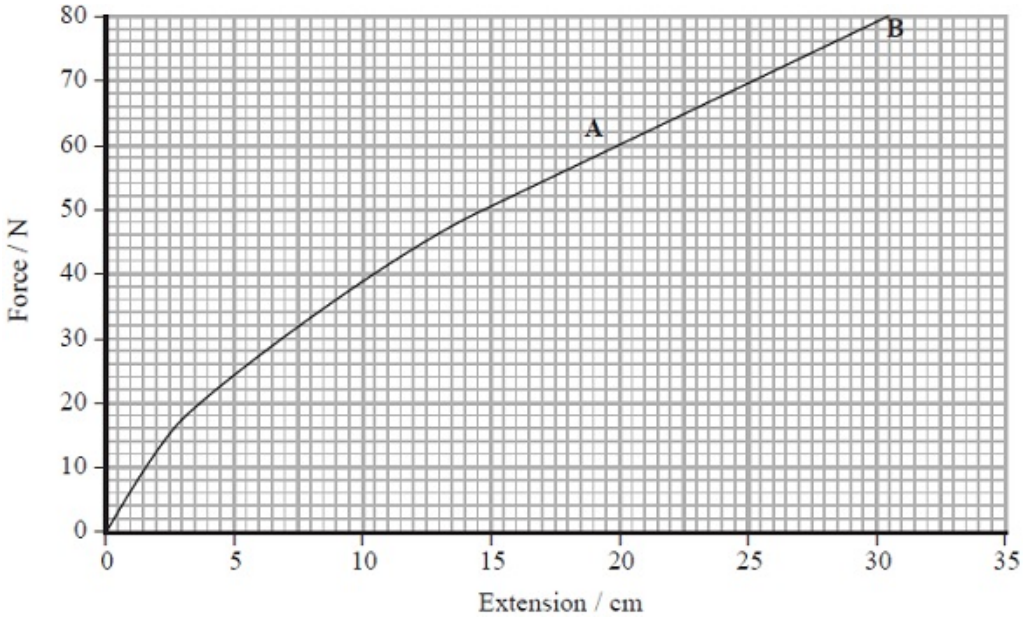
Q11. The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.





A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

(2)

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(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

(2)

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(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

	A	B	C	D
1	Total stretching force / N	Extension / cm	Change in extension / m	Work done (force × change in extension) / J
2	0	0.0	0.000	0.00
3	10	1.6	0.016	0.16
4	20	3.5	0.019	0.38
5	30	7.0	0.035	1.05
6	40	10.5	0.035	1.40
7	50	14.5	0.040	2.00
8	60	20.0	0.055	3.30
9	70	25.2	0.052	3.64
10	80	30.5	0.053	4.24
11			Total work done	16.17

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

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(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

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Time = ...

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

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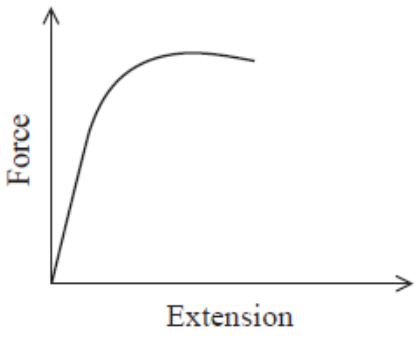
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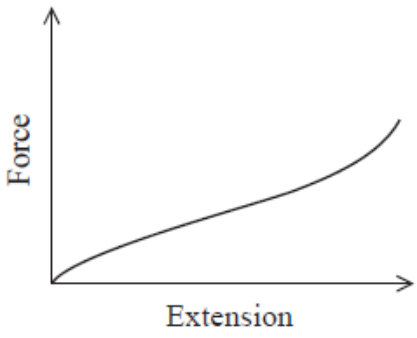
(Total for Question = 11 marks)

Q12.

In a physics lesson the following graphs are given to the students. The graphs show the relationship between force and extension for samples of two different materials, A and B.



Sample A



Sample B

A student states that sample A obeys Hooke's law for small extensions and sample B does not.

Use the graphs to explain the validity of the student's statement.

(3)

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(Total for question = 3 marks)

Q13.

A spring obeys Hooke's law. A force of 2.0 N extends the spring by 0.30 m.

A 6.0 N force will extend the spring by

☒ **A** 0.10 m

☒ **B** 0.30 m

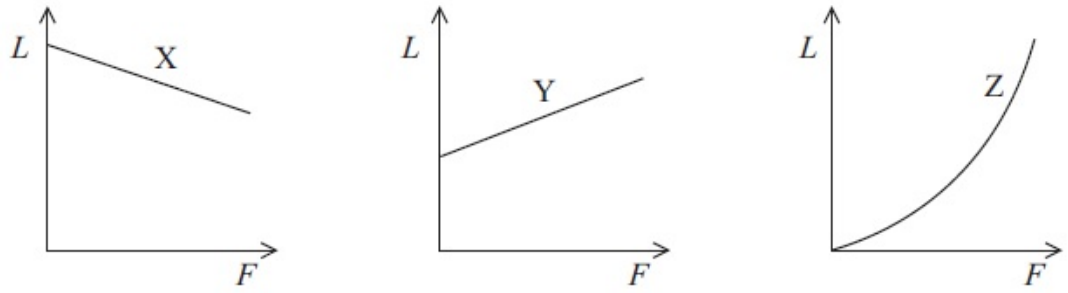
☒ **C** 0.60 m

☒ **D** 0.90 m

(Total for question = 1 mark)

Q14.

Three springs X, Y and Z have forces applied to them. For each spring a graph is plotted of length L of the spring against force F. The graphs are shown below:



Which of the springs obey Hooke's law?

☒ **A** X and Y

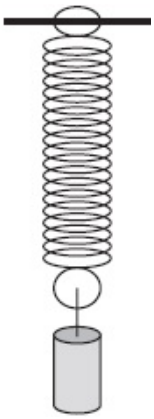
☒ **B** X and Z

☒ **C** Y and Z

☒ **D** Y only

(Total for question = 1 marks)

Q15. A spring is suspended from a bar. When a load of 6.0 N is added to the bottom of the spring, its length changes from 0.040 m to 0.13 m.



To find the spring constant of the spring you would use

$\frac{6.0\,\text{N}}{0.090\,\text{m}}$ **A** $\frac{0.13\,\text{m}}{6.0\,\text{N}}$

$\frac{6.0\,\text{N}}{0.090\,\text{m}}$ **B** $\frac{6.0\,\text{N}}{0.13\,\text{m}}$

$\frac{6.0\,\text{N}}{0.090\,\text{m}}$ **C** $\frac{6.0\,\text{N}}{0.090\,\text{m}}$

$\frac{6.0\,\text{N}}{0.090\,\text{m}}$ **D** $\frac{0.090\,\text{m}}{6.0\,\text{N}}$

(Total for Question = 1 mark)

Q16.

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)

Q17.

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}.

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

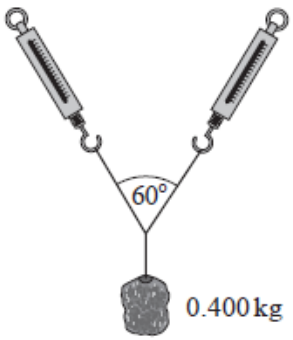


Diagram not to scale

(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.

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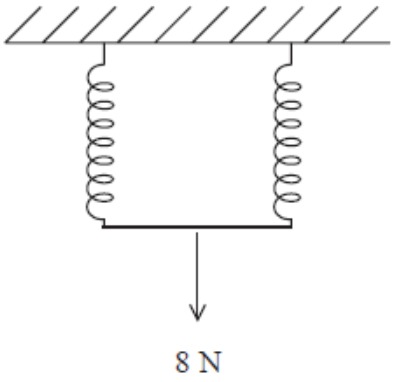
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Δx = ...

(Total for question = 6 marks)

Q18.

Two identical springs are suspended from a fixed support and a force applied as shown in the diagram. The spring constant of each spring is 80 N m^{-1}.



The extension of this arrangement will be

☒ **A** 5 cm

☒ **B** 10 cm

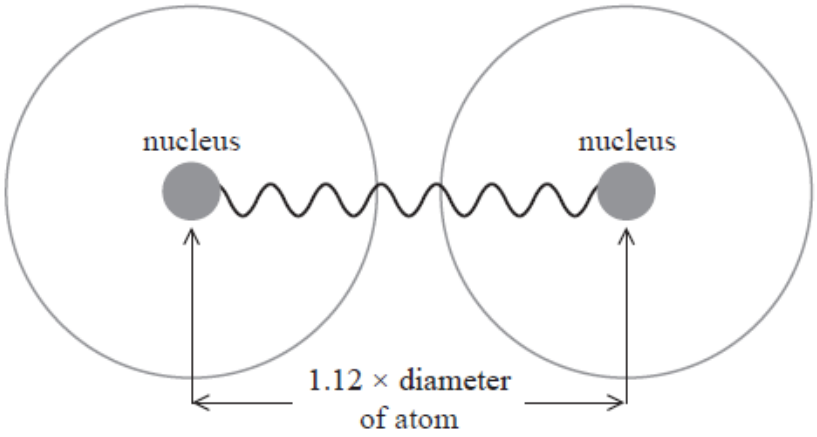
☒ **C** 20 cm

☒ **D** 40 cm

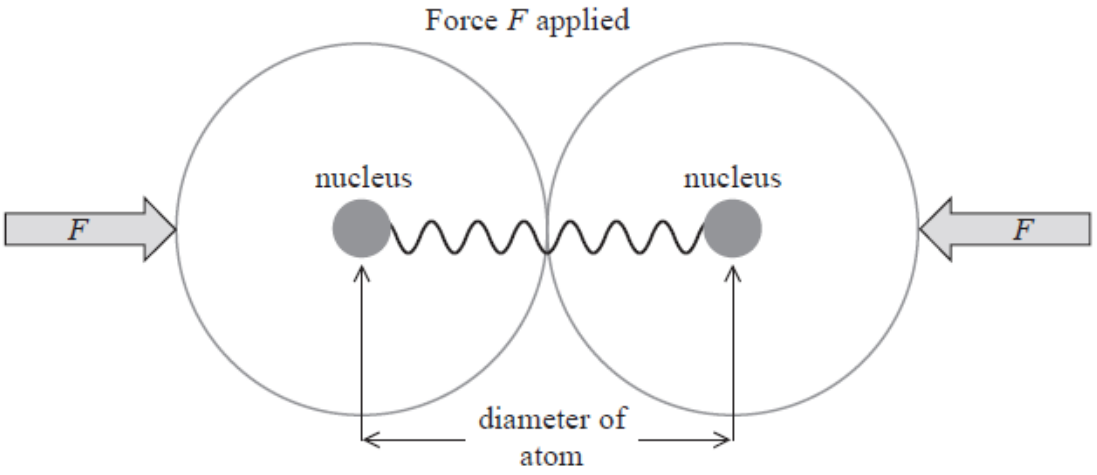
(Total for question = 1 mark)

Q19.

The forces between the two atoms in a molecule of hydrogen can be modelled using a spring. When in equilibrium the nuclei are separated by 1.12 × diameter of the atom.



(a) When the atoms are squashed together by a force *F*, the spring is under compression.



When the force F acts on the atoms, the separation between the nuclei becomes equal to the diameter of the atom.

Calculate the force F.

spring constant for hydrogen = 1130 N m^{-1}

diameter of an atom of hydrogen = 1.06 × 10^{-10} m

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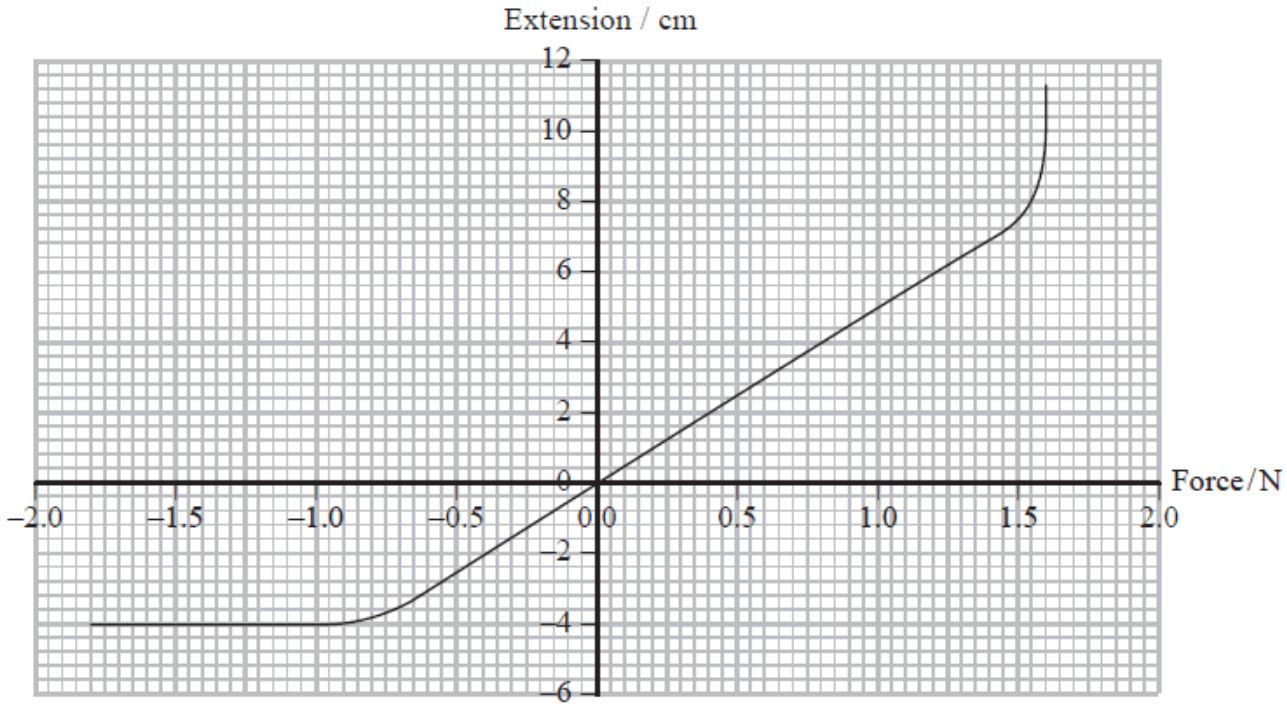
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Force = ...

(b) A student carries out an experiment to model the forces between atoms.

A varying force is applied to the end of a spring. The student measures the length of the spring and calculates the extension for each force applied.

The student plots the following graph.



(i) Explain the shape of the graph.

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(ii) Use the graph to calculate the spring constant.

(2)

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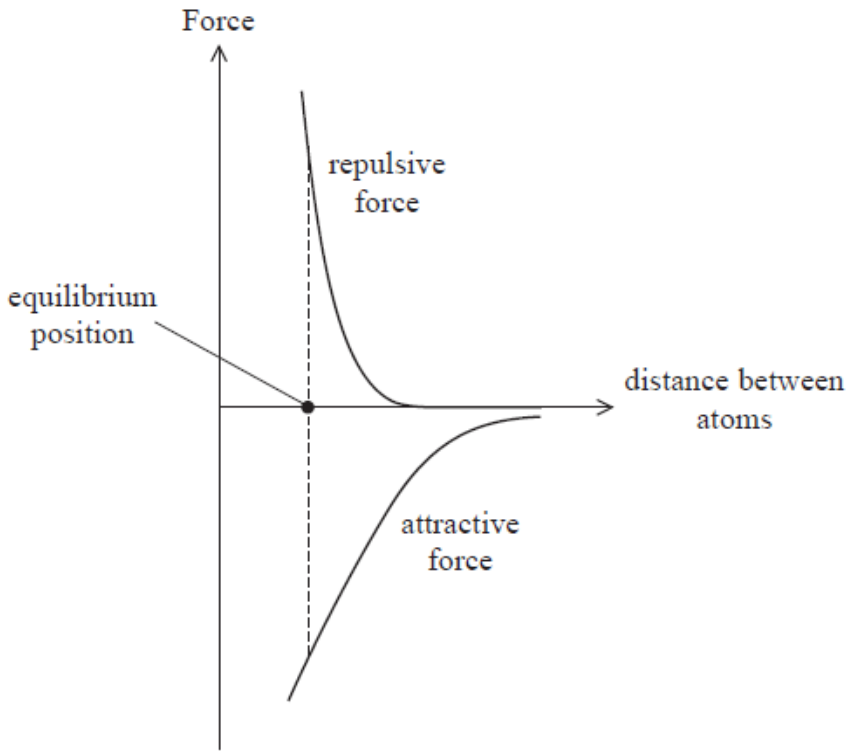
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Spring constant = ...

*(c) The graph below shows how the forces acting between two atoms consist of a repulsive force and an attractive force. At the equilibrium position, the sum of these forces is zero.



Use the graph to explain why the forces between atoms are attractive when they are pulled apart and repulsive when pushed together.

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(Total for question = 11 marks)

Q20.

The picture shows a toy hanging from a spring.



(Source: m4.sourcingmap.com/photo_new/20120821/g/ux_a12082100ux0119_ux_g03.jpg)

The toy has a mass of 0.066 kg. When it is hanging freely on the spring, the spring extends by 4.5cm.

When the toy is pulled downwards and released, it undergoes simple harmonic motion.

Calculate the frequency of the oscillations.

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Frequency = ...

(Total for question = 5 marks)

Q1.

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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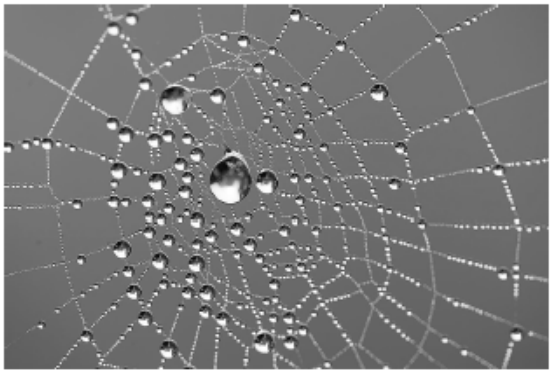
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Extension = ...

(Total for question = 6 marks)

Q2.

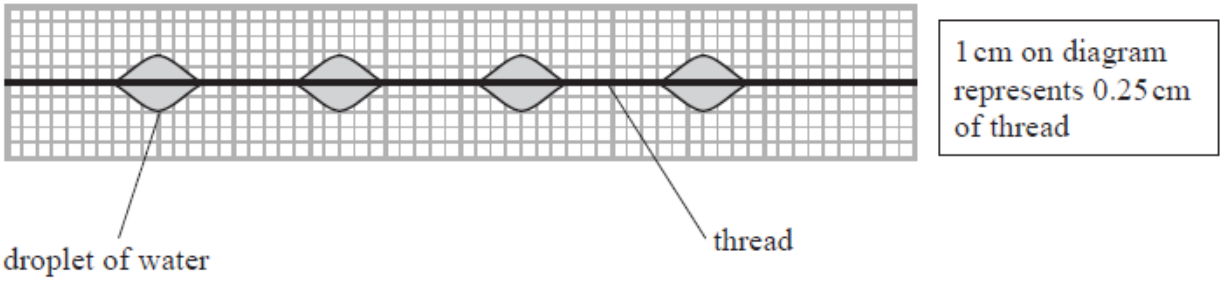
The photograph shows part of a spider's web where water droplets have collected at certain points. The web is made from spider silk which is made by the spider.



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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Q3.

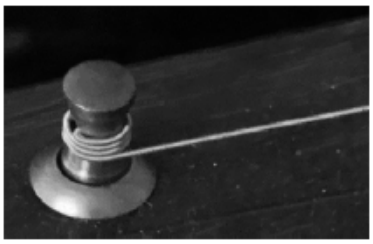
The photograph shows a guitar.



When a guitar string is plucked, a standing wave is created.

One end of the guitar string is wrapped around a cylindrical tuning peg. Turning the peg changes the total length of the string and hence changes the tension in the string.

This changes the frequency of vibration of the string.



(i) The length of one string is 68 cm.

Calculate the extension required to produce a tension of 93.4 N in the string.

Young modulus of string material = $1.8 \times 10^{9}\,\text{N}\,\text{m}^{-2}$

cross-sectional area of string = $6.6 \times 10^{-7}\,\text{m}^{2}$

(4)

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Extension = ...

(ii) The vibrating length of string is unchanged by turning the tuning peg.

Explain the effect that tightening the string has on the frequency of the sound produced.

(2)

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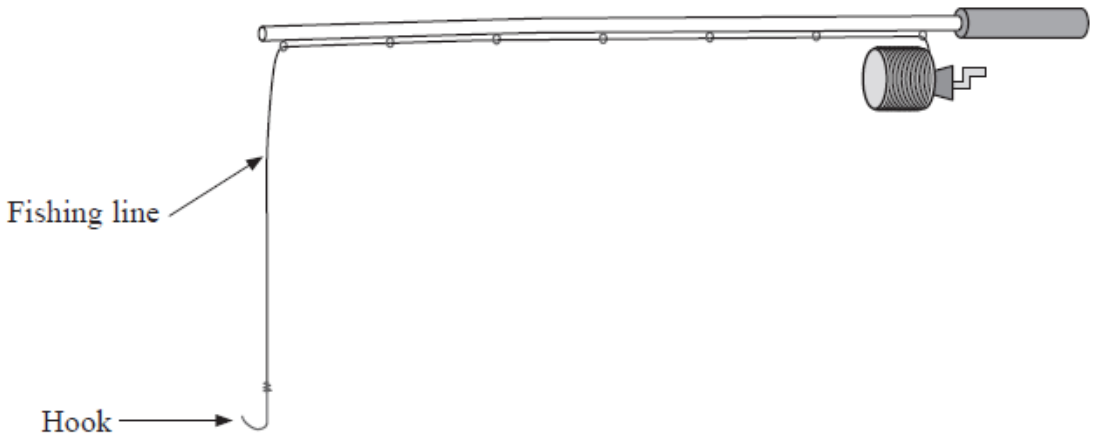
(Total for question = 6 marks)

Q4.

The following three properties can be used to describe copper.

Ductile Malleable Tough

(a) Both nylon and copper can be used to make fishing lines. Copper fishing lines sink faster than those made of nylon. This makes copper fishing lines more suitable for deep water fishing.



(i) By considering the forces acting on the submerged line, explain why nylon is less suitable than copper for deep water fishing. Include a suitable calculation in your answer.

Both lines have the same cross-sectional area.

cross-sectional area of lines = 1.30×10^{-7} m^2

density of saltwater = 1030 kg m^{-3}

weight of 20.0 m of copper line = 0.220 N

weight of 20.0 m of nylon line = 0.0280 N

(4)

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(ii) A fish becomes caught on the hook and the copper line extends. Calculate the extension produced.

cross-sectional area of copper line = 1.30×10^{-7} m^3

load on line = 65.0 N

original length of line = 20.0 m

Young modulus of copper = 129 GPa

(3)

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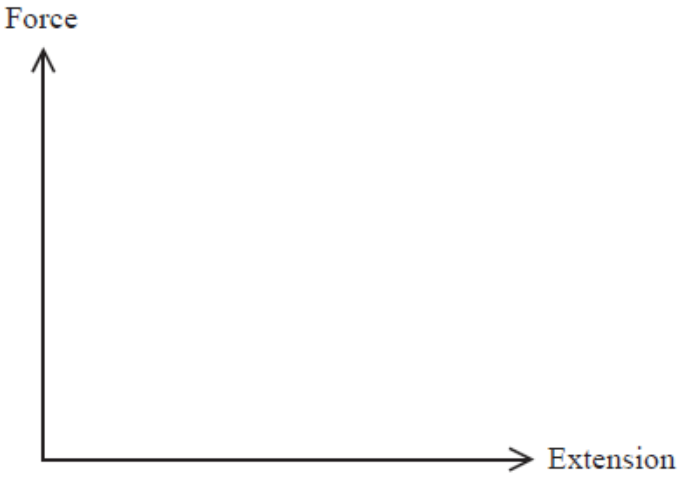
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Extension = ...

(b) Some people use fishing lines that have been pre-stretched by loading and unloading.

(i) Sketch the force-extension graph for a copper line during the process of pre-stretching.

(3)



(ii) Suggest a reason why some people prefer to use this type of line.

(1)

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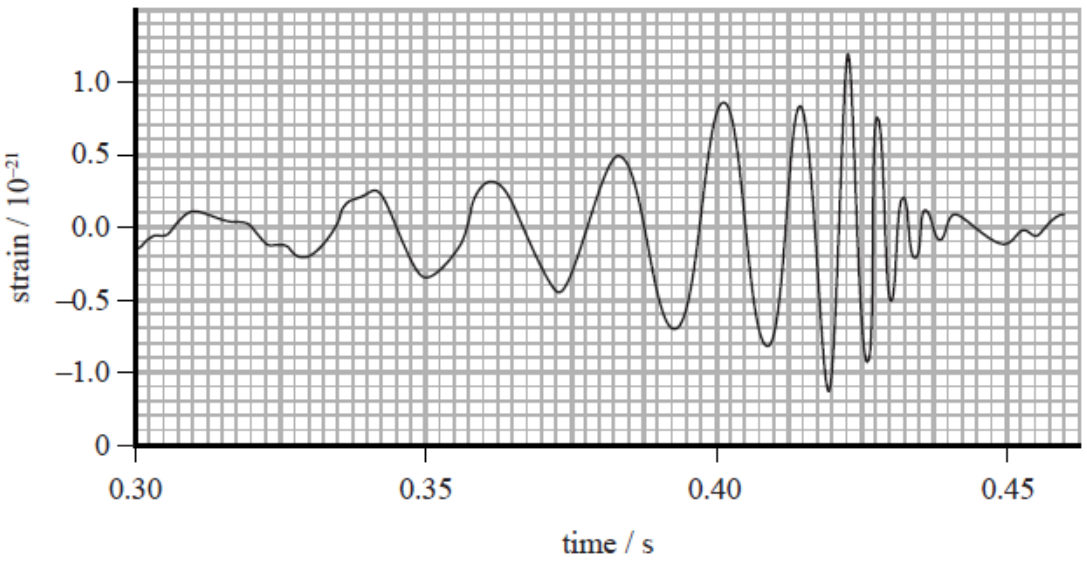
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(Total for question = 11 marks)

Q5.

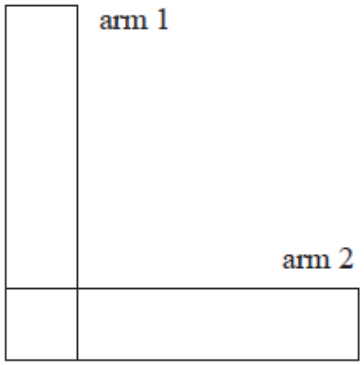
In 2016 scientists at the Laser Interferometer Gravitational-Wave Observatory (LIGO) announced that gravitational waves had been detected.

The signal they detected is shown on the graph.



Gravitational waves alternately compress and stretch matter by very small amounts as they pass through.

The LIGO detector has two arms, at 90° to each other, each 4 km long. As a gravitational wave passes the detector, the arms change length. The detector continuously compares the lengths of the two arms.



(i) An article states that 'the maximum change in the 4 km length of the arm is about 0.001 times the diameter of a proton'.

Determine whether this statement applies to the gravitational wave shown in the graph.

diameter of proton = 8.8×10^{-16} m

(3)

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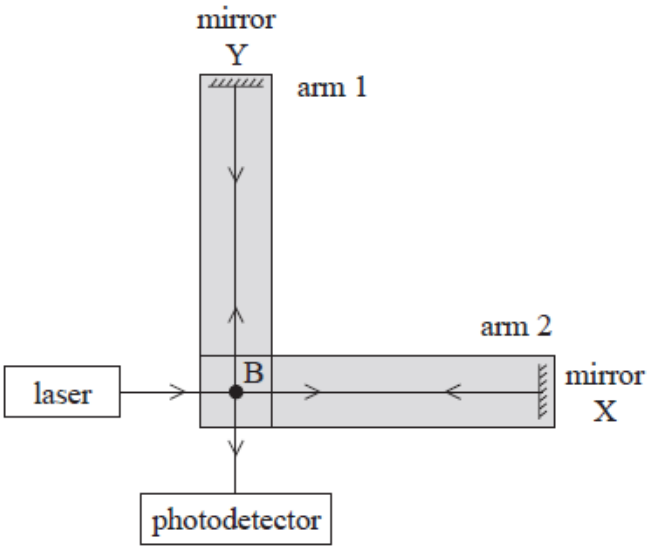
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(ii) In the LIGO detector, any change in the lengths of the arms is detected using a laser beam and photodetector.



The laser beam is split into two at B, one beam travelling to one mirror and the other beam travelling to the other mirror. After reflection at the mirrors, the beams are recombined at B and reach the photodetector. The photodetector measures the intensity of the incident light.

The system is arranged so that when no gravitational waves are present, the beams have a path difference of half a wavelength at the photodetector.

Explain how the photodetector detects very small changes in the length of one arm, when the other arm stays the same length.

(4)

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(iii) The system could be arranged so that when no gravitational waves are present, the beams have zero path difference at the photodetector.

Explain whether using an initial path difference of half a wavelength is a more sensitive way of detecting changes in length than having an initial path difference of zero.

(2)

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(Total for question = 9 marks)

Q6.

Read the extract and answer the questions that follow.

Gravitricity is developing a new technology to capture and store the excess power generated by renewable energy resources. A large load is suspended by cables in a disused mineshaft. During periods of low power demand, excess generated power is used to winch the load upwards. During periods of high demand, the load is lowered down the shaft, causing electricity to be generated. The system can produce electricity at low power for several hours, or a short burst of electricity at high power.

(Source based on: https://gravitricity.com/)

(c) A load of 5.0×10^3 tonnes is held stationary by several vertical steel cables. The strain on the cables is 5.0×10^{-3}.

Calculate the total cross-sectional area of the cables holding the load.

Young modulus of steel = 180 GPa

1 tonne = 1.0×10^3 kg

(2)

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Cross-sectional area = ...

(d) The speed of the load in the shaft will depend on the variation of the electricity supply and demand throughout the day.

Explain why the total area of the cables will need to be greater than that calculated in (c) to limit the strain to no more than 0.005

(3)

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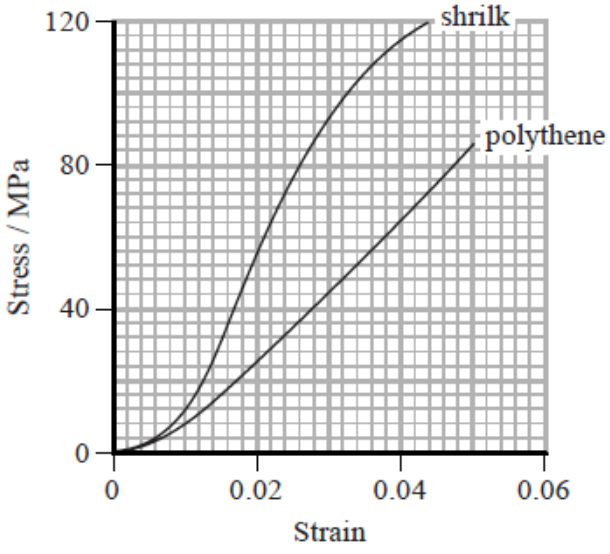
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(Total for question = 5 marks)

Q7.

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)

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Force = ...

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

(2)

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Extension = ...

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

(3)

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(Total for question = 8 marks)

Q8.

In 2010, Andre Geim and Konstantin Novoselov were awarded the Nobel Prize in Physics for producing, identifying and studying graphene.

Graphene is a form of carbon which exists only as a single atomic layer of graphite. It has a breaking stress of 130 GPa compared to 0.5 GPa for steel. Some scientists claim that graphene is the strongest material ever measured.

(a) Explain why graphene, despite its greater strength, is unlikely to replace steel in many applications.

(2)

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(b) Graphite used in pencils consists of many layers of carbon. It can be assumed that a pencil deposits approximately 100 layers of carbon atoms when drawn across a piece of paper.

A student carried out an experiment to determine the resistivity of the graphite in a pencil.

A line of length 0.200m and width 0.50mm was drawn on a piece of paper. An ohmmeter was then used to measure the resistance of the graphite line.



Calculate the resistivity of graphite.

resistance = $1.029 \times 10^{6}\ \Omega$
diameter of carbon atom = 1.4×10^{-10} m

(4)

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Resistivity of graphite = ...

(c) Photocells traditionally use silicon to generate electricity using visible light. Research demonstrates that unlike silicon, graphene is able to respond at all wavelengths and releases multiple electrons as it absorbs one photon.

Deduce why it would be an advantage to use graphene in photocells to generate electricity.

(3)

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(Total for question = 9 marks)

Q9.

A student carried out an experiment to determine the Young modulus for a sample of wire original length l_0 and cross-sectional area A. One end of the wire was fixed and a force F was applied to the free end of the wire. The new length l was measured.

The Young modulus can be determined using

☒ **A** $\frac{Fl}{(l - l_0)A}$

☒ **B** $\frac{Fl_0}{(l - l_0)A}$

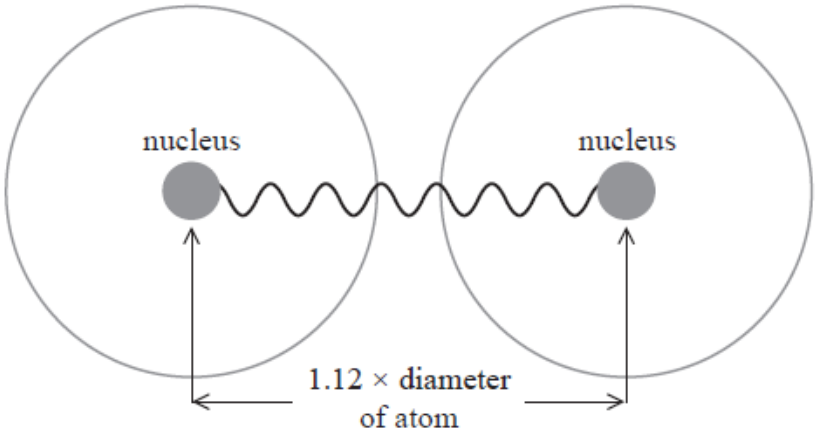
☒ **C** $\frac{F(l - l_0)}{l_0 A}$

☒ **D** $\frac{F(l - l_0)}{lA}$

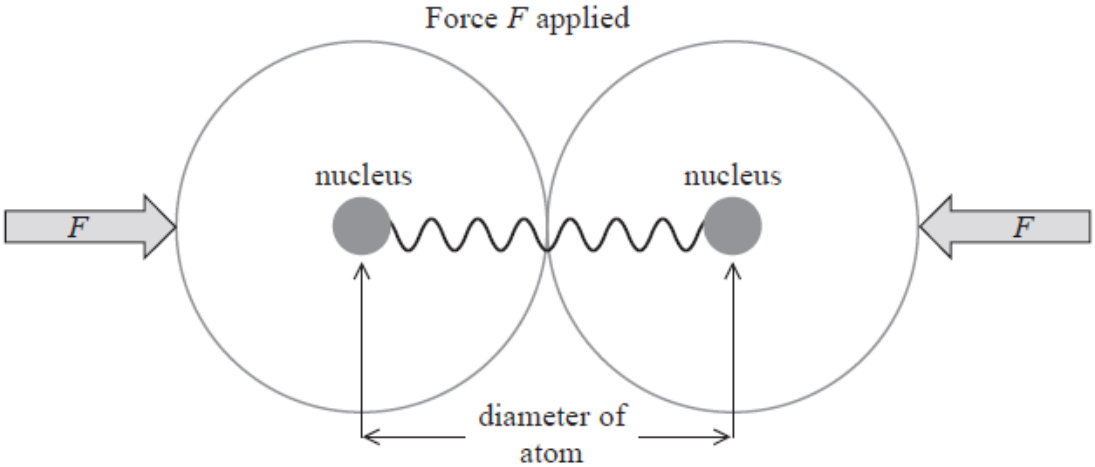
(Total for question = 1 mark)

Q10.

The forces between the two atoms in a molecule of hydrogen can be modelled using a spring. When in equilibrium the nuclei are separated by 1.12 × diameter of the atom.



(a) When the atoms are squashed together by a force *F*, the spring is under compression.



When the force F acts on the atoms, the separation between the nuclei becomes equal to the diameter of the atom.

Calculate the force F.

spring constant for hydrogen = 1130 N m^{-1}

diameter of an atom of hydrogen = 1.06×10^{-10} m

(3)

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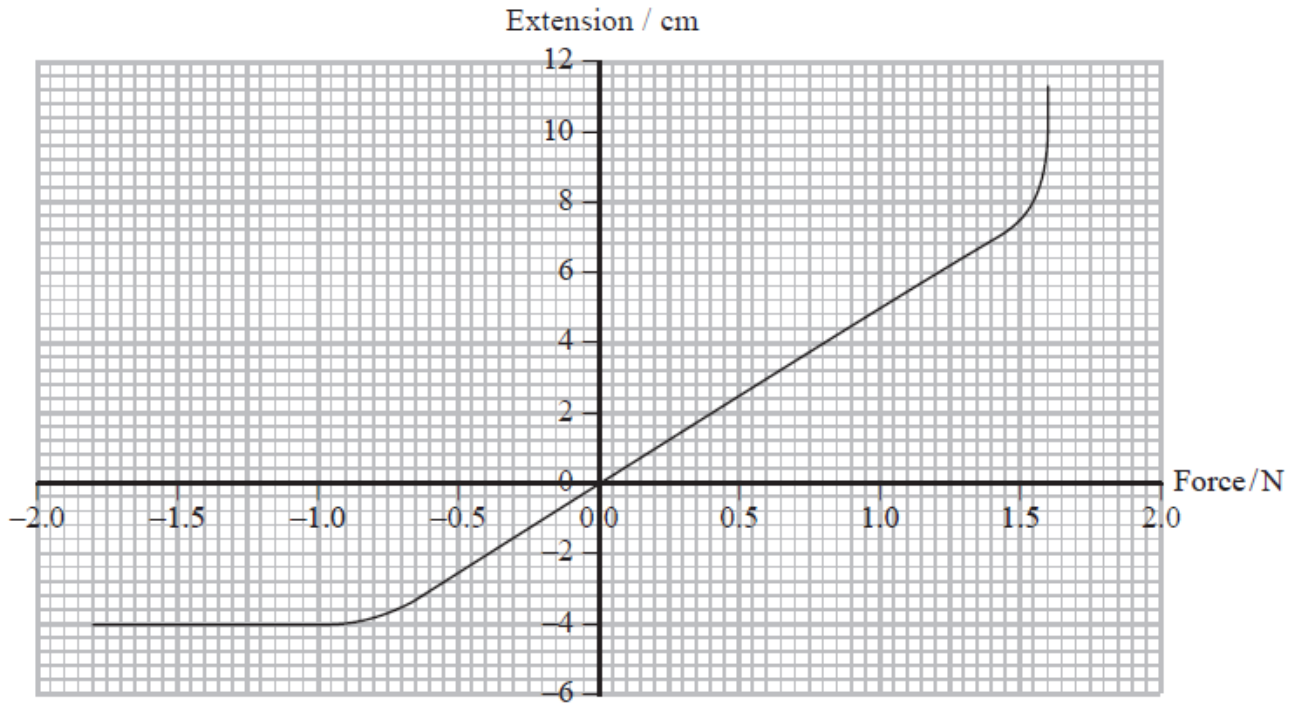
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Force = ...

(b) A student carries out an experiment to model the forces between atoms.

A varying force is applied to the end of a spring. The student measures the length of the spring and calculates the extension for each force applied.

The student plots the following graph.



(i) Explain the shape of the graph.

(3)

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(ii) Use the graph to calculate the spring constant.

(2)

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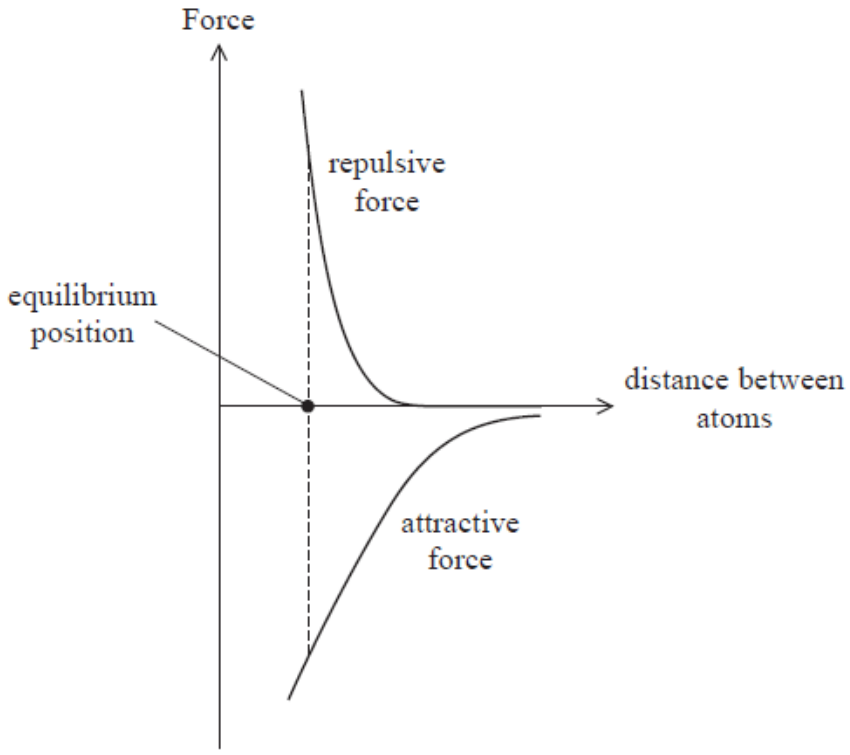
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Spring constant = ...

*(c) The graph below shows how the forces acting between two atoms consist of a repulsive force and an attractive force. At the equilibrium position, the sum of these forces is zero.



Use the graph to explain why the forces between atoms are attractive when they are pulled apart and repulsive when pushed together.

(3)

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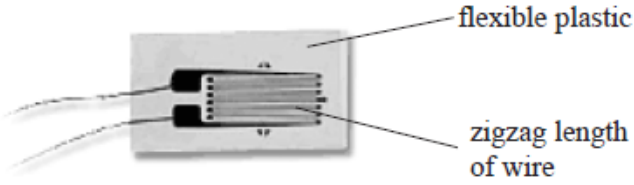
(Total for question = 11 marks)

Q11.

A medical scanner uses a moving table to position the patient. Strain gauges are used to monitor the shape of the table which enables a more precise positioning of the patient.



Strain gauges consist of a thin length of wire attached, in a zigzag pattern, to a small flexible piece of plastic. The strain gauge is attached to the table. When the table is subjected to forces, the dimensions of the plastic change. This causes a change in the length of the wire and hence a change in the resistance of the wire.



(a) Resistance can be measured directly using an ohmmeter or indirectly using measurements from a voltmeter and ammeter.

Describe **two** benefits of using an ohmmeter compared to using a voltmeter and an ammeter.

(2)

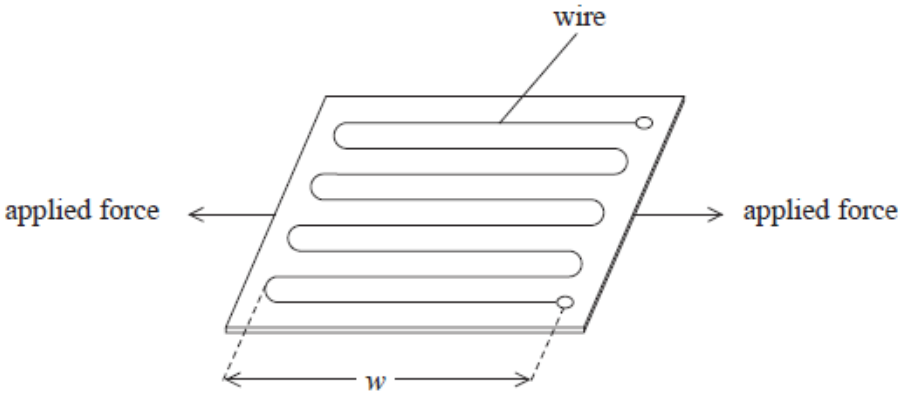
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(b) The diagram shows forces applied to a strain gauge. The 'width' of the strain gauge is defined by the distance *w*.



(i) State and justify how the applied forces change the resistance of the wire.

(2)

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(ii) The gauge factor *GF* of a strain gauge is given by

$$GF = \frac{\Delta R}{\varepsilon R}$$

where ε is the strain
R is the initial resistance
ΔR is the change in resistance

When forces are applied to the strain gauge, the resistance of the gauge changes by 0.10%.

Calculate the change in the width of the strain gauge.

w = 5.0 cm
GF = 2.0

(3)

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Change in width = ...

(c) Explain the benefit of arranging the wire in a zigzag pattern.

(2)

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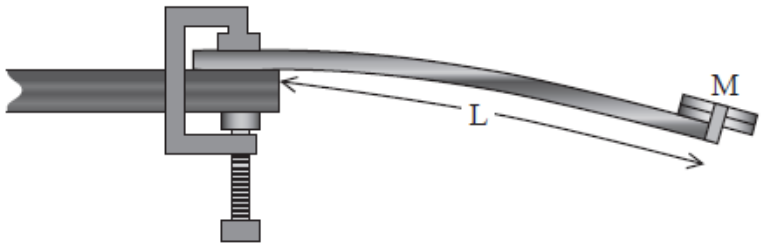
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(Total for question = 9 marks)

Q12.

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)

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(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)

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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

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x-axis

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(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)

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

(2)

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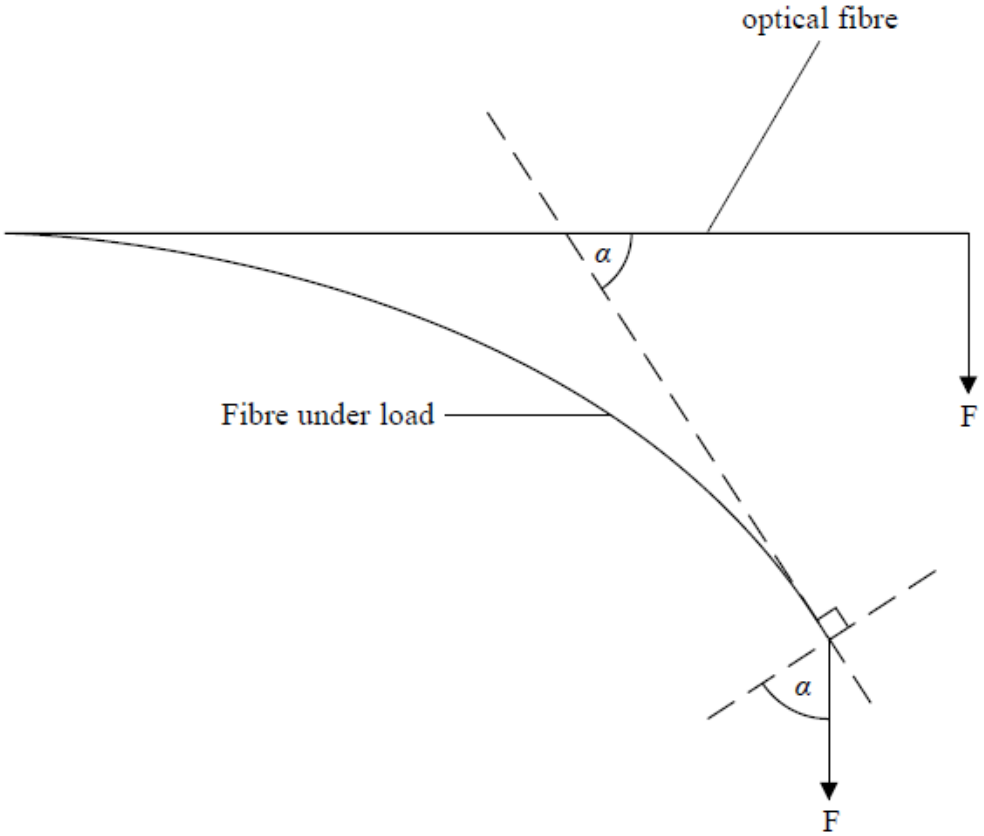
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(Total for question = 10 marks)

Q13.

The diagram shows an optical fibre. A small force F is applied to the end of the optical fibre causing it to bend through an angle α.



Explain why the stress parallel to the surface of the fibre increases as the fibre bends.

(4)

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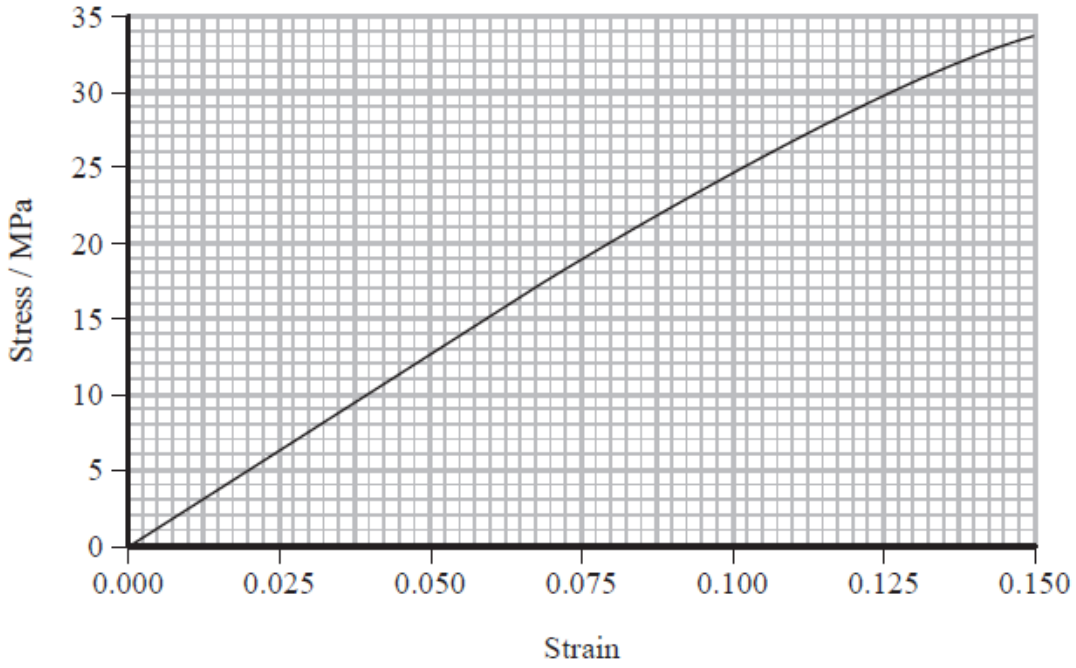
(Total for question = 4 marks)

Q14.

Seat belts are being tested by a car manufacturer. In the test, a car moving at a steady speed of 28 m s^{-1} collides with a wall and stops.

A crash-test dummy in the driving seat is wearing a seat belt made from polyester webbing. The seat belt has a cross-sectional area of 0.85 cm^2 and a total length of 2.0 m. A student suggests that in the collision the seat belt absorbs all the kinetic energy of the dummy.

The graph shows how stress varies with strain for the seat belt.



(i) Show that the area under the graph represents the energy stored per unit volume in the seat belt.

(2)

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(ii) Use the graph to determine whether the seat belt absorbs all the kinetic energy of the dummy from part (a).

In this collision, the maximum strain of the seat belt is 0.075

(3)

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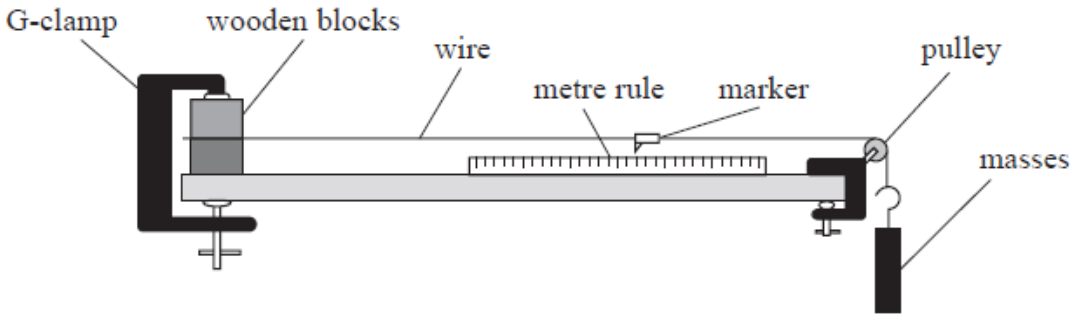
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(Total for question = 5 marks)

Q15.

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)

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(Total for question = 4 marks)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A mass of 24 kg is suspended from a steel wire of length 1.5 m. The wire has cross-sectional area 3.1×10^{-6} m^2.

The Young modulus of steel is 1.8×10^{11} Pa.

Which of the following gives the extension of the wire?

☒ **A** $\frac{24 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **B** $\frac{24 \times 9.81 \times 1.5}{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}$

☒ **C** $\frac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 1.5}$

☒ **D** $\frac{1.8 \times 10^{11} \times 3.1 \times 10^{-6}}{24 \times 9.81 \times 1.5}$

(Total for question = 1 mark)

Q17.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q18.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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

☒ **B** $\frac{\frac{\Delta x}{x}}{\frac{F}{A}}$

☒ **C**

$\frac{\frac{F}{A}}{\frac{\Delta x}{x}}$

☒ **D** $\frac{\frac{F}{A}}{\frac{x}{\Delta x}}$

(Total for question = 1 mark)

Q19.

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)

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Young modulus = ...

(Total for question = 3 marks)

Q20.

A copper wire and a steel wire of identical lengths *l* are soldered together. The compound wire is stretched by a force *F* and the total length increases by 0.010 m.



cross-sectional area of copper = 0.80×10^{-6} m^2

cross-sectional area of steel = 1.3×10^{-6} m^2

Young modulus of copper = 1.3×10^{11} Pa

Young modulus of steel = 1.8×10^{11} Pa

(a) (i) Show that the extension of the copper wire is about twice the extension of the steel wire.

(3)

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(ii) Hence calculate the extension of the copper wire.

(2)

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Extension = ...

(Total for question = 5 marks)

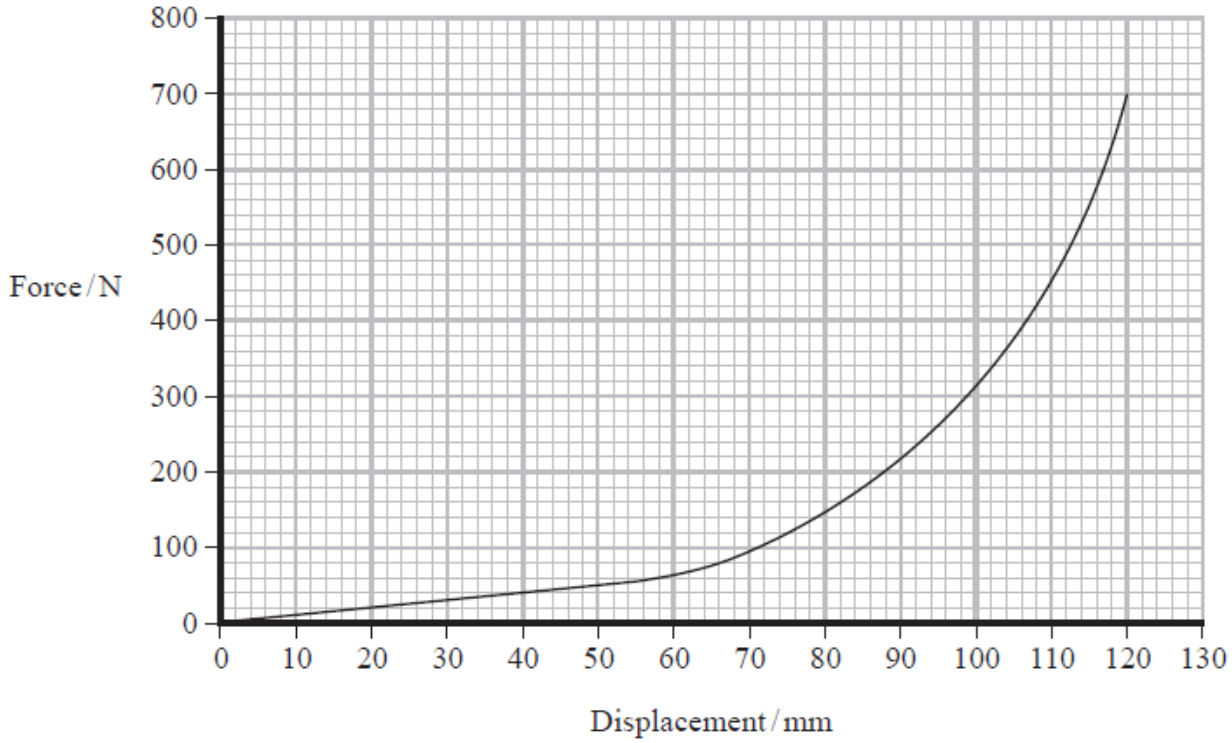
Q1.

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)

Q2.

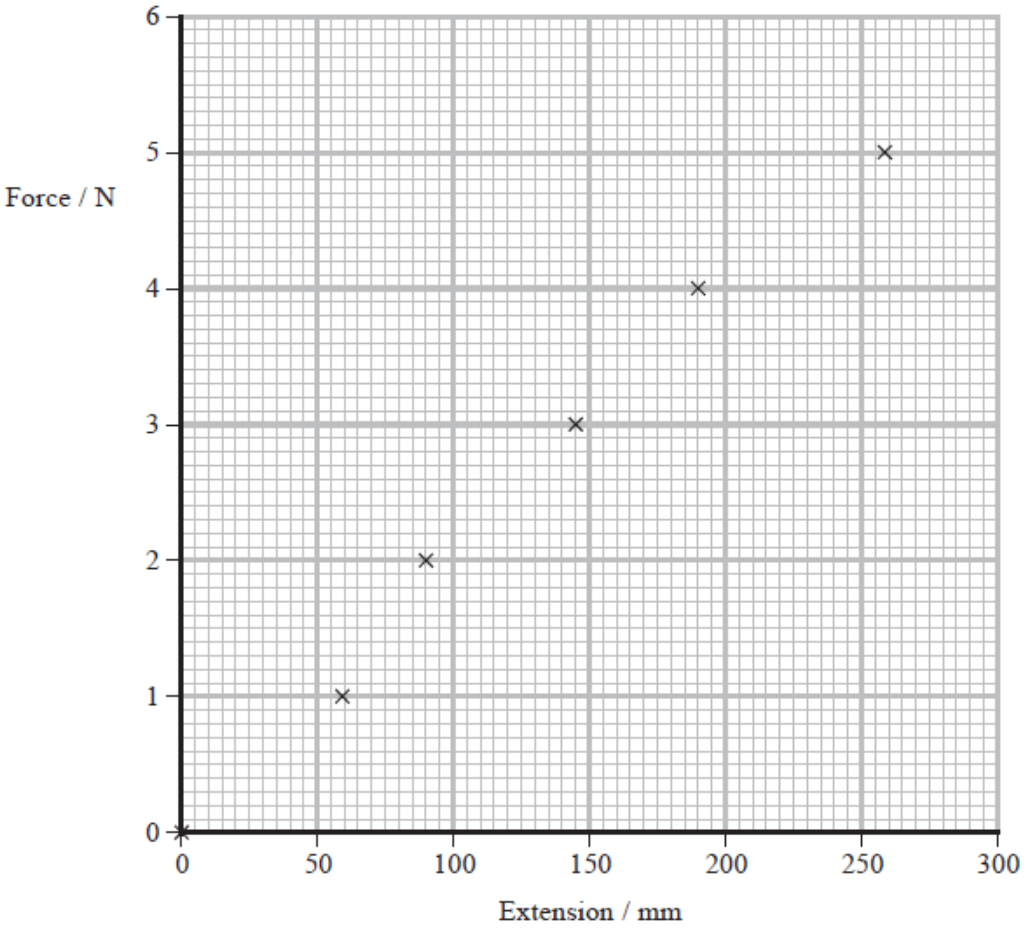
A manufacturer gives the following information about a spring.

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%
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)

Q3.

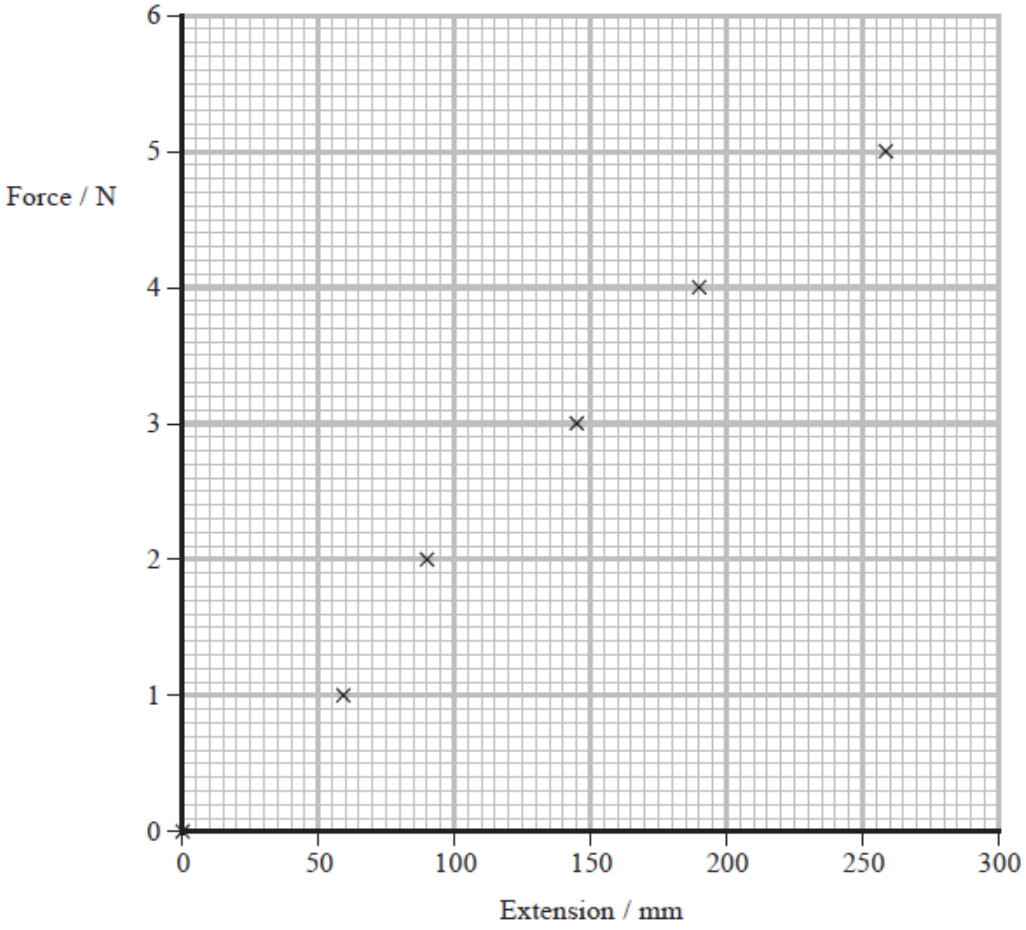
A manufacturer gives the following information about a spring.

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.



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

(6)

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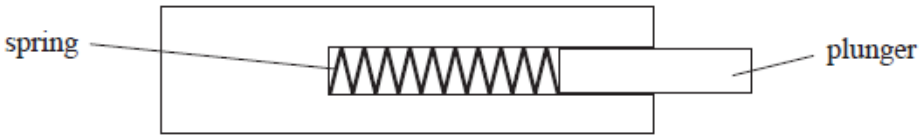
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(Total for question = 6 marks)

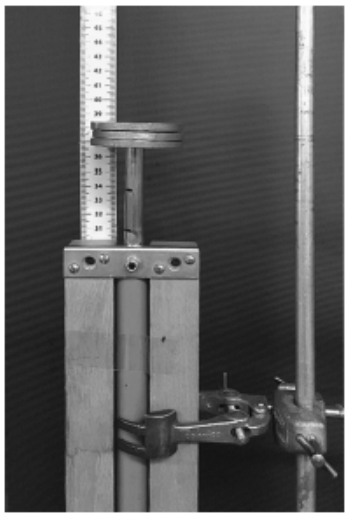
Q4.

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.

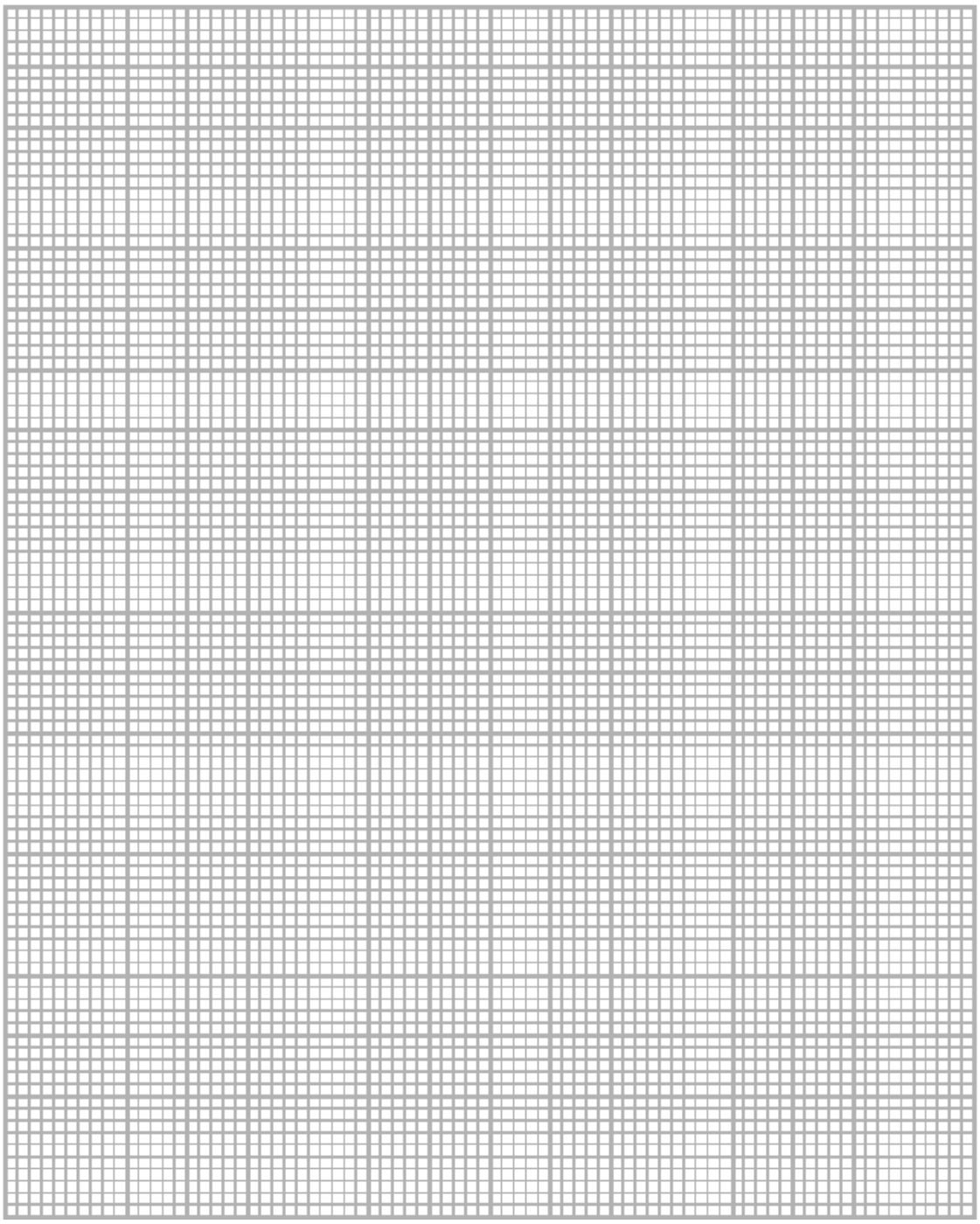


The recorded results are shown in the table.

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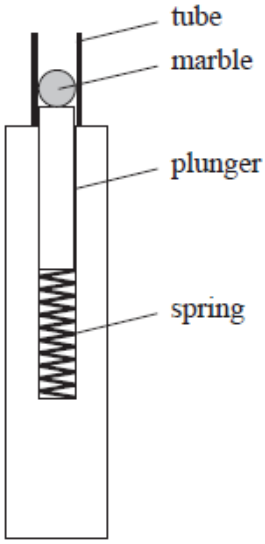
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(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



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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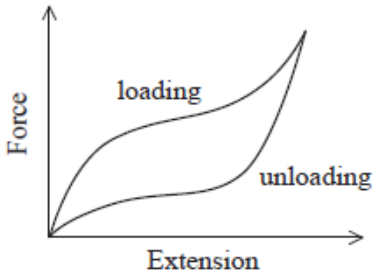
(Total for question = 14 marks)

Q5.

* 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)

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(Total for question = 6 marks)

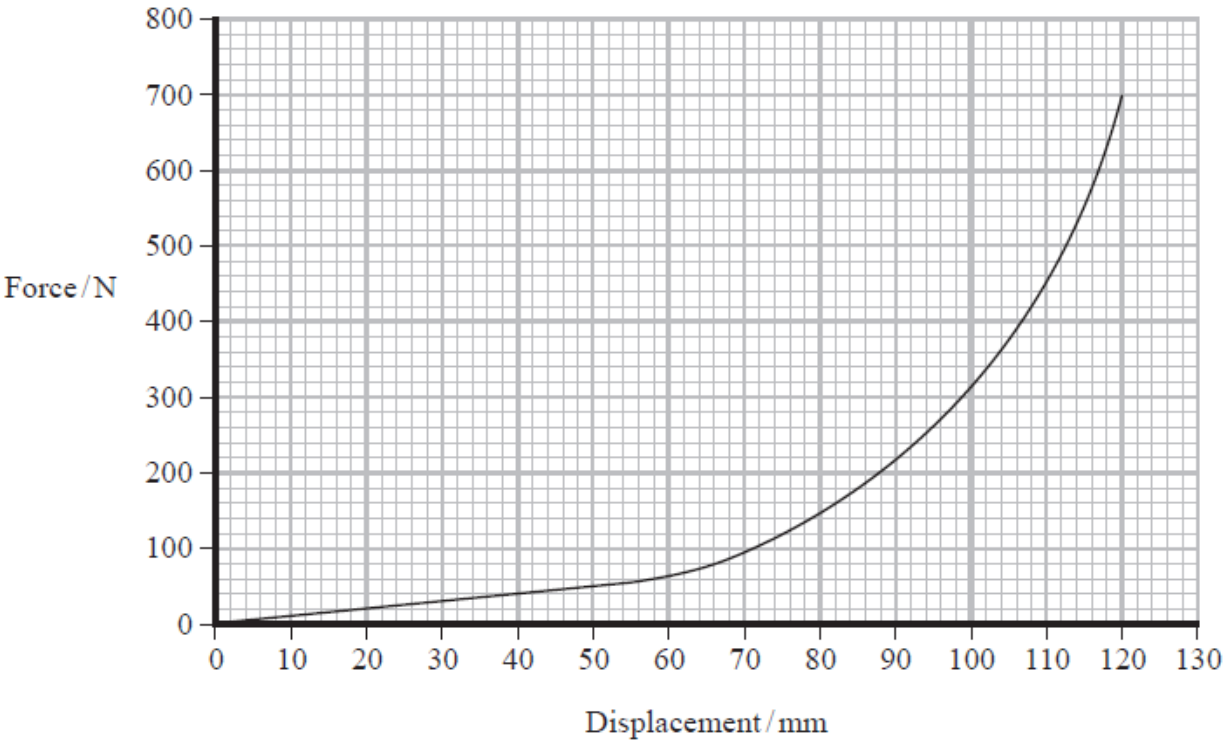
Q6.

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.



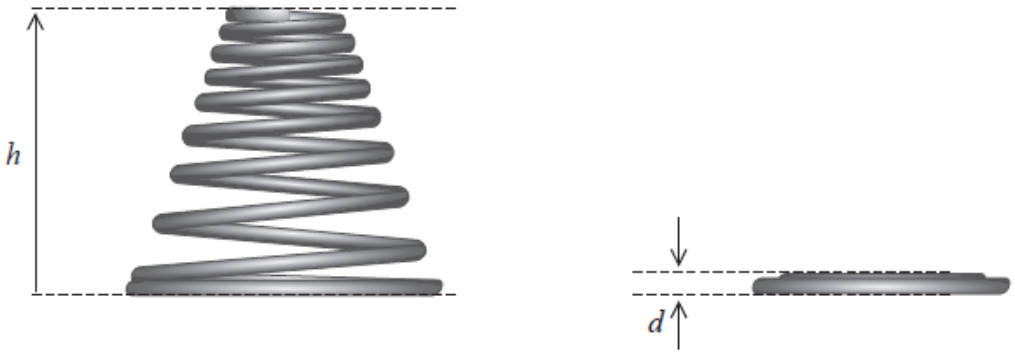
(Source: © Anatolii Riabokon/Alamy Stock Vector)

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.

When fully compressed all the coils lie flat inside each other.



The height h of the spring when unloaded is 126 mm.

Calculate the diameter d of the wire in the spring.

(2)

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Diameter = ...

(Total for question = 2 marks)

Q7.

Answer the question with a cross in the box you think is correct (☒). If you change your mind about an answer, put a line through the box (☒) and then mark your new answer with a cross (☒).

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)

Q8.

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.

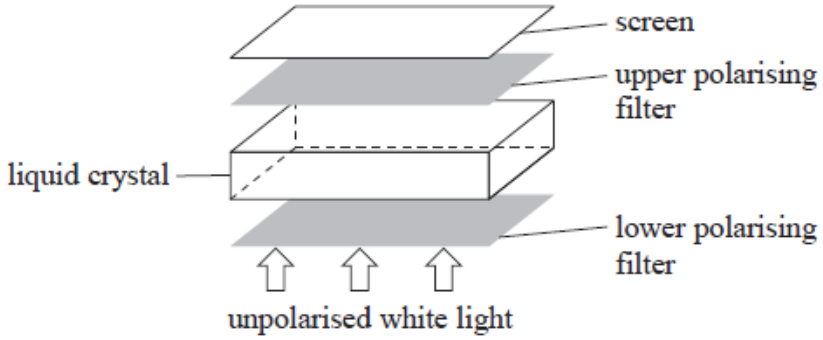
☒ **D** The stress at which the steel breaks.

(Total for question = 1 mark)

Q9.

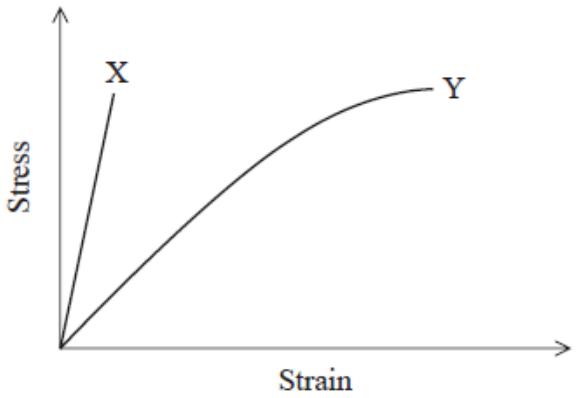
A liquid-crystal display uses a series of segments to form letters and numbers on a screen.

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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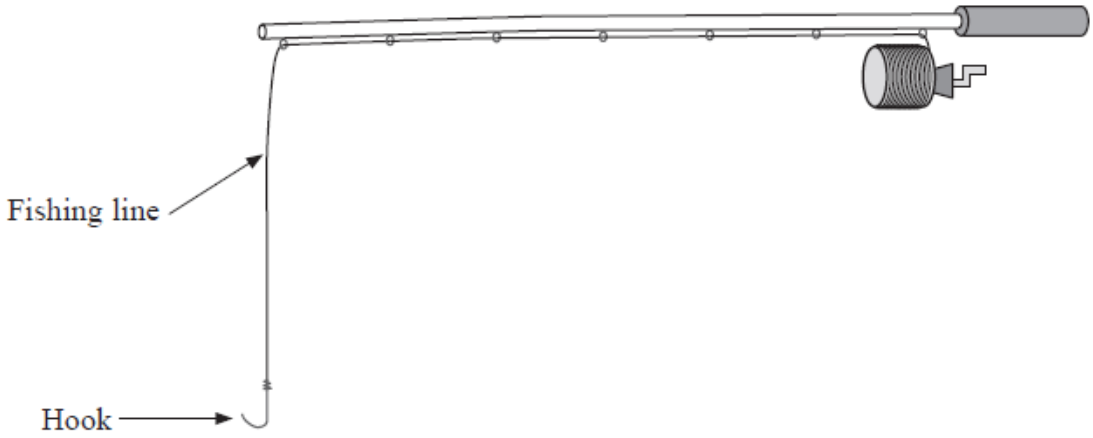
(Total for question = 4 marks)

Q10.

The following three properties can be used to describe copper.

Ductile Malleable Tough

(a) Both nylon and copper can be used to make fishing lines. Copper fishing lines sink faster than those made of nylon. This makes copper fishing lines more suitable for deep water fishing.



(i) By considering the forces acting on the submerged line, explain why nylon is less suitable than copper for deep water fishing. Include a suitable calculation in your answer.

Both lines have the same cross-sectional area.

cross-sectional area of lines = 1.30×10^{-7} m^2

density of saltwater = 1030 kg m^{-3}

weight of 20.0 m of copper line = 0.220 N

weight of 20.0 m of nylon line = 0.0280 N

(4)

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(ii) A fish becomes caught on the hook and the copper line extends. Calculate the extension produced.

cross-sectional area of copper line = 1.30×10^{-7} m^3

load on line = 65.0 N

original length of line = 20.0 m

Young modulus of copper = 129 GPa

(3)

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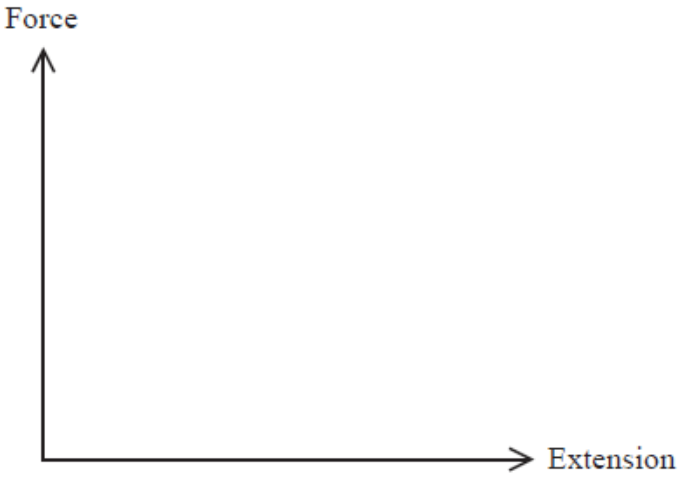
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Extension = ...

(b) Some people use fishing lines that have been pre-stretched by loading and unloading.

(i) Sketch the force-extension graph for a copper line during the process of pre-stretching.

(3)



(ii) Suggest a reason why some people prefer to use this type of line.

(1)

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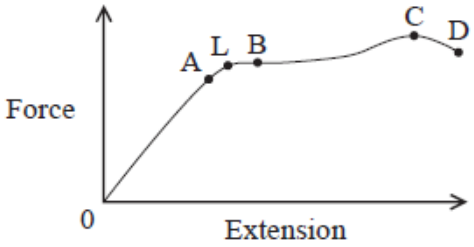
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(Total for question = 11 marks)

Q11.

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)

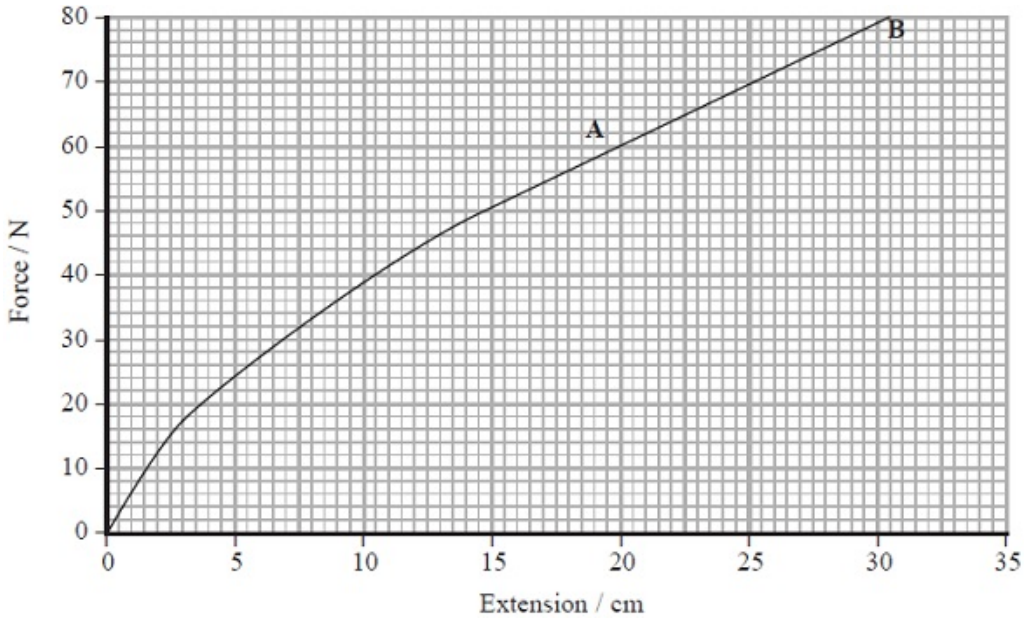
Q12. The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.





A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

(2)

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(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

(2)

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(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

	A	B	C	D
1	Total stretching force / N	Extension / cm	Change in extension / m	Work done (force × change in extension) / J
2	0	0.0	0.000	0.00
3	10	1.6	0.016	0.16
4	20	3.5	0.019	0.38
5	30	7.0	0.035	1.05
6	40	10.5	0.035	1.40
7	50	14.5	0.040	2.00
8	60	20.0	0.055	3.30
9	70	25.2	0.052	3.64
10	80	30.5	0.053	4.24
11			Total work done	16.17

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

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(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

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Time = ...

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

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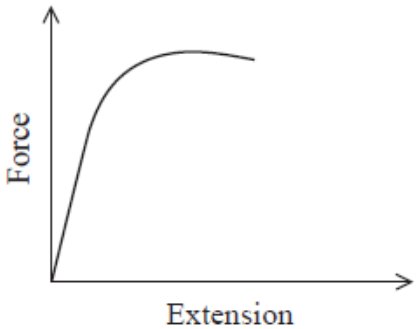
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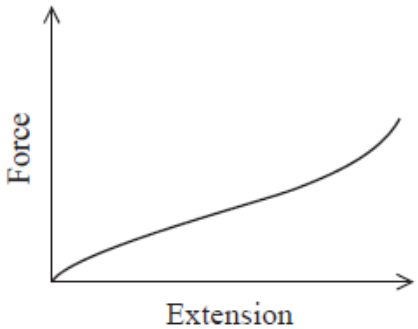
(Total for Question = 11 marks)

Q13.

In a physics lesson the following graphs are given to the students. The graphs show the relationship between force and extension for samples of two different materials, A and B.



Sample A



Sample B

A student states that sample A obeys Hooke's law for small extensions and sample B does not.

Use the graphs to explain the validity of the student's statement.

(3)

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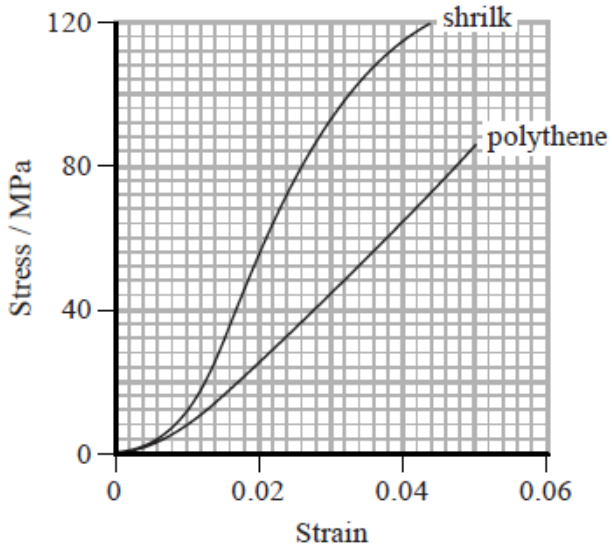
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(Total for question = 3 marks)

Q14.

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)

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Force = ...

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

(2)

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Extension = ...

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

(3)

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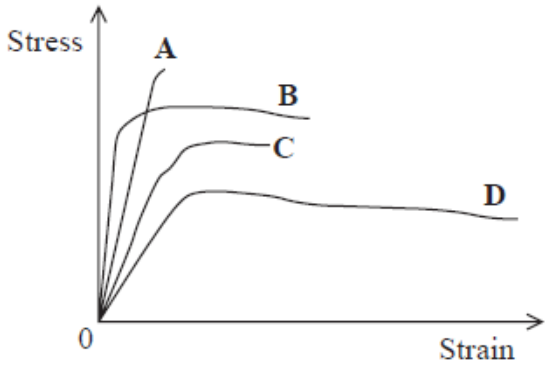
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(Total for question = 8 marks)

Q15.

Stress-strain graphs are drawn for four different materials, **A**, **B**, **C** and **D**.



Which of the materials has the greatest strength?

☒ **A**

☒ **B**

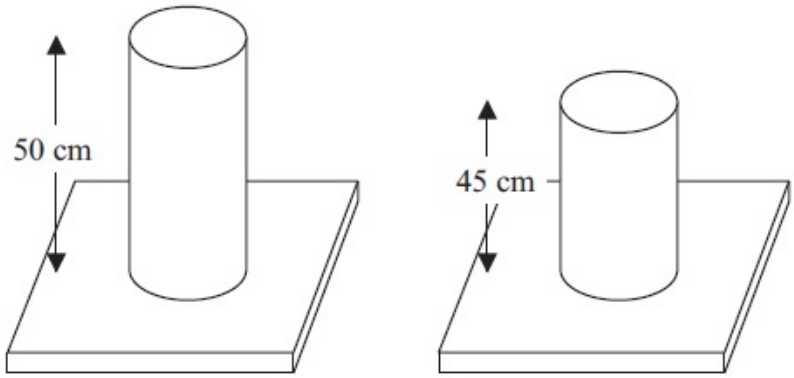
☒ **C**

☒ **D**

(Total for question = 1 mark)

Q16.

A cylinder of length 50 cm has a force applied to it. The new length of the cylinder is 45 cm.



The quantity determined using is $\frac{5\text{ cm}}{50\text{ cm}}$ is

☒ **A** compressive strain.

☒ **B** compressive stress.

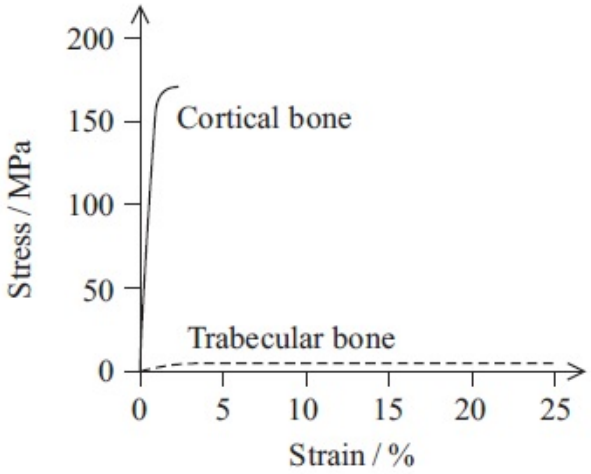
☒ **C** tensile strain.

☒ **D** tensile stress.

(Total for question = 1 marks)

Q17.

The graph shows the stress-strain curve for two types of human bone under compression.



(a) Use the graph to identify and describe **one** property of cortical bone.

(2)

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(b) The table gives the following information for the two types of bone.

Material	Young modulus / GPa	Maximum compressive stress / MPa	Maximum tensile stress / MPa
Cortical bone	17.9	170	120
Trabecular bone	0.076	2.2	

(i) State the difference between compressive stress and tensile stress.

(1)

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(ii) State how the graph could be used to confirm the value of the Young modulus for cortical bone.

(1)

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(iii) A person of mass 90 kg stands on one foot. Show that the maximum weight which can be supported is about 70 times this person's weight. Assume all the weight is supported by the femur (thigh bone) and that it is made of cortical bone.

cross-sectional area of femur = 3.7×10^{-4} m^2

(4)

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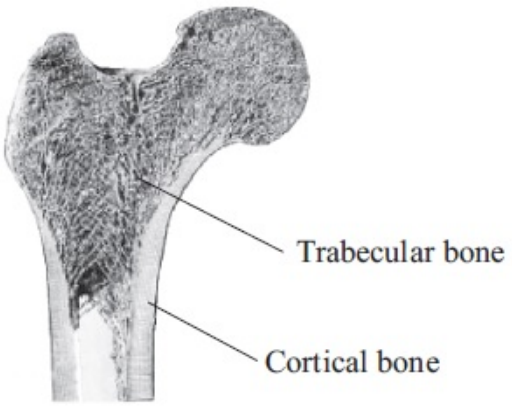
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(iv) It is stated in a text book that a femur can support about 30 times a person's weight.



Explain how the structure shown in the diagram would account for the difference from the calculated value.

(2)

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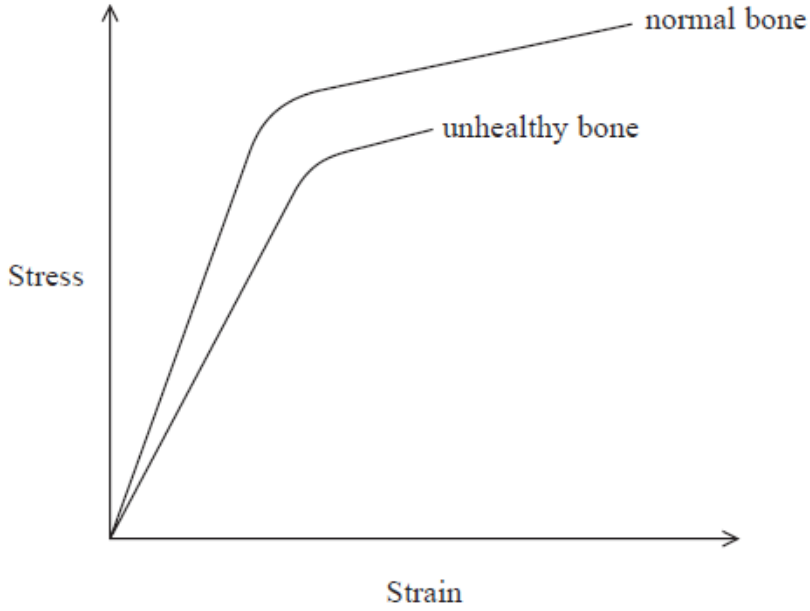
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(Total for question = 10 marks)

Q18.

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)

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(Total for question = 3 marks)

Q19.

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)

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(ii) The rope extends by 2.5 cm when used as shown.

Calculate the energy stored within the rope.

(2)

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Energy stored = ...

(iii) State one assumption made in this calculation.

(1)

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(Total for question = 9 marks)

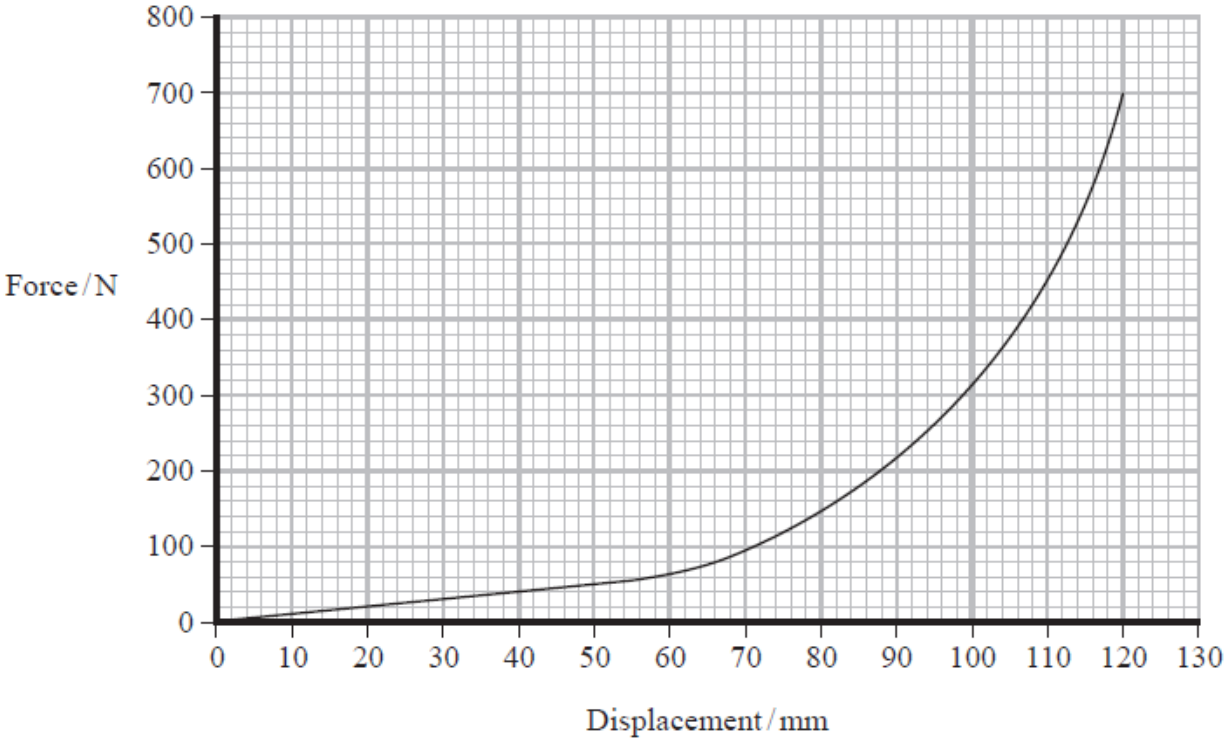
Q20.

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)

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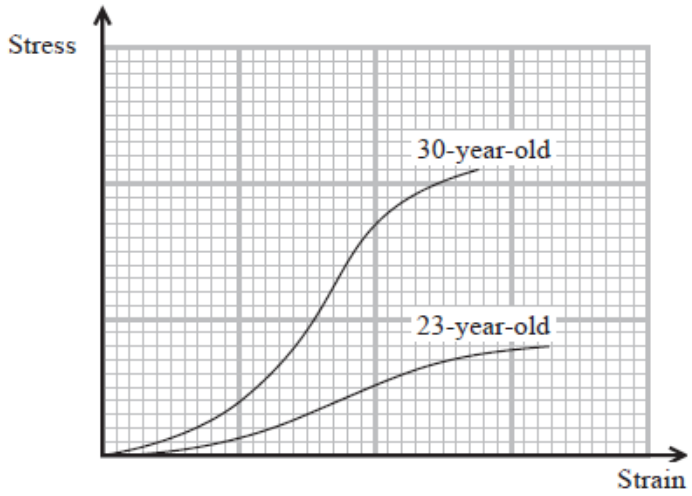
Spring constant = ...

(Total for question = 2 marks)

Q1.

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)

Q2.

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)

Q3.

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.

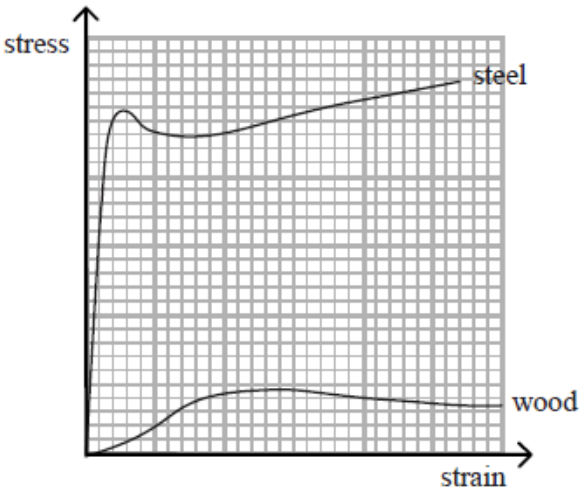
Whereas height remains one of the best ways to attain intense speeds, a coaster car can also be shot from its starting point via electromagnetic propulsion or a catapult. Cars on these launched coasters have the potential to go from zero to 130 km h^{-1} in two seconds.

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.

(5)

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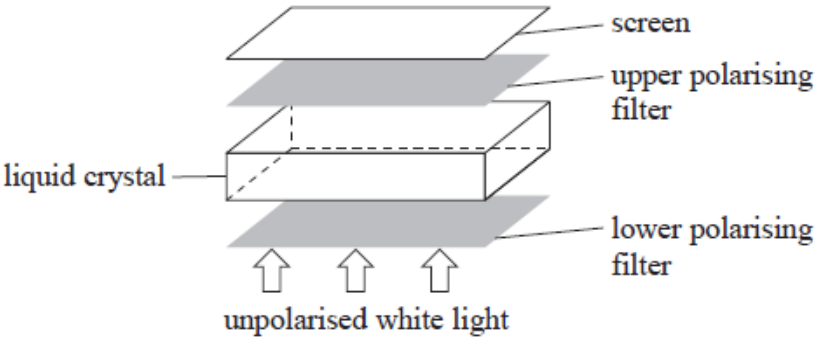
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(Total for question = 5 marks)

Q4.

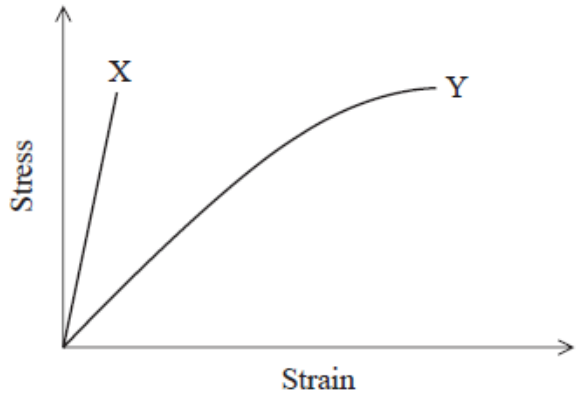
A liquid-crystal display uses a series of segments to form letters and numbers on a screen.

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.

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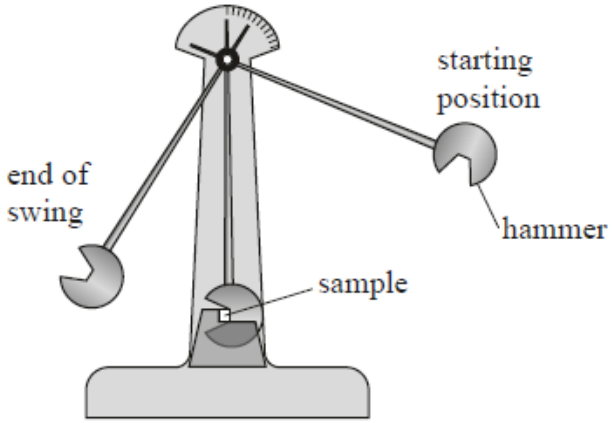
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(Total for question = 4 marks)

Q5.

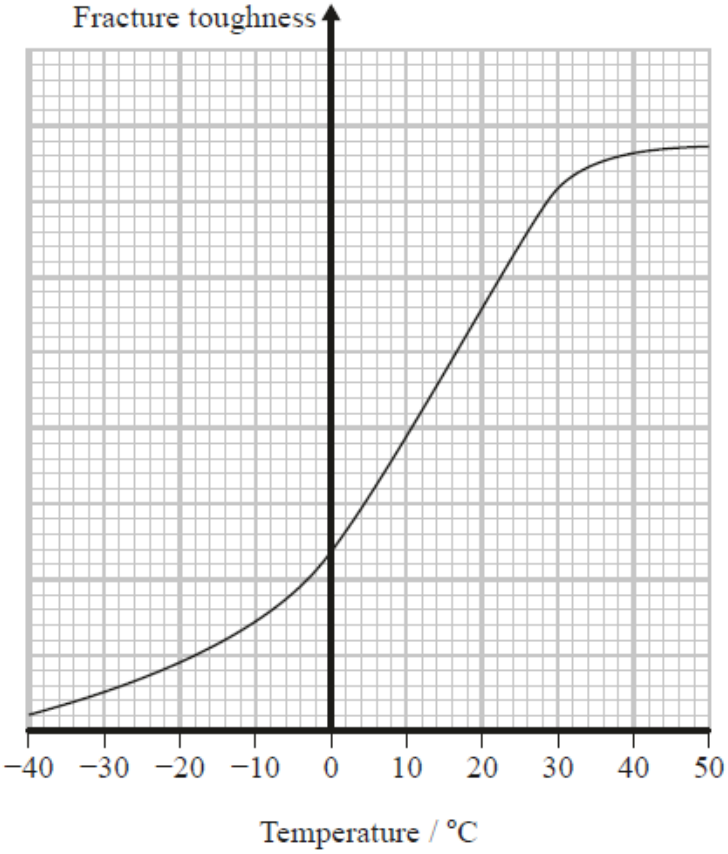
Read the passage and answer the questions below.



(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.

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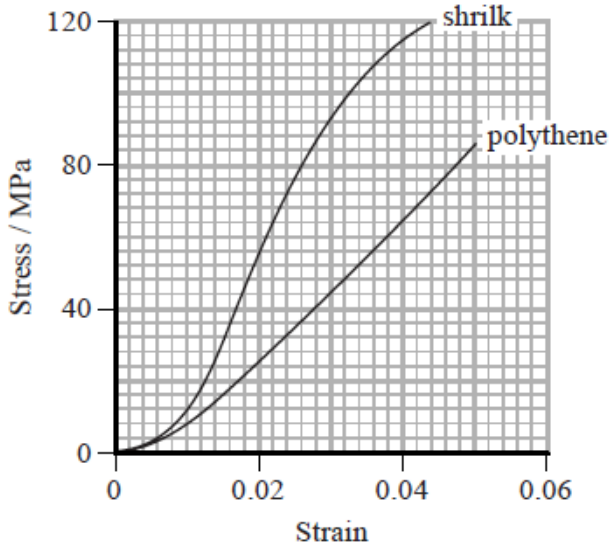
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(Total for question = 3 marks)

Q6.

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)

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Force = ...

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

(2)

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Extension = ...

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

(3)

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(Total for question = 8 marks)

Q7.

In 2010, Andre Geim and Konstantin Novoselov were awarded the Nobel Prize in Physics for producing, identifying and studying graphene.

Graphene is a form of carbon which exists only as a single atomic layer of graphite. It has a breaking stress of 130 GPa compared to 0.5 GPa for steel. Some scientists claim that graphene is the strongest material ever measured.

(a) Explain why graphene, despite its greater strength, is unlikely to replace steel in many applications.

(2)

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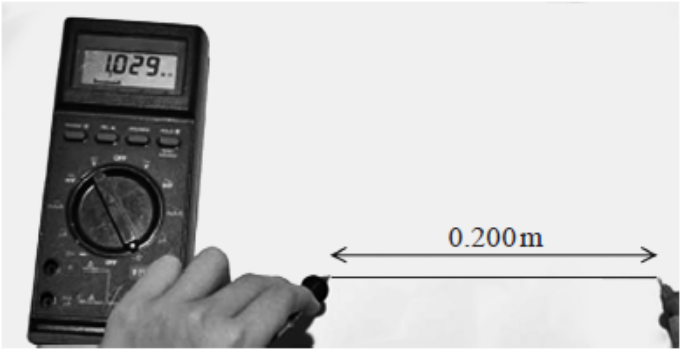
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(b) Graphite used in pencils consists of many layers of carbon. It can be assumed that a pencil

deposits approximately 100 layers of carbon atoms when drawn across a piece of paper.

A student carried out an experiment to determine the resistivity of the graphite in a pencil.

A line of length 0.200m and width 0.50mm was drawn on a piece of paper. An ohmmeter was then used to measure the resistance of the graphite line.



Calculate the resistivity of graphite.

resistance = $1.029 \times 10^{6}\ \Omega$
diameter of carbon atom = 1.4×10^{-10} m

(4)

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Resistivity of graphite = ...

(c) Photocells traditionally use silicon to generate electricity using visible light. Research demonstrates that unlike silicon, graphene is able to respond at all wavelengths and releases multiple electrons as it absorbs one photon.

Deduce why it would be an advantage to use graphene in photocells to generate electricity.

(3)

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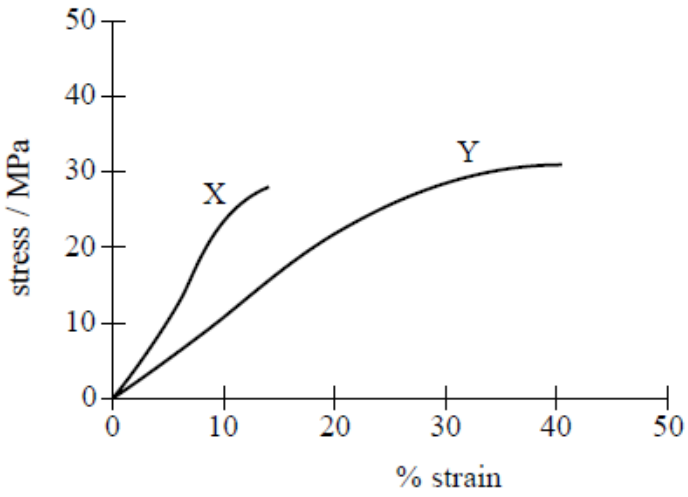
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(Total for question = 9 marks)

Q8.

The graph shows the behaviour of two materials when placed under stress.



We can conclude from the graph that

☒ **A** material X is stiffer and stronger than material Y.

☒ **B** material Y is stiffer and stronger than material X.

☒ **C** material X is stiffer but weaker than material Y.

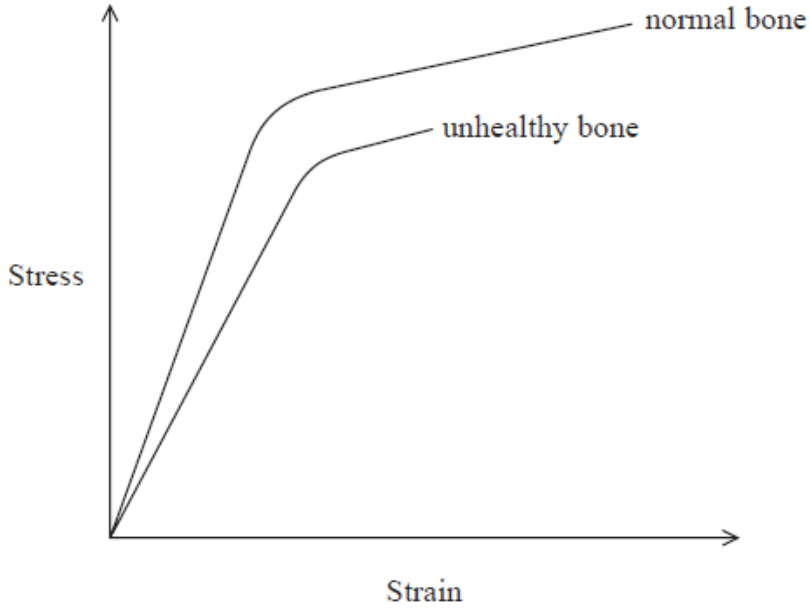
☒ **D** material Y is stiffer but weaker than material X.

(Total for question = 1 mark)

Q9.

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)

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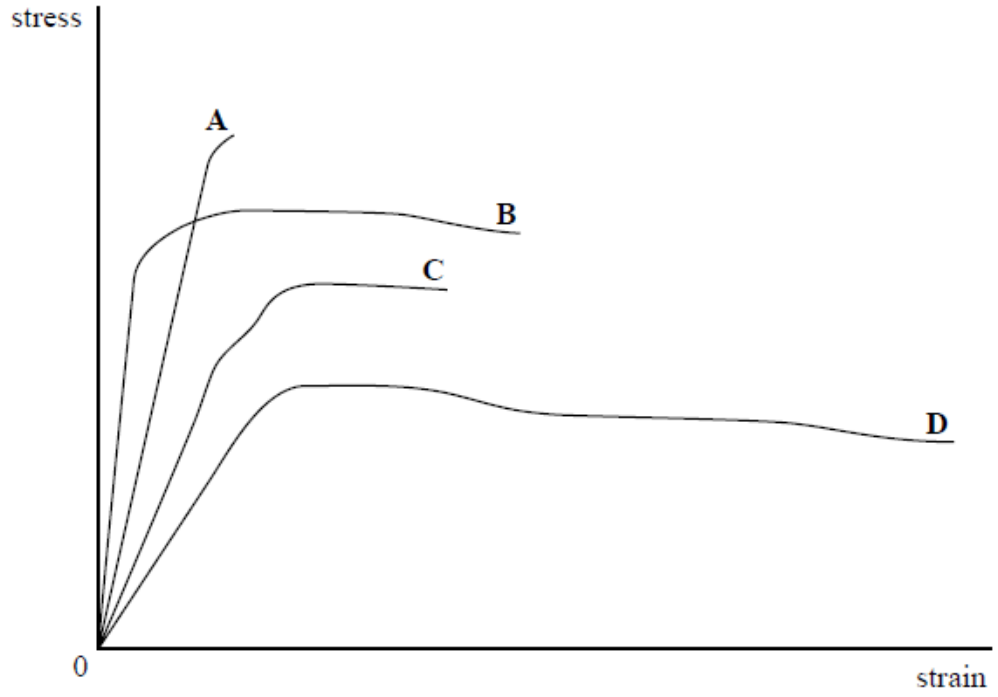
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(Total for question = 3 marks)

Q10.



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)

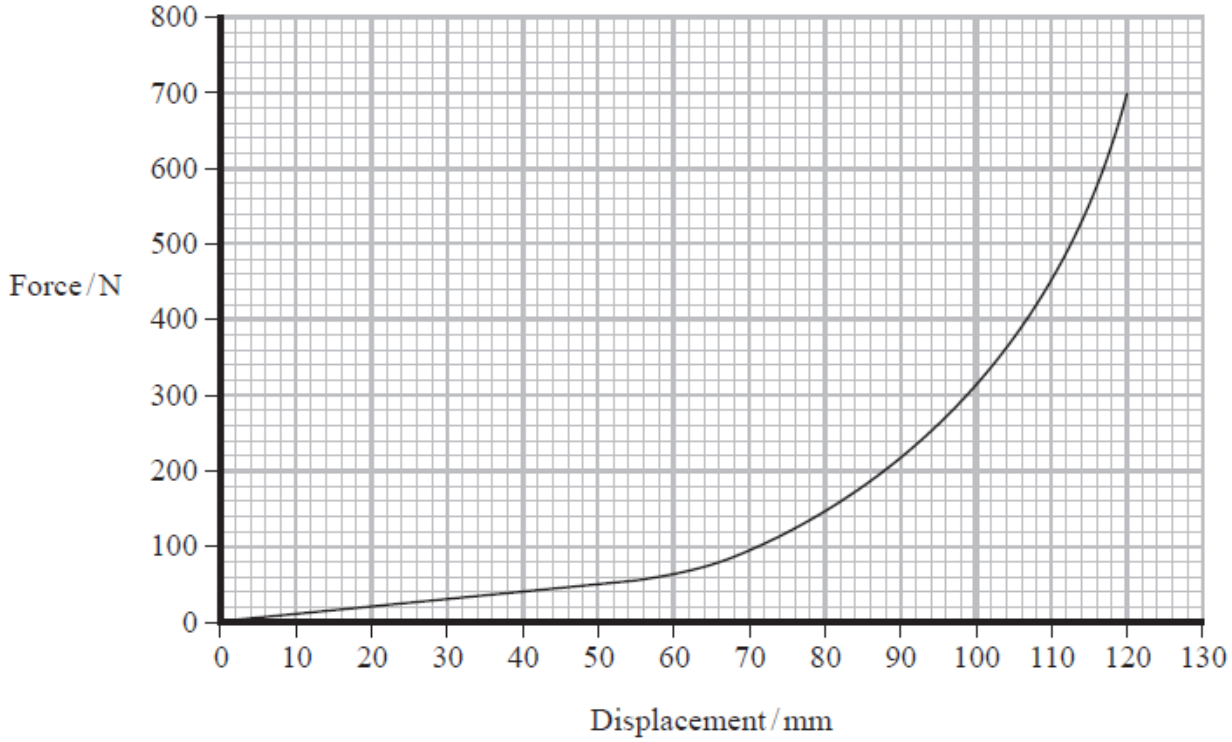
Q1.

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)

Q2.

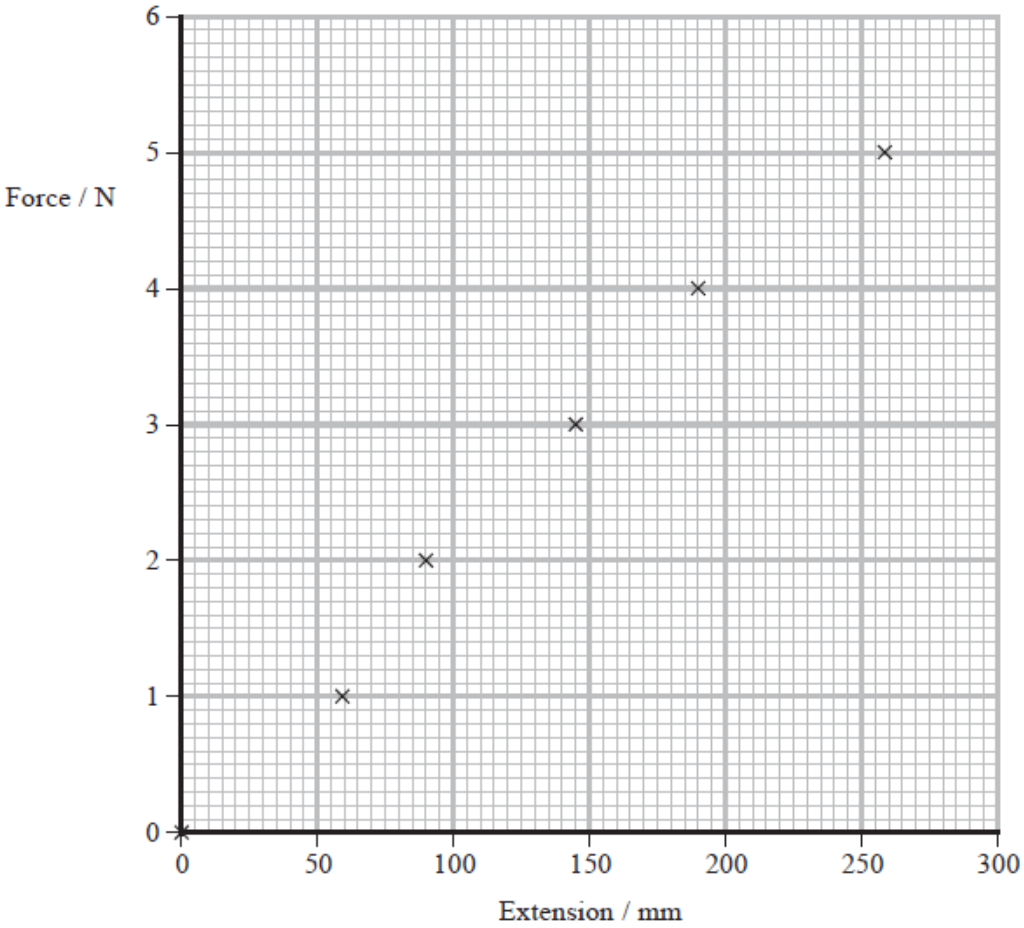
A manufacturer gives the following information about a spring.

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%
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.



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

(6)

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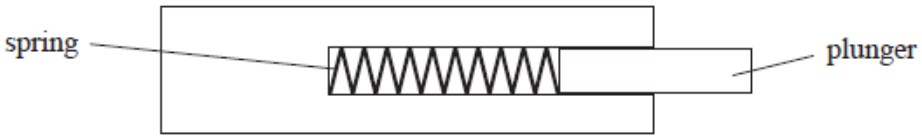
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(Total for question = 6 marks)

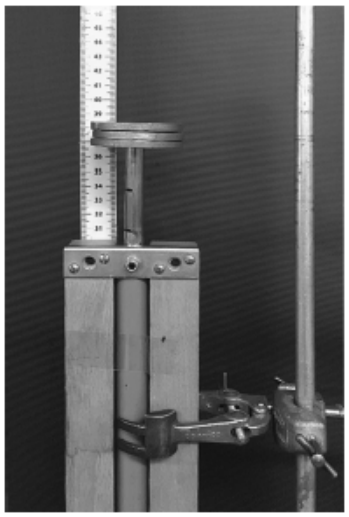
Q3.

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.

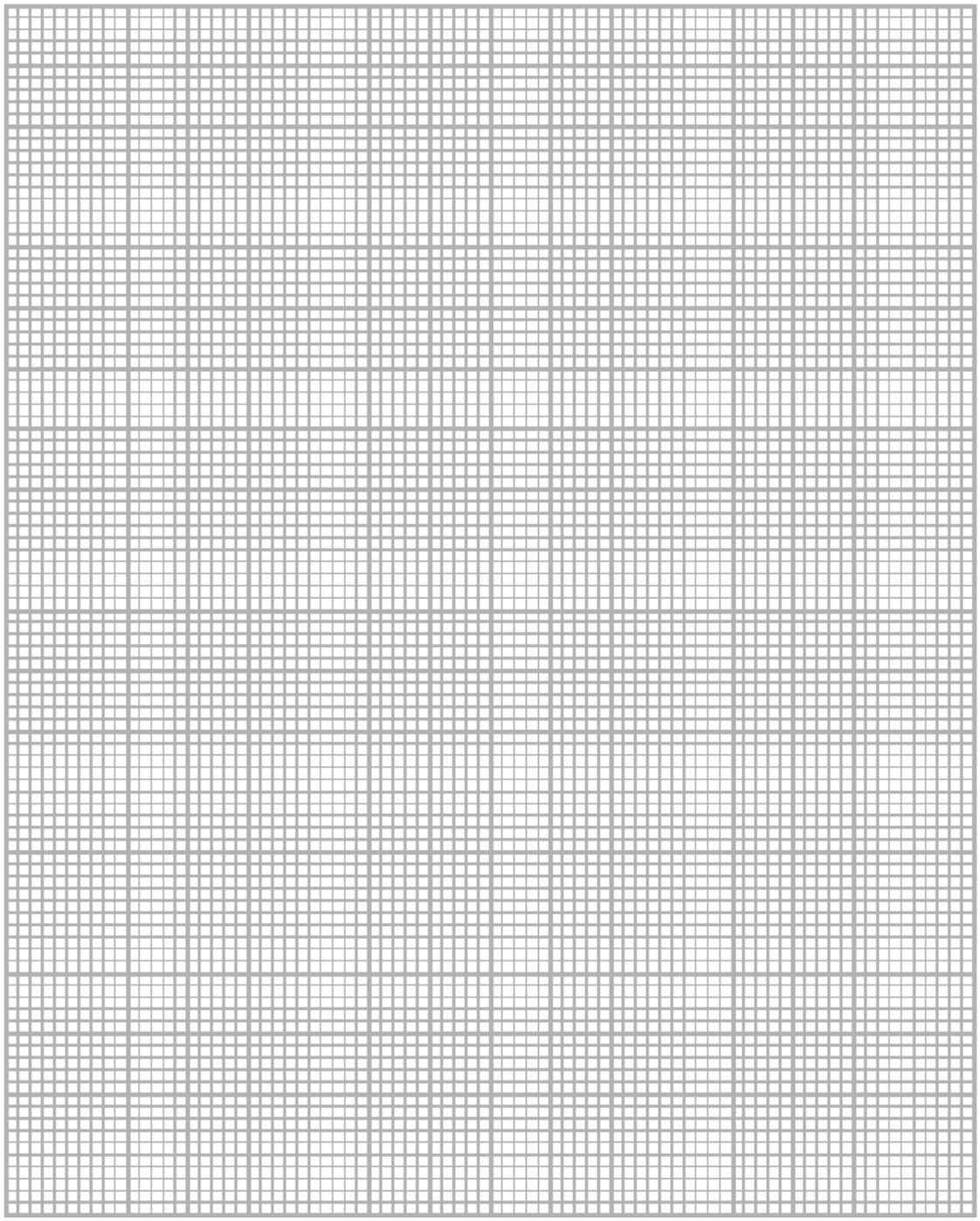


The recorded results are shown in the table.

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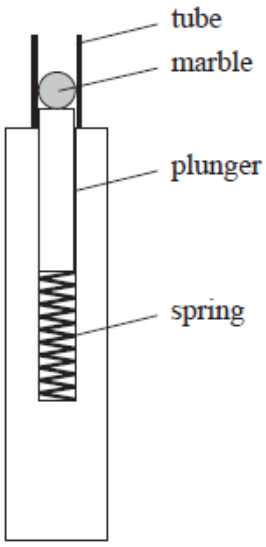
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(b) Another trolley was adapted by placing a tube around the plunger so that it could be used to launch marbles. A marble was placed in the tube while the plunger was depressed. When the plunger was released it launched the marble.



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)

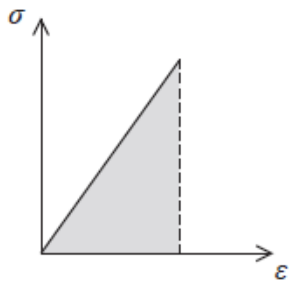
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(Total for question = 14 marks)

Q4.

A force was applied across the ends of an iron bar. The following stress-strain graph was obtained.



The shaded area represents

☒ **A** $\frac{\text{work done}}{2 \times \text{volume}}$

☒ **B** $\frac{\text{work done}}{\text{volume}}$

☒ **C** $\frac{2 \times \text{work done}}{\text{volume}}$

☒ **D** work done

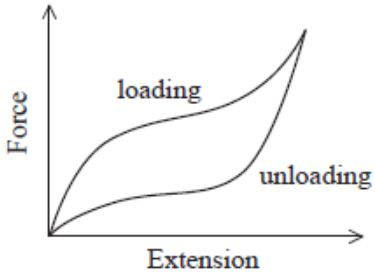
(Total for question = 1 mark)

Q5.

* 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)

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(Total for question = 6 marks)

Q6.

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)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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 $2F$ is applied to a spring with stiffness $2k$?

☐ **A** $\frac{E}{2}$

☐ **B** E

☐ **C** $2E$

☐ **D** $8E$

(Total for question = 1 mark)

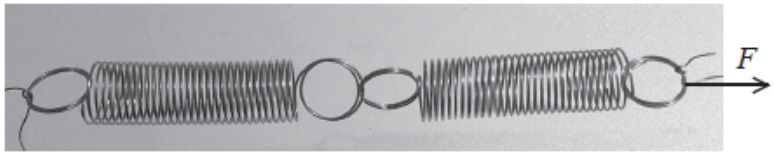
Q8.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

Q9.

A spring obeys Hooke's law. A force of 2.0 N extends the spring by 0.30 m.

The energy stored in the spring when a force of 2.0 N is applied is

☒ **A** 0.09 J

☒ **B** 0.30 J

☒ **C** 0.60 J

☒ **D** 0.90 J

(Total for question = 1 mark)

Q10.

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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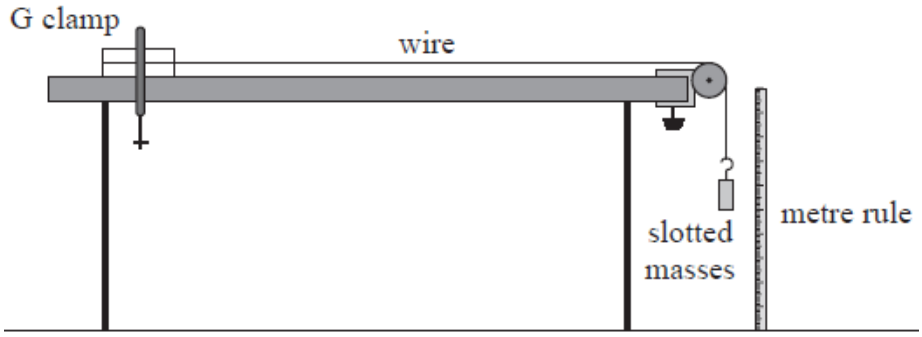
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Energy stored = ...

(Total for question = 2 marks)

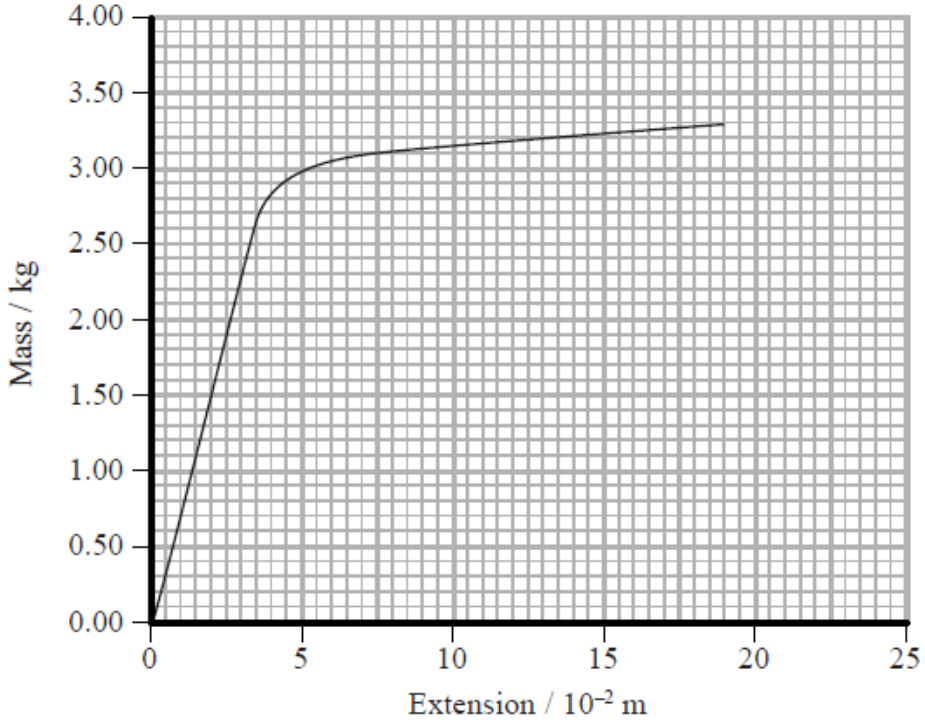
Q11.

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.

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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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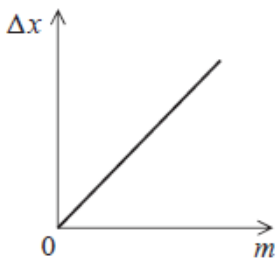
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(Total for question = 10 marks)

Q12.

A spring is hung vertically and masses are added to the lower end.
The graph shows how the extension Δx 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)

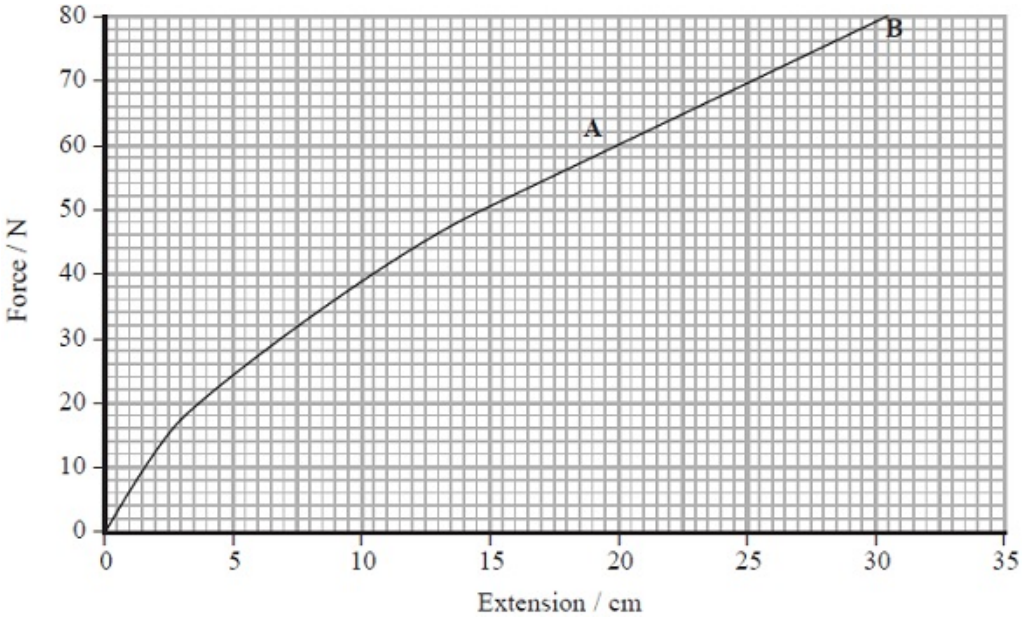
Q13. The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.





A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

(2)

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(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

(2)

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(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

	A	B	C	D
1	Total stretching force / N	Extension / cm	Change in extension / m	Work done (force × change in extension) / J
2	0	0.0	0.000	0.00
3	10	1.6	0.016	0.16
4	20	3.5	0.019	0.38
5	30	7.0	0.035	1.05
6	40	10.5	0.035	1.40
7	50	14.5	0.040	2.00
8	60	20.0	0.055	3.30
9	70	25.2	0.052	3.64
10	80	30.5	0.053	4.24
11			Total work done	16.17

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

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(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

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Time = ...

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

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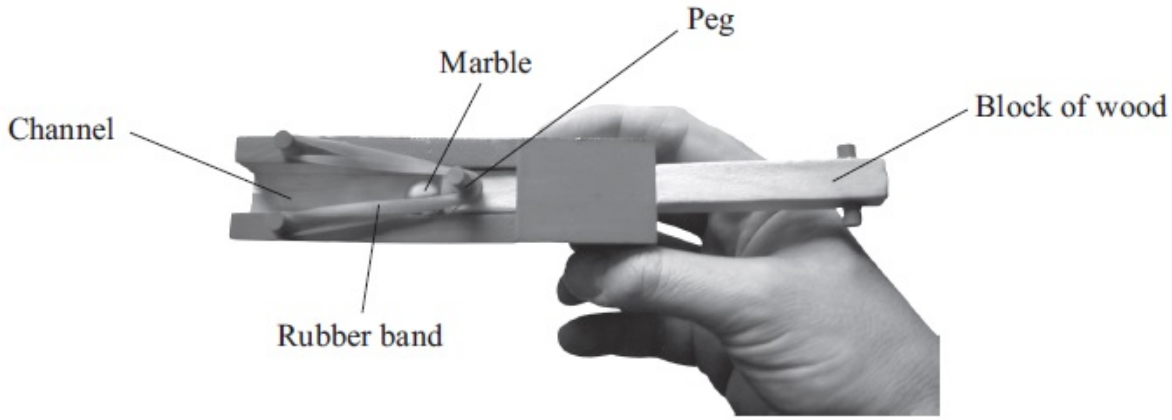
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(Total for Question = 11 marks)

Q14.

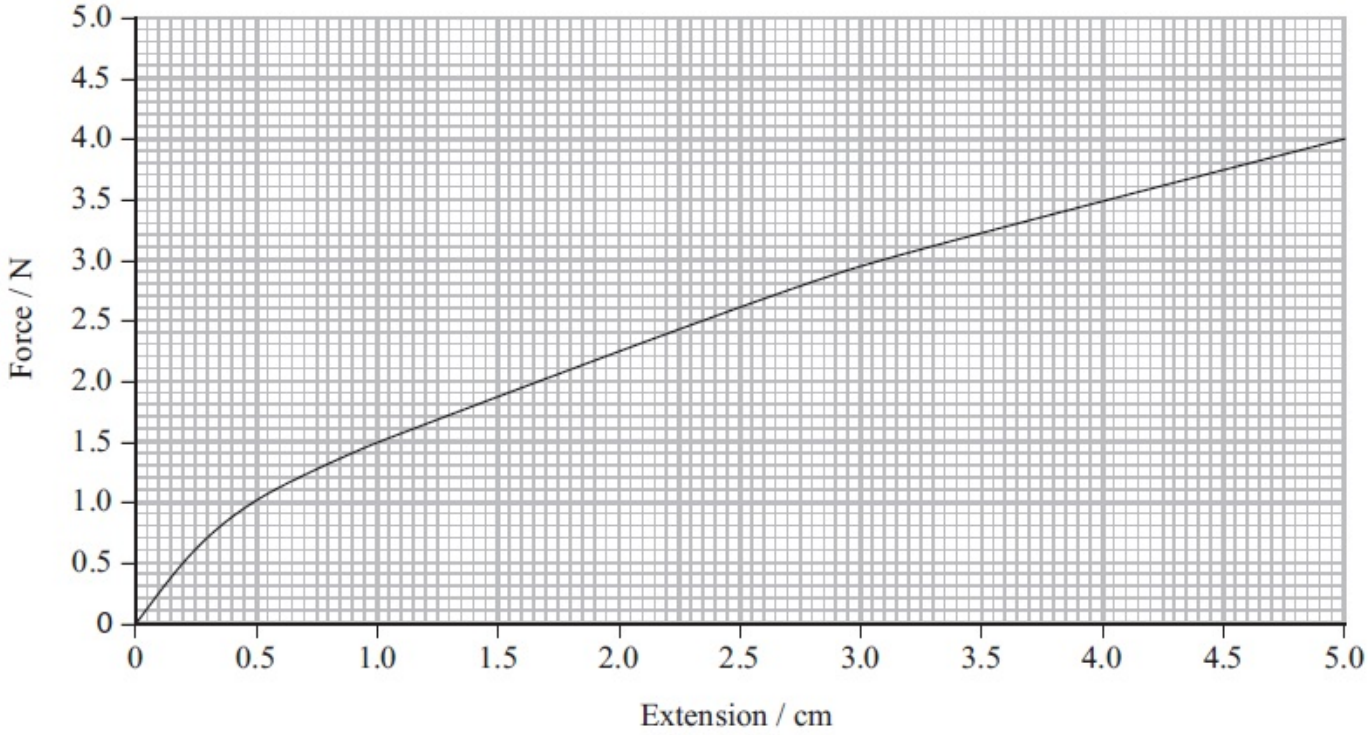
The photograph shows a marble launcher.



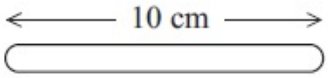
To load: pull the block of wood backwards, stretching the rubber band, place a marble into the channel.

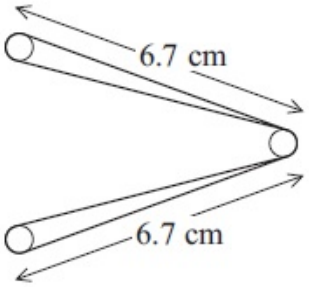
To launch: release the block so it is pulled forward by the rubber band, pushing the marble through the channel.

(a) The graph shows the results of an experiment to investigate the properties of the rubber band.



(i) The diagram shows the arrangement of the rubber band when it is stretched ready to launch a marble. The unstretched length of the rubber band is 10 cm.





Unstretched rubber band

Stretched rubber band

Use the graph to show that the tension is about 3 N.

(2)

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(ii) A student uses the graph to obtain an approximate value of the energy stored before launching. Show that 0.06 J is a reasonable approximate value.

(2)

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(iii) The student launches the marble vertically in order to determine the energy transferred to it when it is launched. Show that the maximum possible height attainable is about 2 m.

mass of marble = 3.8 g

(2)

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(b) The student obtains the following set of measurements for the height reached.

30.0 cm, 30.3 cm, 25.8 cm, 29.7 cm

(i) Explain why the student obtained a value of 30.0 cm for the height reached.

(2)

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(ii) Explain why the height reached is so much less than 2 m.

(2)

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(iii) Suggest how the marble launcher could be adapted so that the height reached by the marble could be increased.

(1)

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(Total for question = 11 marks)

Q15.

A metal wire is stretched elastically. The area under the force-extension graph for this process is equal to the

☒ **A** breaking stress of the wire.

☒ **B** elastic limit of the wire.

☒ **C** elastic strain energy in the wire.

☒ **D** Young modulus of the metal.

(Total for question = 1 mark)

Q16.

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)

Q17.

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)

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(ii) The rope extends by 2.5 cm when used as shown.

Calculate the energy stored within the rope.

(2)

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Energy stored = ...

(iii) State one assumption made in this calculation.

(1)

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(Total for question = 9 marks)

Q18.

A spring with a spring constant 140 Nm^{-1} is extended. The elastic potential energy stored is 1.6 J

The extension of the wire is found using

☒ **A** $\frac{1.6}{140}$

☒ **B** $\frac{2 \times 1.6}{140}$

☒ **C** $\sqrt{\frac{1.6}{140}}$

☒ **D** $\sqrt{\frac{2 \times 1.6}{140}}$

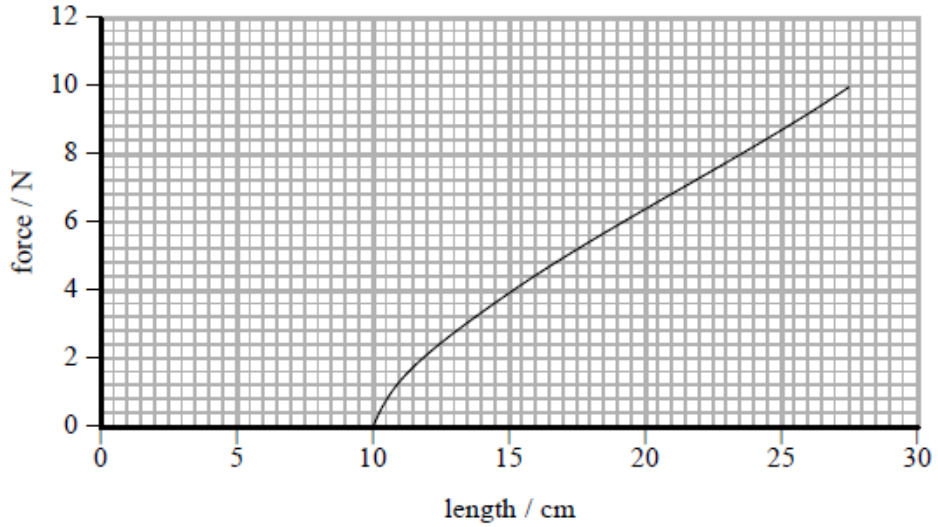
(Total for question = 1 mark)

Q19.

The photograph shows a toy that fires rubber bands.



A student investigates the properties of one of the rubber bands and obtains the following graph.



(a) The student wants to determine the mass of one of the rubber bands. He places five rubber bands on a balance and obtains a reading of 2 g. He divides the reading on the balance by five to determine the mass of one rubber band.

Explain how he could improve his result.

(3)

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(b) The rubber band is stretched by 17.4 cm when it is placed on the toy.

Show that the work done on the rubber band is about 1 J.

(3)

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(c) Calculate the maximum possible value for the initial velocity of the rubber band as it is fired from the toy. Assume the mass of a rubber band is 0.4 g.

(2)

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Maximum initial velocity = ...

(d) The student thinks the calculated value of maximum velocity is too high because the band does not travel as far as expected.

Explain how the student could determine the initial velocity with the use of a video camera and why light gates would not be suitable.

(4)

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(Total for question = 12 marks)

Q20.

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 work done on the spring.

(2)

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Work done = ...

(Total for question = 2 marks)