Questions

Q1.

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 compressive force F is applied to an object made of a material with Young modulus E. The original length of the object in the direction of the force is x, and its cross-sectional area is A.

Which expression gives the length of the object after the force is applied?

☒ **A** $x - \frac{AE}{Fx}$

☒ **B** $x + \frac{Fx}{AE}$

☒ **C** $x + \frac{AE}{Fx}$

☒ **D** $x - \frac{Fx}{AE}$

(Total for question = 1 mark)

Q2.

When an increasing force is applied to a steel cable it will eventually reach its elastic limit.

(a) State what is meant by the elastic limit.

(1)

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(b) The elastic limit of a steel cable was reached when a force of 13.4 × 106 N was applied. The extension of the cable was 0.126 m.

length of cable = 6.00 m cross-sectional area of cable = 9.60 × 10-3 m^2

(i) Calculate the strain of the cable at its elastic limit.

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Strain = ...

(ii) Calculate the stress in the cable at its elastic limit.

(2)

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Stress = ...

(Total for question = 5 marks)

Q3.

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 student applies a force to a copper wire.

Which row of the table shows the length and diameter of wire that would produce the greatest extension?

		Length of wire	Diameter of wire
☒	**A**	x	D
☒	**B**	x	$2D$
☒	**C**	$2x$	D
☒	**D**	$2x$	$2D$

(Total for question = 1 mark)

Q4.

The stiffness constant and the Young modulus are terms used in physics.

Which row of the table shows the correct application of these terms?

	Stiffness constant applies to	Young modulus applies to
☒ **A**	materials	materials
☒ **B**	objects	objects
☒ **C**	materials	objects
☒ **D**	objects	materials

(Total for question = 1 mark)

Q5.

One end of a 50 cm length of wire is attached to a support. A load is attached to the free end of the wire, which extends by 2 mm.

Which of the following is the strain for the length of wire?

☒ **A** 0.004

☒ **B** 0.04

☒ **C** 25

☒ **D** 250

(Total for question = 1 mark)

Q6.

Select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A wire breaks when a tensile force T is applied. A second wire, made of the same material, has twice the diameter.

Which of the following is the force required to break the second wire?

☒ **A** $4T$

☒ **B** $2T$

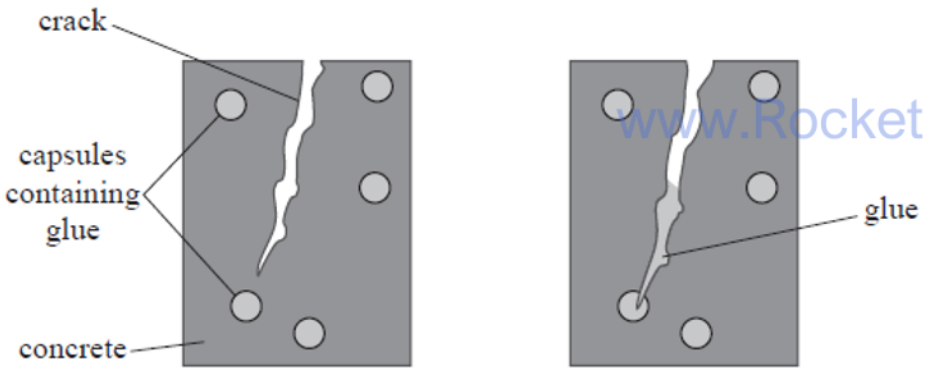
☒ **C** $\frac{T}{2}$

☒ **D** $\frac{T}{4}$

(Total for question = 1 mark)

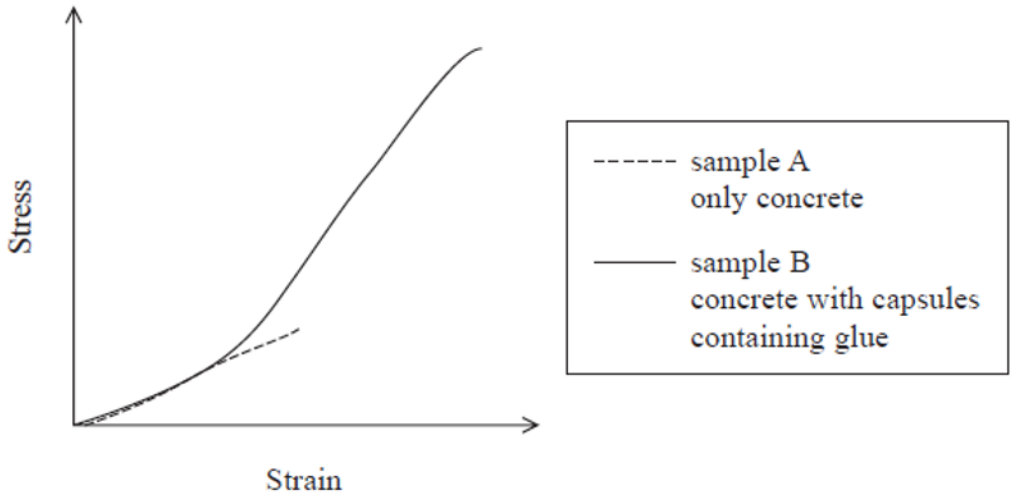
Q7.

When concrete is placed under stress, cracks may form. Scientists are investigating ways to prevent cracks from spreading through the concrete. One way to do this is by adding very small capsules containing glue to the concrete mix. As a crack spreads through the concrete, some capsules break, releasing glue which fills the crack, as shown.



Two samples of concrete, of identical size, were placed under stress. Sample A consisted of concrete only, Sample B consisted of concrete with capsules containing glue.

The stress-strain graphs for the samples up to the maximum stress before fracture are shown.



Explain how adding capsules containing glue changes the properties of the concrete.

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(Total for question = 6 marks)

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 student applied a tensile force to a metal wire of length x and diameter d.

The length of the wire increased by Δx.

The student applied the same force to a second wire made of the same material.

The length of the second wire increased by $2\Delta x$.

Which row of the table could show the length and diameter of the second wire?

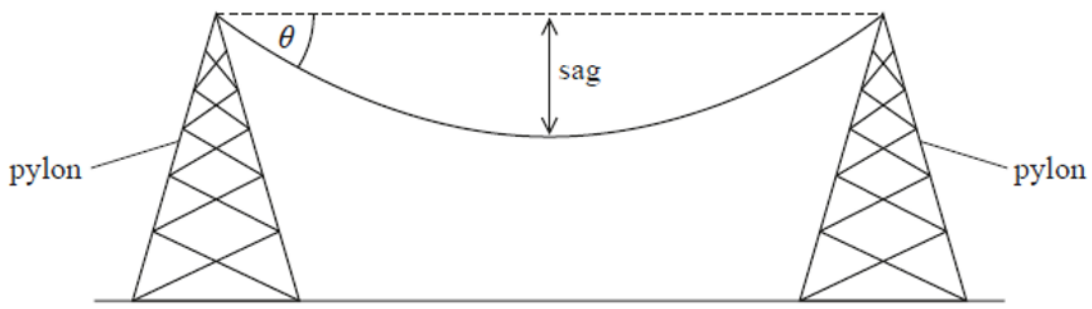
		Length	Diameter
☒	**A**	$0.5x$	$0.5d$
☒	**B**	$0.5x$	$2d$
☒	**C**	$2x$	$0.5d$
☒	**D**	$2x$	$2d$

(Total for question = 1 mark)

Q9.

The transmission of electricity over long distances requires a conducting cable that is suitable to hang from supporting towers called pylons.

The vertical distance from the line of support to the lowest point on the wire is called the sag. Due to the high voltages involved, the cable must maintain a minimum distance from the ground.



(a) The temperature and the tension in the cable affect the sag.

(i) Suggest one further factor that may increase the sag of a cable.

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(ii) A cable of mass M is at an angle θ to the horizontal.

Explain why the tension in the cable decreases as the sag increases.

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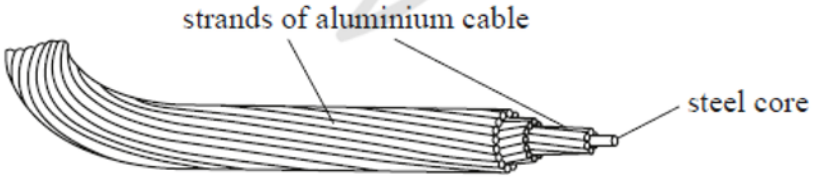
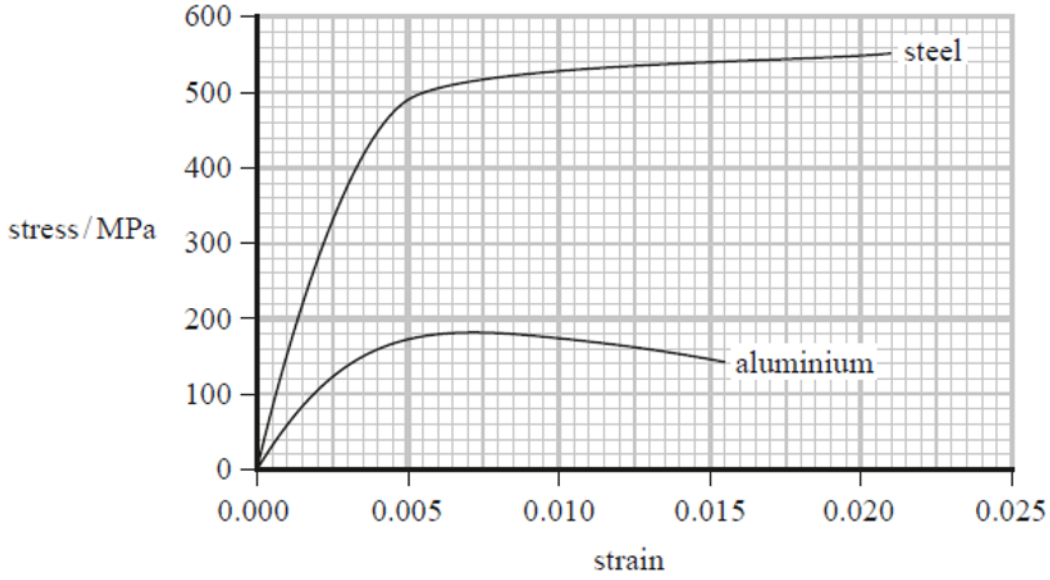
(b) A type of conducting cable used in overhead power lines is ACSR. This cable has a steel core surrounded by strands of aluminium cable of the same diameter.



Stress-strain graphs for samples of steel and aluminium typically used in each strand of the cable are shown.



(i) Show that the Young modulus of steel is about 2×10^{11} Pa.

(2)

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(ii) The pylons are positioned every 270 m.

Show that the stress in a strand of steel is about 70 MPa.

(2)

cross-sectional area of one strand = 2.3×10^{-6} m^2
tension per m for steel = 0.62 N m^{-1}

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(iii) ACSR cables consist of a steel core surrounded by strands of aluminium cable.

The extension produced, due to the tension, for each strand of aluminium is 0.95 m.

Comment on why ACSR cables consist of both a steel core and strands of aluminium cable. You should include a calculation as part of your answer.

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(Total for question = 11 marks)

Q10.

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 sample of a material is in the form of a wire. The material has a large value of the Young modulus.

Which of the following statements best describes the material?

☒ **A** A large force per unit cross-sectional area is required to break the wire.

☒ **B** The mass per unit volume is large.

☒ **C** The ratio of tensile stress to tensile strain is large.

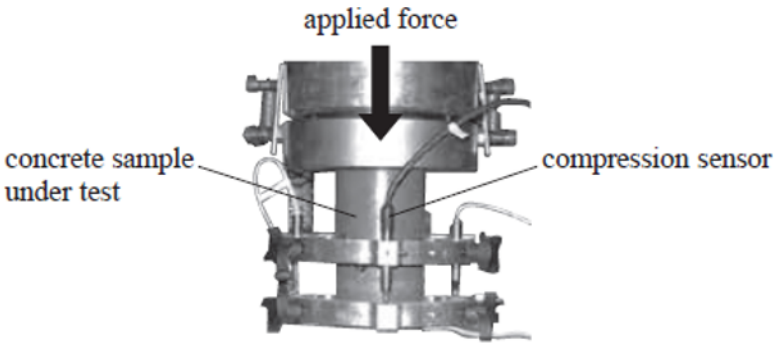
☒ **D** After removing a large stress the sample returns to its original length.

(Total for question = 1 mark)

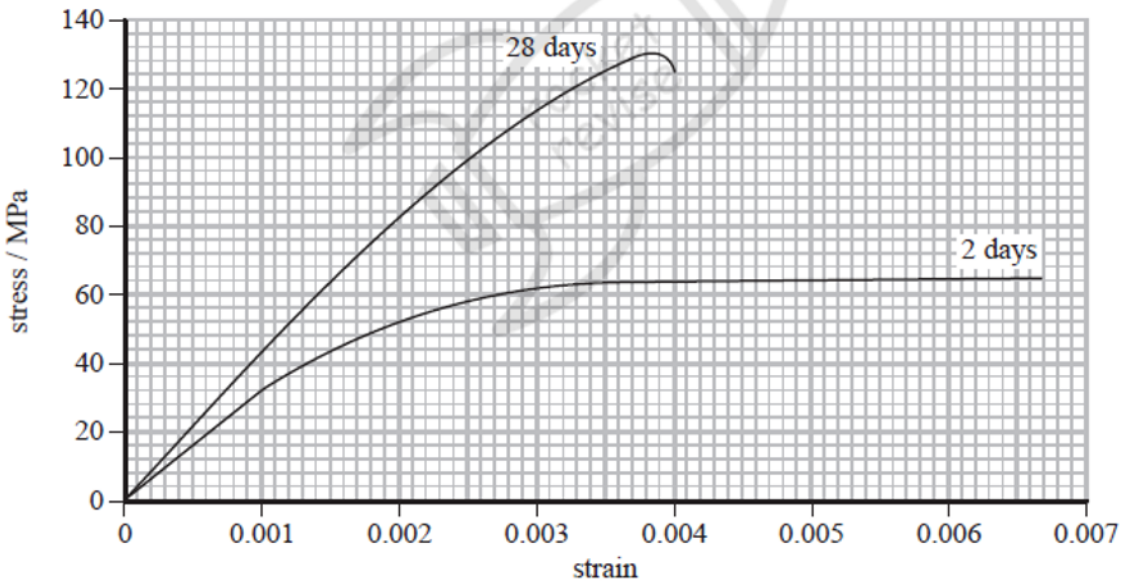
Q11.

When concrete is first made it has a high moisture content. As the concrete dries its properties change.

A manufacturer of concrete carried out compression testing of cylindrical samples of concrete using the equipment shown.



The diagram shows stress-strain graphs, up to the fracture point, for concrete samples 2 days and 28 days after being made.



(a) As the concrete dries its Young modulus increases.

Show that the value for the Young modulus of the concrete after it has dried is at least 1.3 times greater.

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(b) The energy absorbed before fracture by the 28-day old sample is less than the energy absorbed before fracture by the 2-day old sample.

The area under a stress-strain graph gives the energy absorbed per unit volume of the sample.

The energy absorbed before fracture by the 2-day old sample is 0.35 MJ m^{-3}.

Determine the percentage reduction in the energy absorbed before fracture between the 2-day old and the 28-day old samples.
You may assume that the volumes of the cylindrical samples are the same.

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(c) Manufacturers recommend leaving concrete blocks to dry for at least 28 days before use.

Discuss why.

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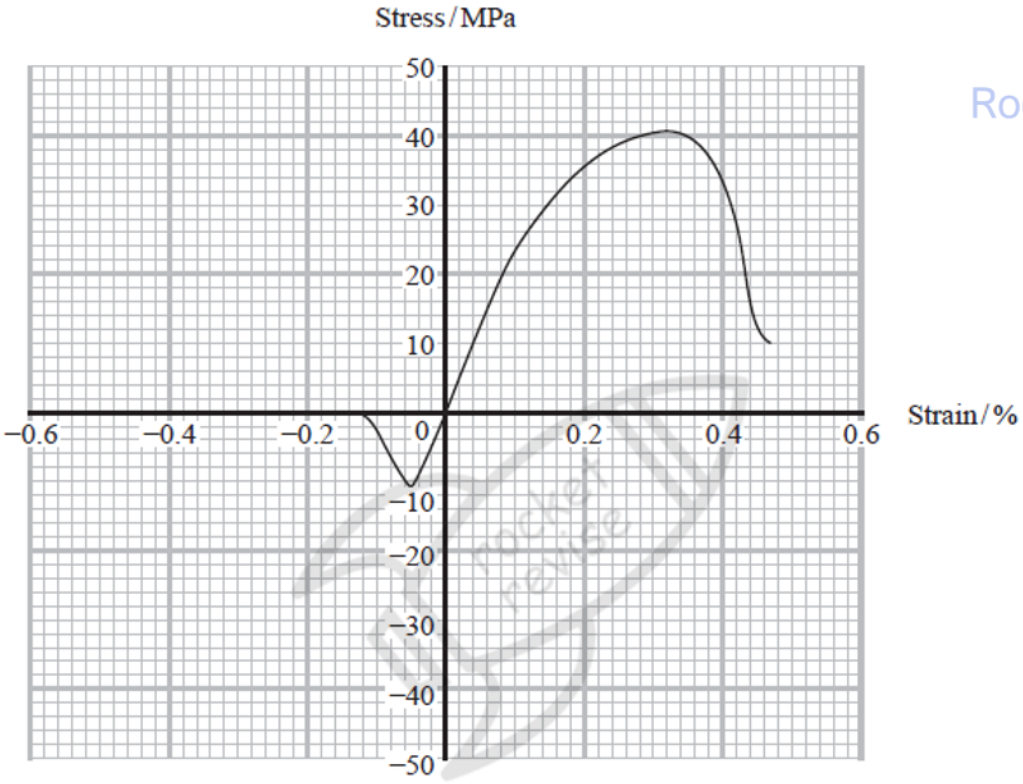
(Total for question = 10 marks)

Q12.

Concrete is a material often used for building.

A stress-strain graph for one type of concrete is shown. Positive values of strain represent compression and negative values of strain represent tension.



(a) Explain how the stress-strain graph shows that concrete is more suitable for use under compression than under tension.

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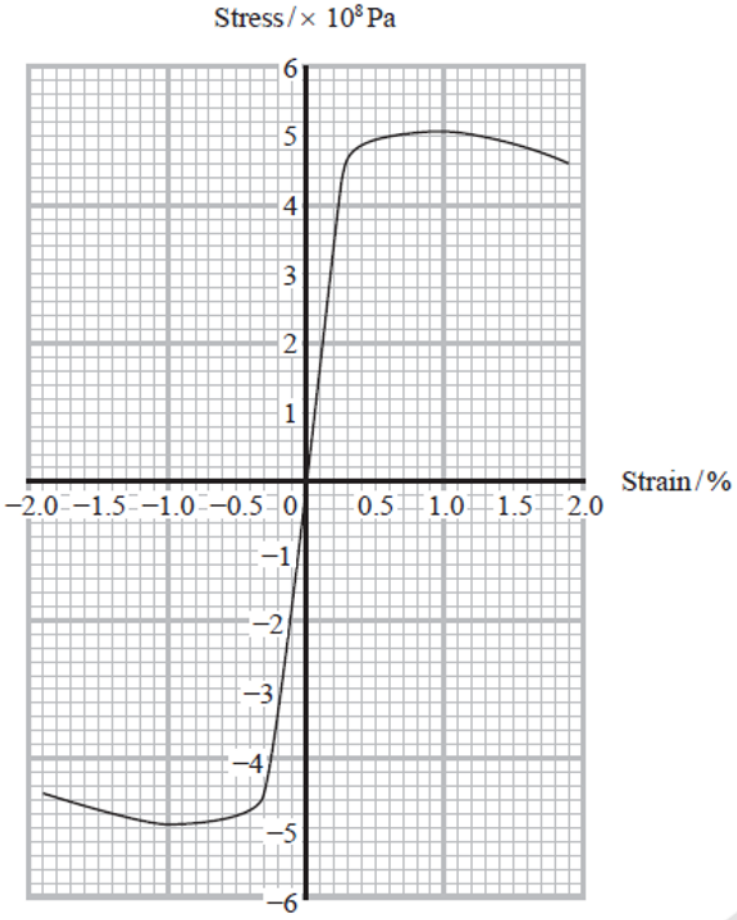
(b) Steel is a metal often used in building. The stress-strain graph for steel is shown.



A steel rod has a diameter of 45 mm.

Calculate the maximum force that could be applied to the steel rod before it fractures.

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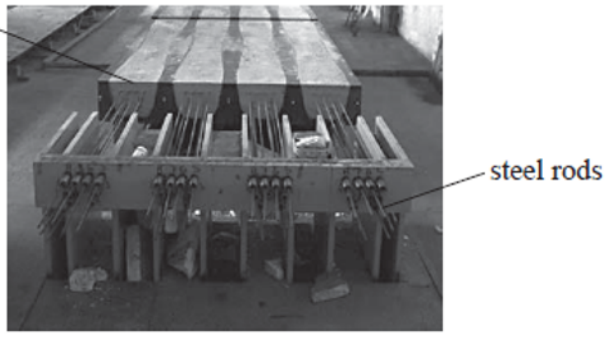
Maximum force = ...

(c) To make concrete suitable for use under large forces steel rods are sometimes embedded in the concrete.

An external tensile force is applied to the steel rods. Concrete is poured into a mould around the rods. Once the concrete has set the external force is removed from the steel rods, placing the concrete in compression.



Source: www.designingbuildings.co.uk

(i) Explain how this process increases the maximum tensile force that the concrete can withstand before fracture.

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(ii) Explain why the external tensile force in the rods must not take the steel beyond its elastic limit.

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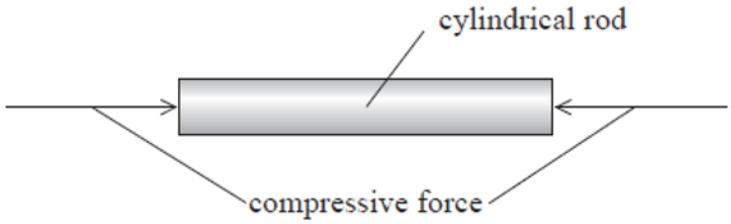
(Total for question = 11 marks)

Q13.

An engineer is designing a metal part for a machine. The part is in the form of a cylindrical rod. The part is designed to behave elastically when compressive forces are applied, as shown.



(a) State what is meant by elastic deformation.

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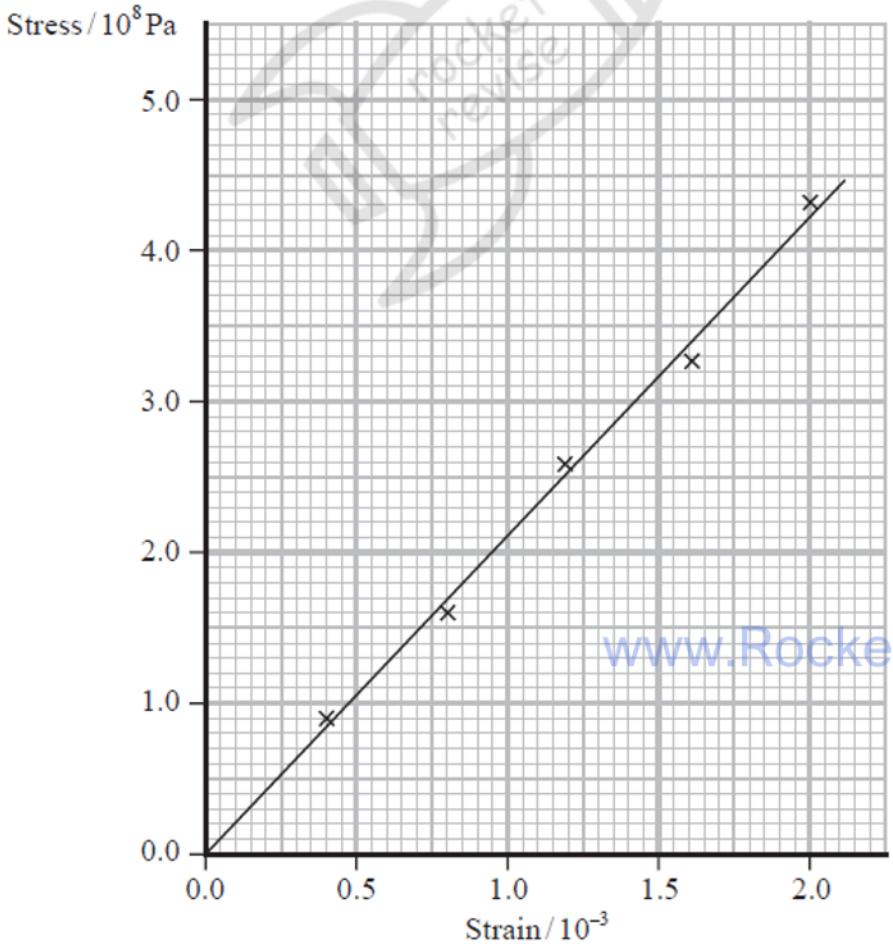
(b) A compressive stress-strain graph for one metal is shown.



(i) Show that the Young modulus for this metal is about 2×10^{11} Pa.

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(ii) The metal part must not compress more than 0.60 mm when a force of 9.5×10^5 N is applied.

Deduce whether this metal is suitable for the part.

length of part = 0.84 m
cross-sectional area of part = 4.8×10^{-3} m^2

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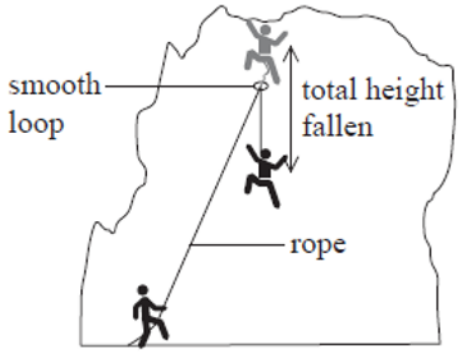
(Total for question = 7 marks)

Q14.

The diagram shows a climber on a rock face. A rope is kept firmly anchored by a person on the ground and passes through a smooth loop to the climber. The climber slips and falls a short distance as shown.

Diagram not to scale



(a) The 'fall factor' is used by climbers to estimate the severity of a climbing fall and is given by

$$\text{'fall factor'} = \frac{\text{height fallen before the rope begins to stretch}}{\text{total unstretched length of rope}}$$

A climber slips and falls with a 'fall factor' of 0.80 before coming to rest.
The energy from the fall is absorbed by the climbing rope.
The maximum strain in the rope is 9.0%.

(i) Show that the maximum force acting on the climber due to the rope is about 10 kN.

Assume the extension of the rope is proportional to its tension.

total unstretched length of rope = 15.0 m
mass of climber = 71 kg

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(ii) A new climber suggests using a longer length of rope between the loop and the climber, as this would absorb more energy after a fall.

Comment on this suggestion.

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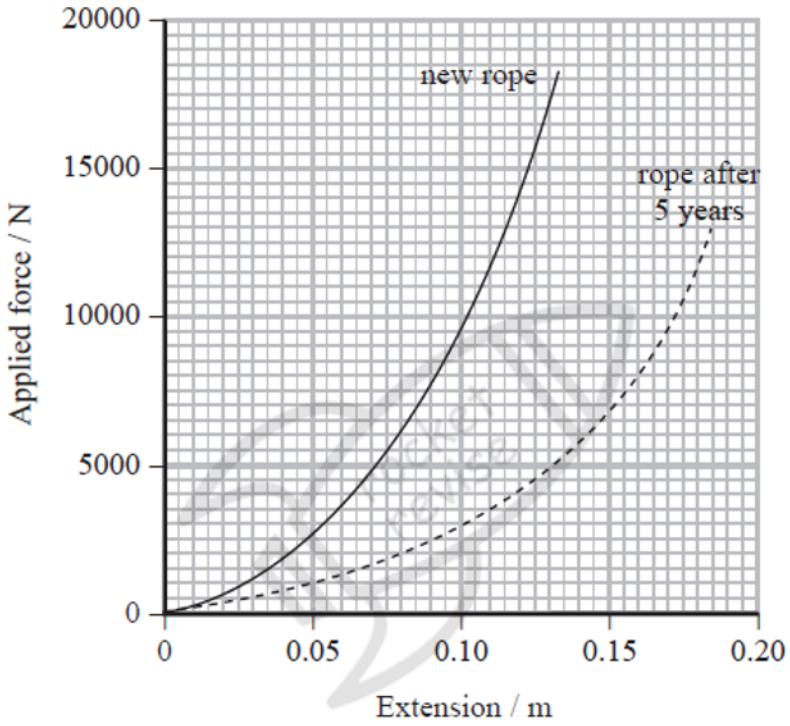
(b) Climbing rope manufacturers recommend that ropes are replaced every 5 years.

The force-extension graphs, up to the breaking point, for a one metre length of a rope when new and after 5 years are shown.



Comment on the manufacturers' recommendation. Your answer should include calculations.

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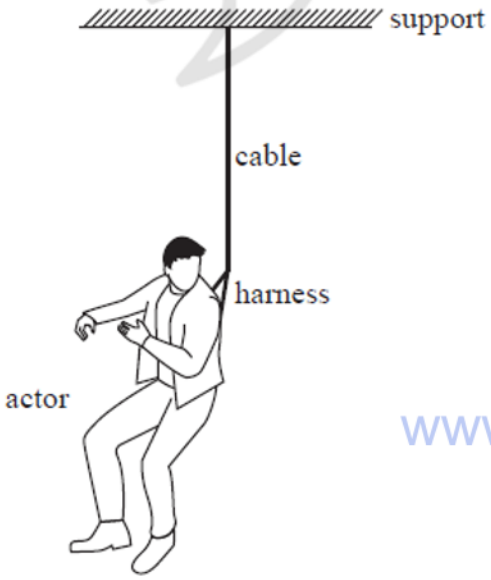
(Total for question = 13 marks)

Q15.

An actor is wearing a harness. The harness is connected to a cable and support, as shown.



(a) The force on the cable must not cause the material of the cable to reach its yield point.

State what is meant by the yield point of a material.

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(b) The cable and harness are used to accelerate the actor vertically off the ground.

(i) Explain why the forces acting on the actor cause him to accelerate upwards.

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(ii) The actor has a mass of 77 kg and is lifted vertically from the ground with an acceleration of 2.1 m s^{-2}.

Show that the tension in the cable is about 920 N.

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(iii) To make sure the actor is safe, the stress in the cable must be less than 15% of the yield point stress.

The cable has a yield point stress of 2.5×10^{8} Pa.

The diameter of the cable is 7.6×10^{-3} m.

Deduce whether it is safe to lift the actor with an acceleration of 2.1 m s^{-2}.

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(c) The original cable is replaced with a new cable made from a different material. This material has a lower Young modulus than the material used to make the original cable.

The new cable is the same length as the original cable but has a greater diameter.

The breaking stress is the same for both cables.

Explain how the work done to break the new cable is different from the work done to break the original cable. Assume that both materials obey Hooke's law up to the breaking point.

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(Total for question = 14 marks)

Q16.

A student carried out an experiment to determine the Young modulus of a sample of stainless steel in the form of a wire. The student added weights to the wire and measured the corresponding extensions.

The wire had an unstretched length of 2.6 m. The diameter of the wire was 5.6×10^{-4} m.

The student plotted a graph of weight against extension. The graph showed that the limit of proportionality was not exceeded.

(a) State what is meant by the limit of proportionality.

(1)

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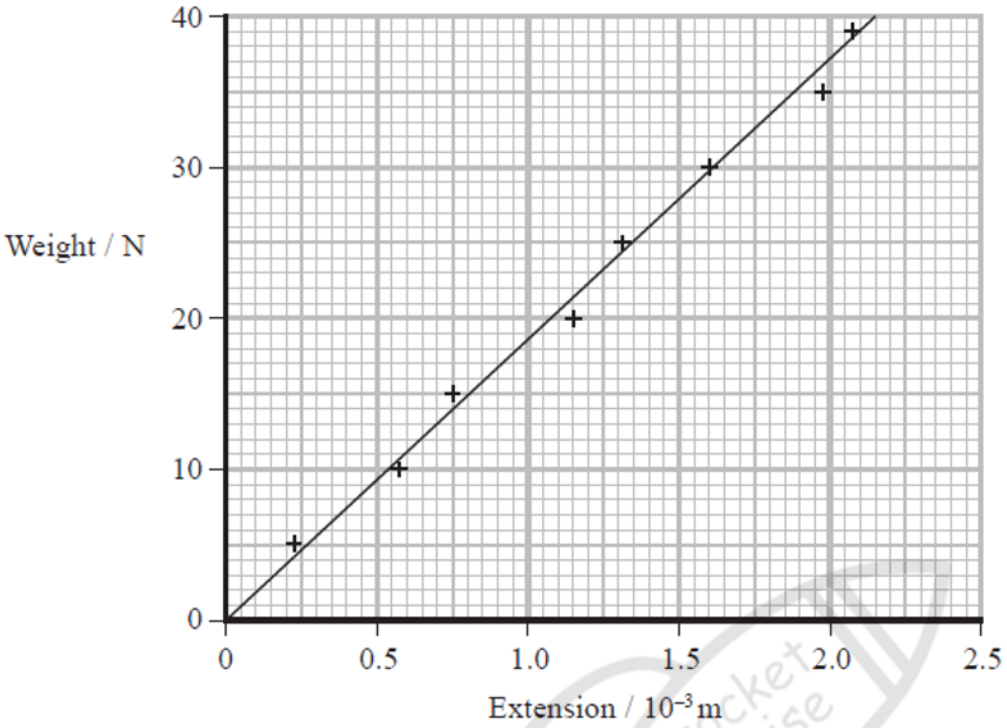
(b) The student's graph is shown below.



(i) Determine the gradient of the graph.

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Gradient = ...

(ii) Determine the Young modulus of stainless steel using your value for the gradient.

(3)

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Young modulus = ...

(c) The breaking stress for this stainless steel is known to be 480 MPa.

Deduce whether it is safe for the student to increase the weight to 100.0 N.

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(Total for question = 9 marks)

Q17.

A steel object is held by an electromagnet. The magnetic force prevents the steel object falling.

(a) State **two** reasons why the weight of the object and the force from the electromagnet are not a Newton third law pair.

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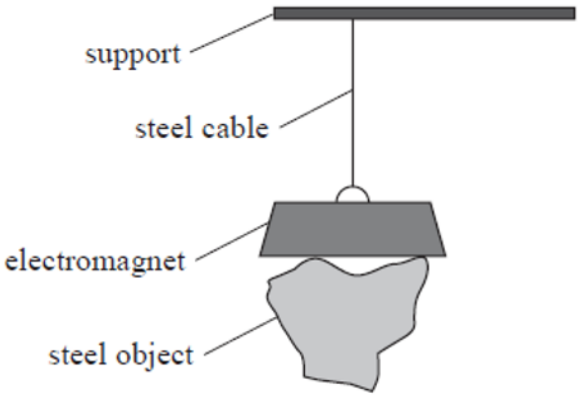
(b) The electromagnet is suspended from a support by a steel cable, as shown.



(i) When the object is suspended, the strain in the cable is 3.0×10^{-4}

Calculate the Young modulus of the steel in the cable.

cross-sectional area of cable = 5.1×10^{-4} m^2
unstretched length of cable = 3.8 m
stiffness of cable = 2.8×10^{7} N m^{-1}

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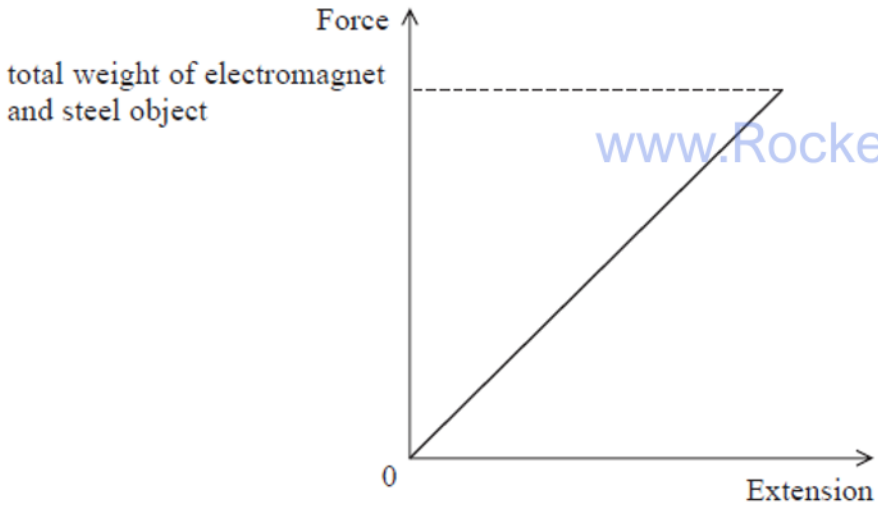
Young modulus = ...

(ii) The force-extension graph for the steel cable is shown below.



When the electromagnet is switched off, the steel object falls.

A student states that "the change in elastic strain energy stored in the cable will be transferred to the gravitational potential energy of the electromagnet".

Discuss the student's statement. You should add to the force-extension graph as part of your discussion.

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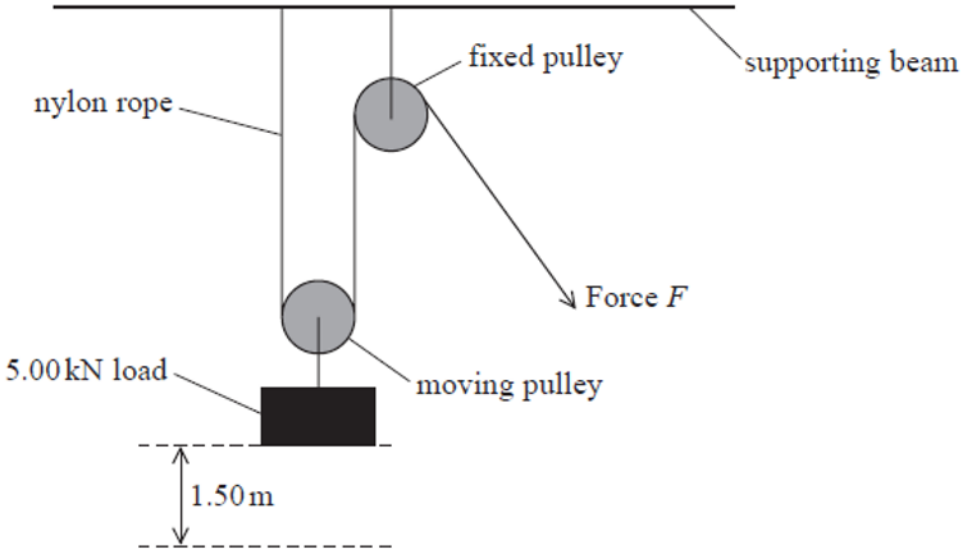
(Total for question = 11 marks)

Q18.

A pulley system is used to lift a 5.00 kN load through a height of 1.50 m. The system consists of one fixed pulley and the other pulley can move. The pulleys are connected by a nylon rope, as shown.



The nylon rope will stretch when it is used in this way. The weight of the pulleys and the rope can be ignored, and you may assume that there is no friction in the pulleys.

The properties of the nylon rope are:

Young modulus of nylon	2.70 GPa
overall length of rope before adding the load	6.00 m
area of cross-section	3.00×10^{-4} m^2

(a) The greater the length of a rope, the smaller the stiffness of the rope.

Explain why.

(2)

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(b) (i) Show that the stiffness k of the nylon rope is about 1.4×10^5 N m^{-1}.

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(ii) The pulley system lifts the 5.00 kN weight at a steady rate.

Determine the extension of the rope while the lift is taking place.

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Extension of rope = ...

(iii) Calculate the work done in stretching the rope.

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Work done in stretching rope = ...

(c) Assess whether the stretching of the rope has a significant effect on the efficiency of the pulley system.

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(Total for question = 12 marks)

Q19.

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 stress σ is applied across the ends of a wire of cross-sectional area A.

Work W is done to extend the wire by Δx.

Which of the following could be used to determine W ?

☐ **A** $W = \frac{1}{2} \times \frac{\sigma}{A} \times \Delta x$

☐ **B** $W = \frac{1}{2} \times \frac{\sigma}{A} \times \Delta x^2$

☐ **C** $W = \frac{1}{2} \times \sigma \times A \times \Delta x$

☐ **D** $W = \frac{1}{2} \times \sigma \times A \times \Delta x^2$

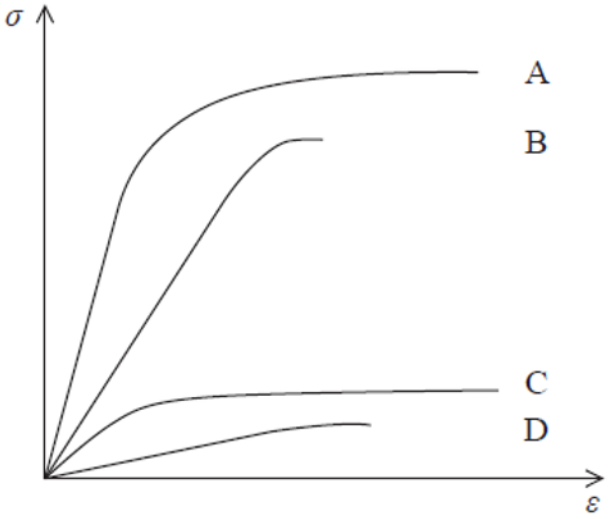
(Total for question = 1 mark)

Q20.

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 graph of stress σ against strain ε, up to the breaking point, is drawn for four samples of wire, A, B, C and D.

Which sample of wire has both a low elastic limit **and** a large region of plastic deformation?



☒ **A**

☒ **B**

☒ **C**

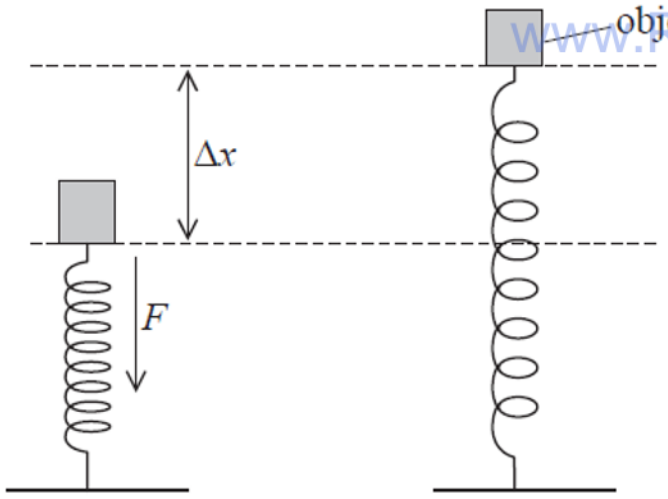
☒ **D**

(Total for question = 1 mark)

Q21.

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 ☒.

An object of mass *m* is resting on top of a spring. The spring is compressed a further distance Δ*x* by a vertical force *F*. The force is removed and the spring returns to its original length as shown.



When Δx becomes zero the object has a vertical speed v.

Which of the following equations describes the energy transfer as the spring returns to its original length?

☒ **A** $\frac{1}{2}F\Delta x = \frac{1}{2}m v^2 - m g \Delta x$

☒ **B** $\frac{1}{2}F\Delta x = \frac{1}{2}m v^2 + m g \Delta x$

☒ **C** $F\Delta x = \frac{1}{2}m v^2 - m g \Delta x$

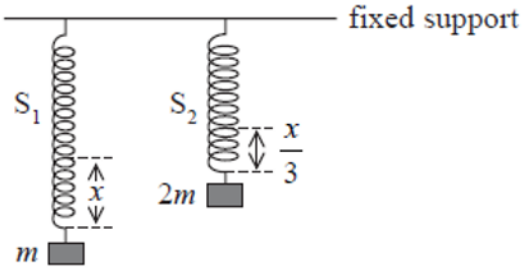
☒ **D** $F\Delta x = \frac{1}{2}m v^2 + m g \Delta x$

(Total for question = 1 mark)

Q22.

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 ☒.

Two different springs, S_1 and S_2, are suspended from a fixed support. Masses are attached to the bottom of S_1 and S_2 as shown.



The extension of S_1 is x, and the extension of S_2 is $\frac{x}{3}$. The elastic strain energy in spring S_1 is E.

Which of the following is the elastic strain energy in spring S_2?

☒ **A** $6E$

☒ **B** $\frac{3E}{2}$

☒ **C** $\frac{2E}{3}$

☒ **D** $\frac{E}{6}$

(Total for question = 1 mark)

Q23.

* In a bungee jump, the bungee jumper falls from a high platform while attached to an elastic cord. The cord is also attached to the platform.

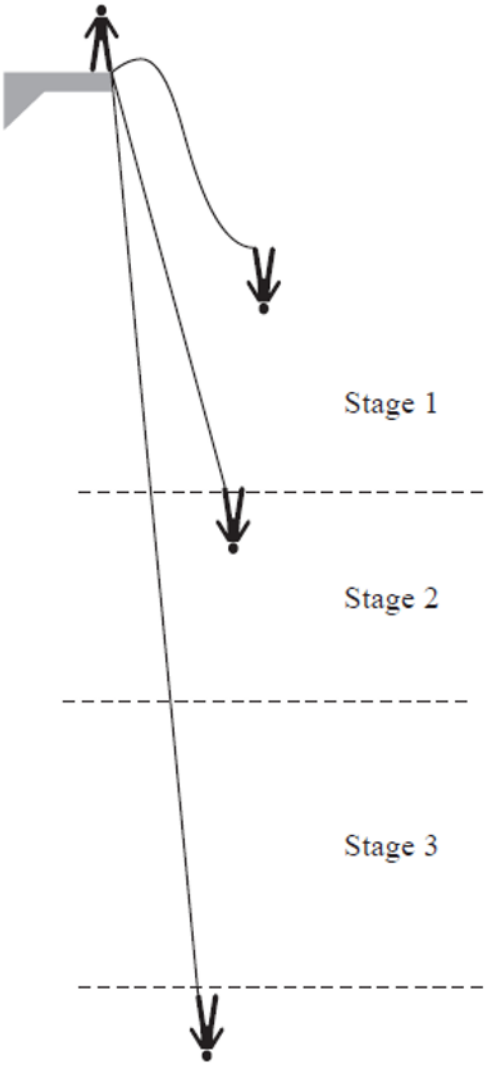
The cord slows the bungee jumper down, so that he comes to rest before reaching the ground.

The fall can be divided into three stages:

Stage 1 – the jumper is in free fall until the cord starts to stretch.

Stage 2 – the cord is stretching until the acceleration of the jumper decreases to zero.

Stage 3 – the cord continues to stretch until the jumper is momentarily at rest.



Explain, in terms of work done, how the kinetic energy of the bungee jumper changes during the three stages of the fall.

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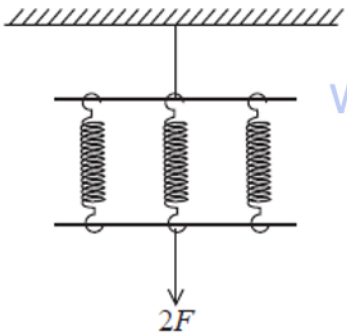
(Total for question = 6 marks)

Q24.

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 certain spring is stretched by a tensile force F, the elastic energy stored in the spring is E.

Three of these springs are arranged in parallel and stretched by a tensile force of $2F$, as shown.



Which of the following expressions gives the elastic energy stored in the parallel system?

☒ **A** $\frac{1}{3}E$

☒ **B** $\frac{2}{3}E$

☒ **C** $\frac{4}{3}E$

☒ **D** $2E$

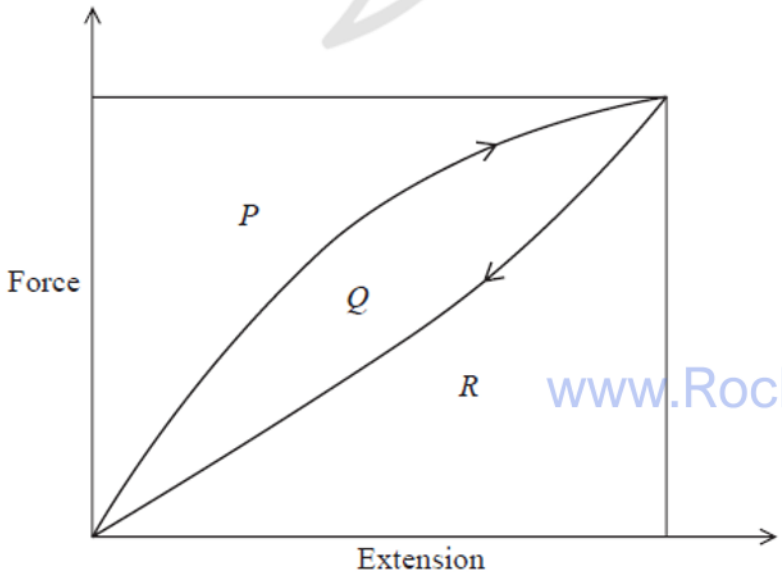
(Total for question = 1 mark)

Q25.

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 rubber band is initially stretched by an increasing force. When the force is gradually decreased, the rubber band returns to its original length.

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



P, *Q* and *R* represent different areas of the graph.

Which of the following gives the work done in stretching the rubber band up to its maximum extension?

☒ **A** $P + Q$

☒ **B** $Q + R$

☒ **C** R

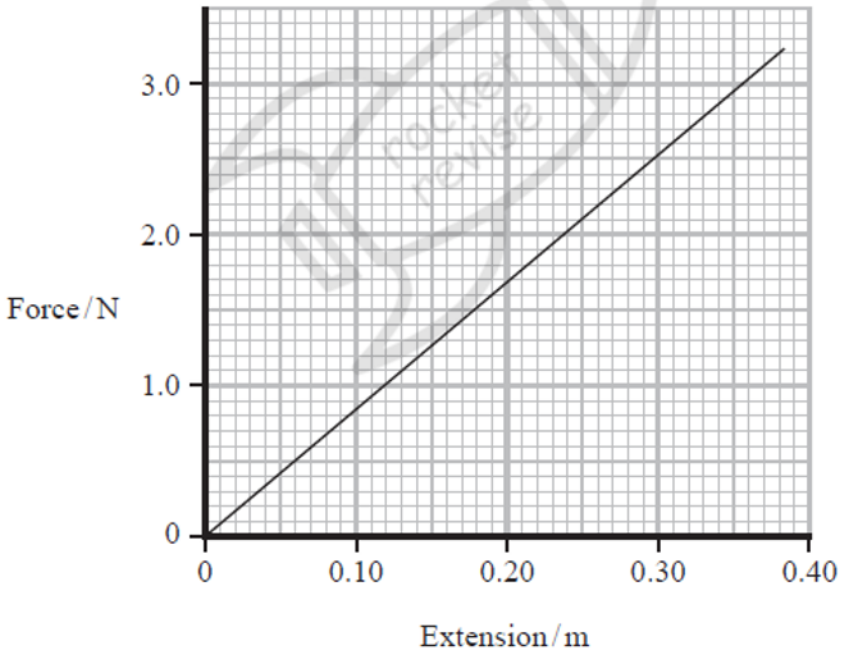
☒ **D** Q

(Total for question = 1 mark)

Q26.

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 force-extension graph for a spring is shown.



Which of the following gives the work done, in joules, to extend the spring by 0.30 m from its original length?

☒ **A** 0.30×2.5

☒ **B** $0.5 \times 0.30 \times 2.5$

☒ **C** $\frac{2.5}{0.30}$

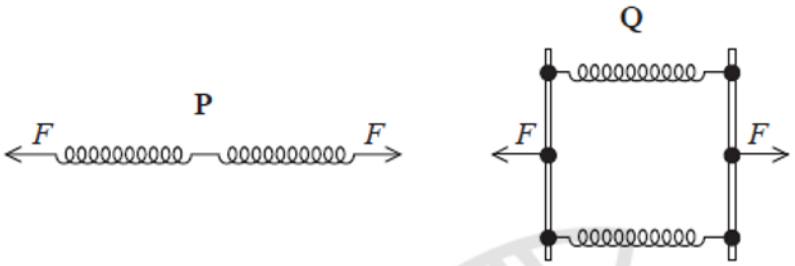
☒ **D** $\frac{0.30}{2.5}$

(Total for question = 1 mark)

Q27.

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

Two arrangements, **P** and **Q**, of identical springs are subjected to the same tensile force F as shown.



When one spring is subjected to a tensile force F, the elastic strain energy for the spring is E.

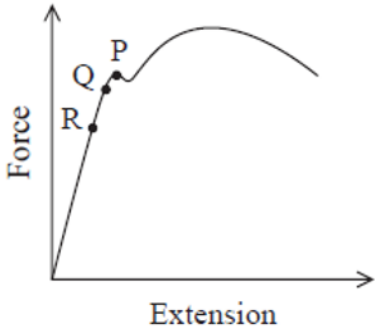
Which row of the table gives the total elastic strain energy for each arrangement?

		P	Q
☒	**A**	½E	2E
☒	**B**	½E	½E
☒	**C**	2E	2E
☒	**D**	2E	½E

(Total for question = 1 mark)

Q28.

A length of steel wire is fixed at one end. An increasing force is applied to the other end of the wire. The force extension graph for the wire is shown.



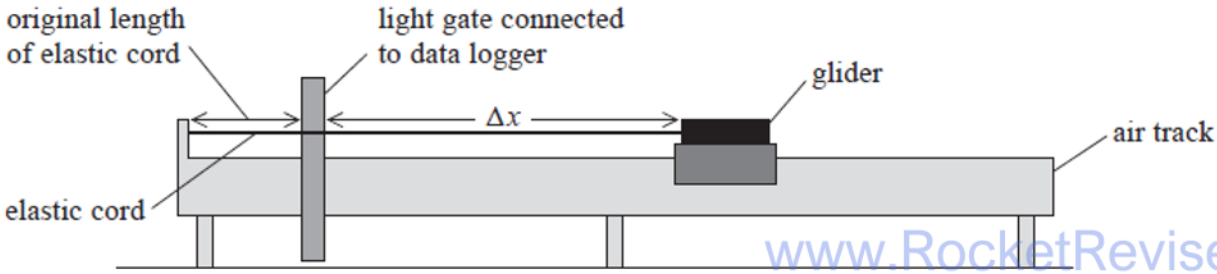
Which row of the table identifies points P, Q and R on the graph?

	P	Q	R
☒ A	elastic limit	limit of proportionality	yield point
☒ B	elastic limit	yield point	limit of proportionality
☒ C	yield point	elastic limit	limit of proportionality
☒ D	yield point	limit of proportionality	elastic limit

(Total for question = 1 mark)

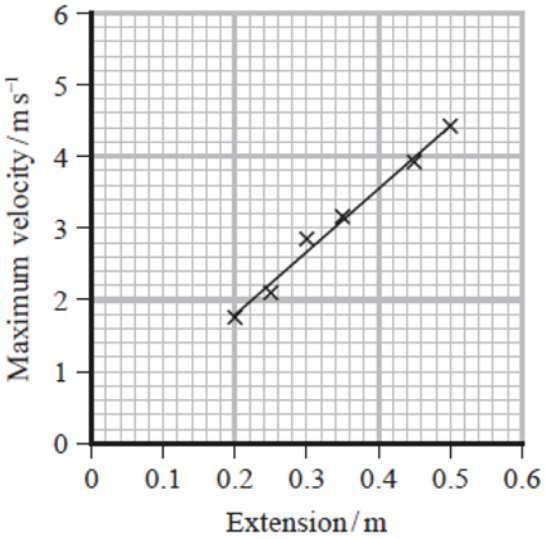
Q29.

An elastic cord was fixed between the end of an air track and a glider.
The glider was pulled to the right, giving the elastic cord an extension Δ *x* as shown.



The glider was released, and it moved to the left. A light gate was used to measure the maximum velocity of the glider. This was repeated for different values of Δ *x*.

A student obtained the following results.



(a) The principle of conservation of energy predicts that the graph should be a straight line through the origin. For the range of values of Δx used, the elastic cord obeyed Hooke's law.

(i) Explain this prediction.

(4)

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(ii) Determine the stiffness k of the elastic cord.

mass of glider = 300 g

(3)

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k = ...

(b) When the glider was moved to the right by more than 0.5 m, the graph began to curve.

Explain why the shape of the graph changed.

(2)

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(Total for question = 9 marks)

Q30.

A force F was applied to compress a spring by a distance x.

A second spring of double the stiffness was compressed by the same distance x.

Which of the following gives the magnitude of the force applied to the second spring?

☒ **A** $4F$

☒ **B** $2F$

☒ **C** F

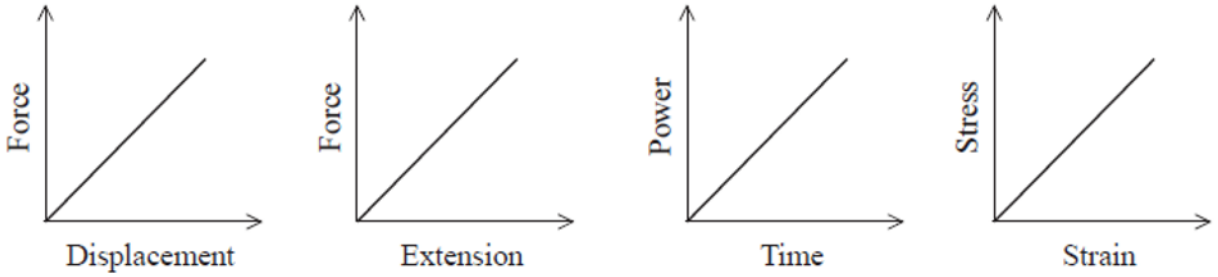
☒ **D** $\frac{F}{2}$

(Total for question = 1 mark)

Q31.

The area under each of the following graphs represents a physical quantity.

For which graph is the area under the graph **not** equal to work done?

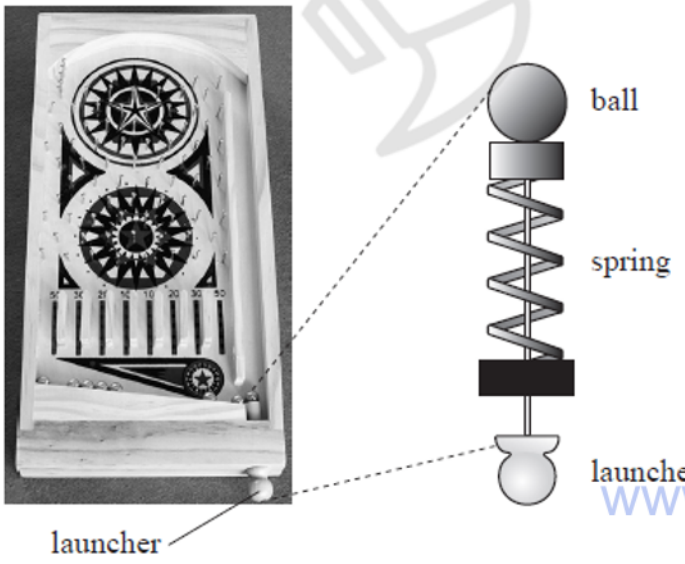


☒ **A** ☒ **B** ☒ **C** ☒ **D**

(Total for question = 1 mark)

Q32.

The photograph shows a toy pinball machine. The launcher is pulled back, compressing a spring. The spring obeys Hooke's law. When the launcher is released, the spring returns to its original length and a small ball is launched horizontally into the machine.



(Source: © Valery Voennyy/Alamy Stock Photo)

When the launcher is pulled back, the spring is compressed by 5.0 cm. When the spring is released, the ball is launched at a speed of 8.0 cm s^{-1}.

(a) Show that the kinetic energy of the ball just after launching is about 4×10^{-5} J.

mass of ball = 12 g

(2)

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(b) Determine the force on the ball when the spring is released.

(2)

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Force = ...

(c) Determine the stiffness of the spring.

(2)

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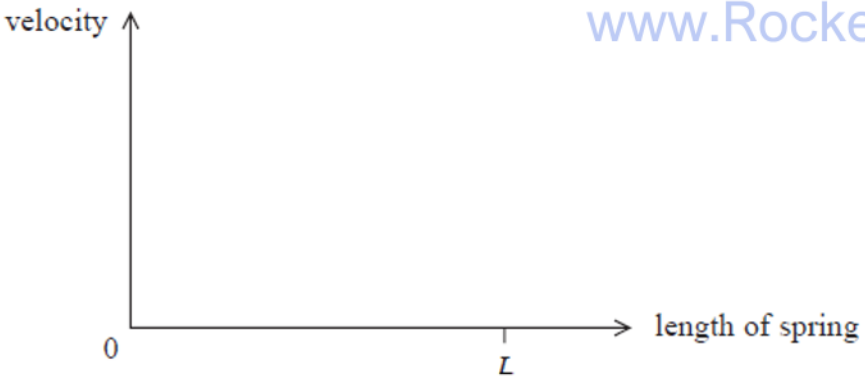
Stiffness = ...

(d) The spring returns to its original length *L*.

Sketch a graph, on the axes below, to show how the velocity of the ball varies with the length of the spring.

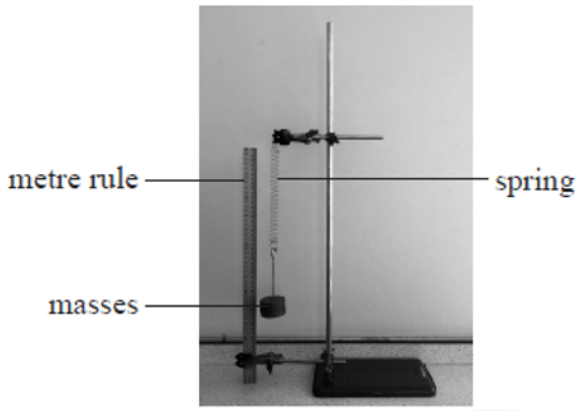
(4)



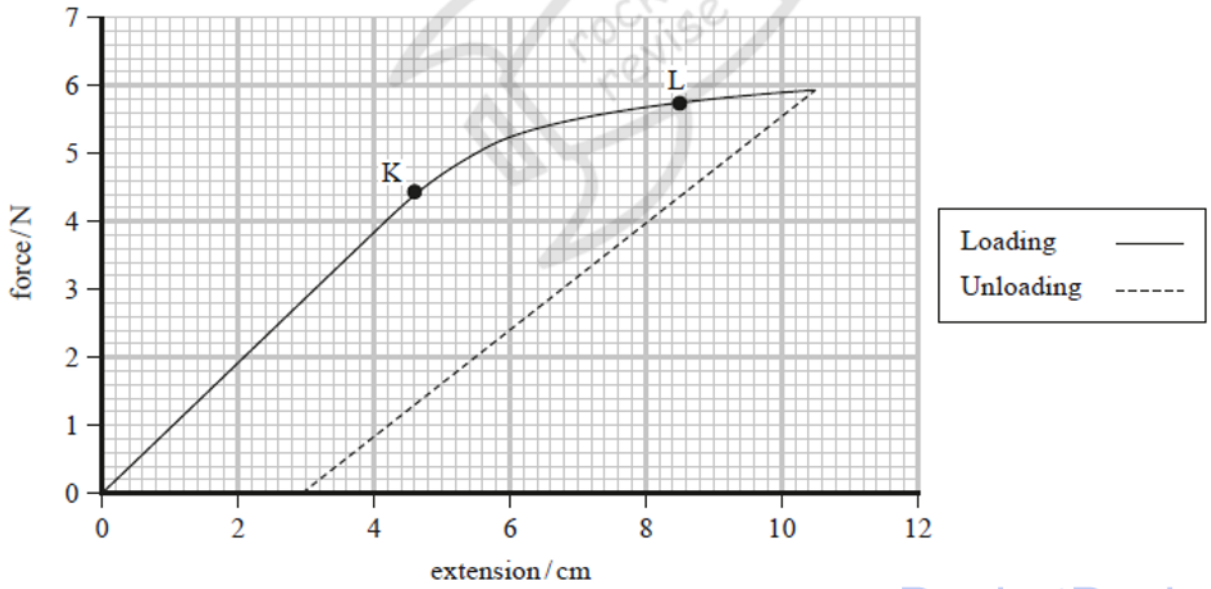
(Total for question = 10 marks)

Q33.

A student used the equipment shown to investigate the behaviour of a spring.



The student recorded the position of the spring on the metre rule for increasing loads. He plotted the graph shown for the loading and unloading of the spring.



(a) The student continued to increase the load until the spring exceeded the elastic limit at point L.

(i) State the significance of point K.

(1)

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(ii) Explain the significance of point L.

(2)

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(iii) The graph for the unloading of the spring is also shown on the axes.

Suggest why the unloading graph has a different gradient to the loading graph.

(1)

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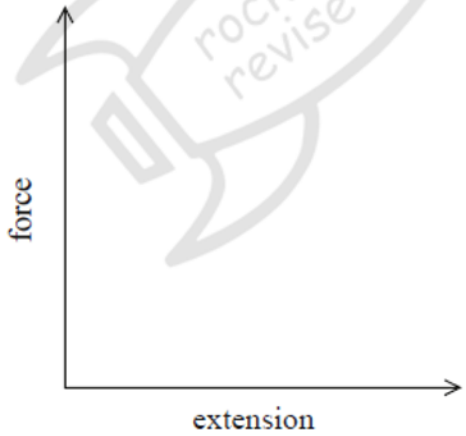
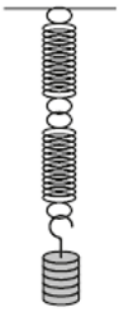
(b) A second student repeated the investigation but forgot to subtract the original length of the spring from his measurements.

Sketch, on the axes below, the shape of the graph he would obtain for the loading of the spring.

(1)



(c) A third student repeated the investigation using two new springs connected in series as shown.



The springs were identical to the spring used in the original investigation.

Explain why the spring constant for this arrangement of the springs would be half that for one spring.

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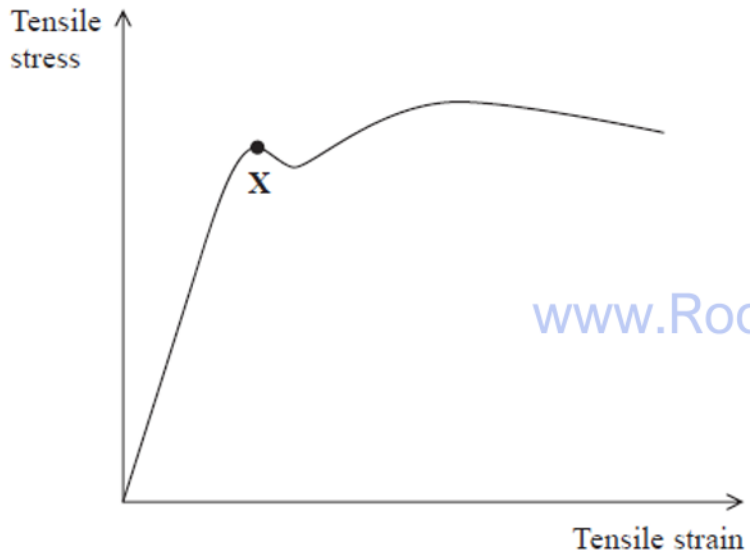
(Total for question = 9 marks)

Q34.

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 copper rod was placed under tensile stress and the tensile strain in the rod was measured.

The graph shows how the tensile stress required to cause a tensile strain in the rod depends upon the tensile strain.



What does point X represent?

☒ **A** the fracture point of the rod

☒ **B** the limit of proportionality for copper

☒ **C** the maximum tensile stress in the rod

☒ **D** the yield point of copper

(Total for question = 1 mark)

Q35.

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 ☒.

Which of the following could be used to describe the elastic limit of a material?

☒ **A** The stress above which the material will not obey Hooke's law.

☒ **B** The stress above which the material will be deformed when the stress is removed.

☒ **C** The stress at which the material undergoes a sudden increase in extension.

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

(Total for question = 1 mark)