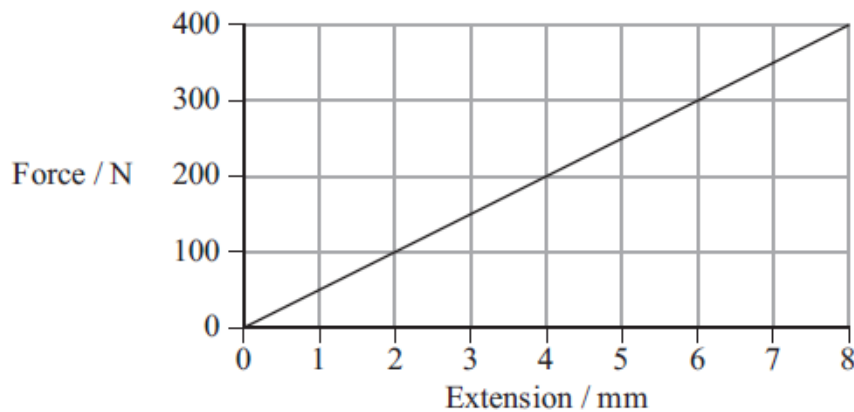


Questions

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 (☒).

The force-extension graph for a spring is shown.



A tensile force of 50 N is applied to the spring.

An additional tensile force of 300 N is then applied to the spring.

Which expression gives the change in elastic strain energy, in J, when the additional force is applied?

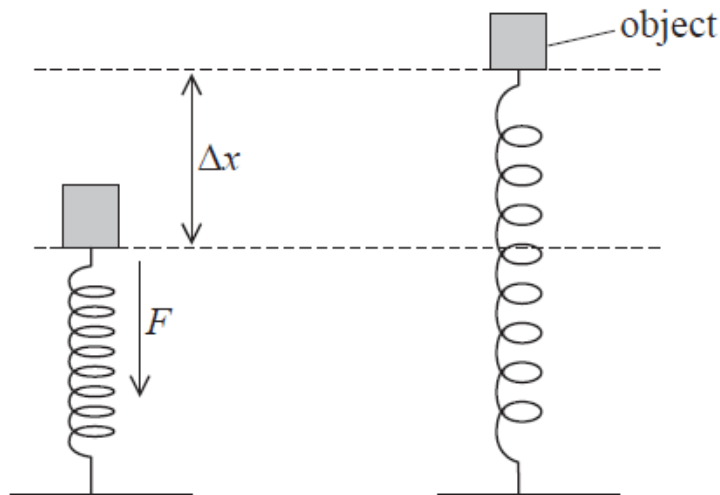
- ☐ A $\frac{300 \times 6 \times 10^{-3}}{2}$
- ☐ B $\frac{(300 + 50) \times 6 \times 10^{-3}}{2}$
- ☐ C $\frac{(300 + 50 + 50) \times 6 \times 10^{-3}}{2}$
- ☐ D $\frac{(300 + 50) \times 7 \times 10^{-3}}{2}$

(Total for question = 1 mark)

Q2.

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 Δx 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)

Q3.

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.

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(b) The elastic limit of a steel cable was reached when a force of $13.4 \times 10^6 \text{ N}$ was applied. The extension of the cable was 0.126 m.

length of cable = 6.00 m cross-sectional area of cable = $9.60 \times 10^{-3} \text{ m}^2$

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

(2)

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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)

Q4.

* The photograph shows a toy car that contains a spring. Pulling the car backwards along the floor compresses the spring. Energy is stored in the compressed spring.



The car is released and the spring returns to its original state. There is a forward force on the car from the floor and the car moves forwards.

Explain why the floor exerts a forward force on the car and how this force affects the motion of the car as the spring returns to its original state.

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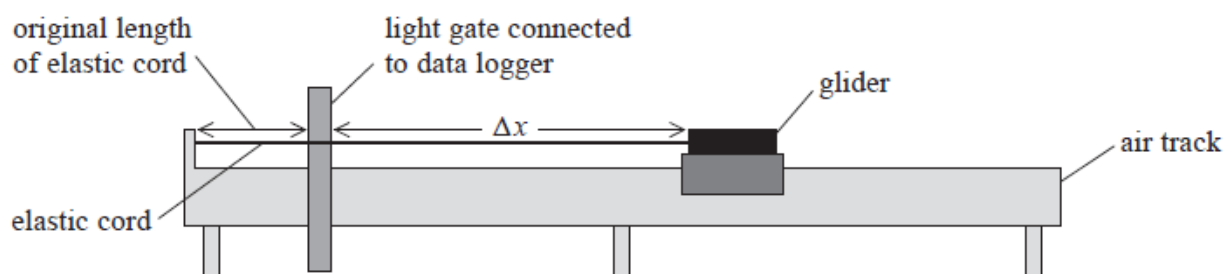
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(Total for question = 6 marks)

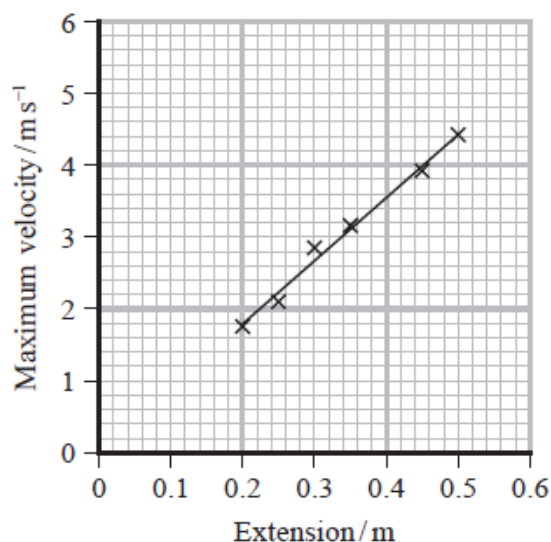
Q5.

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 Δx 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 Δx .

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)

Q6.

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.

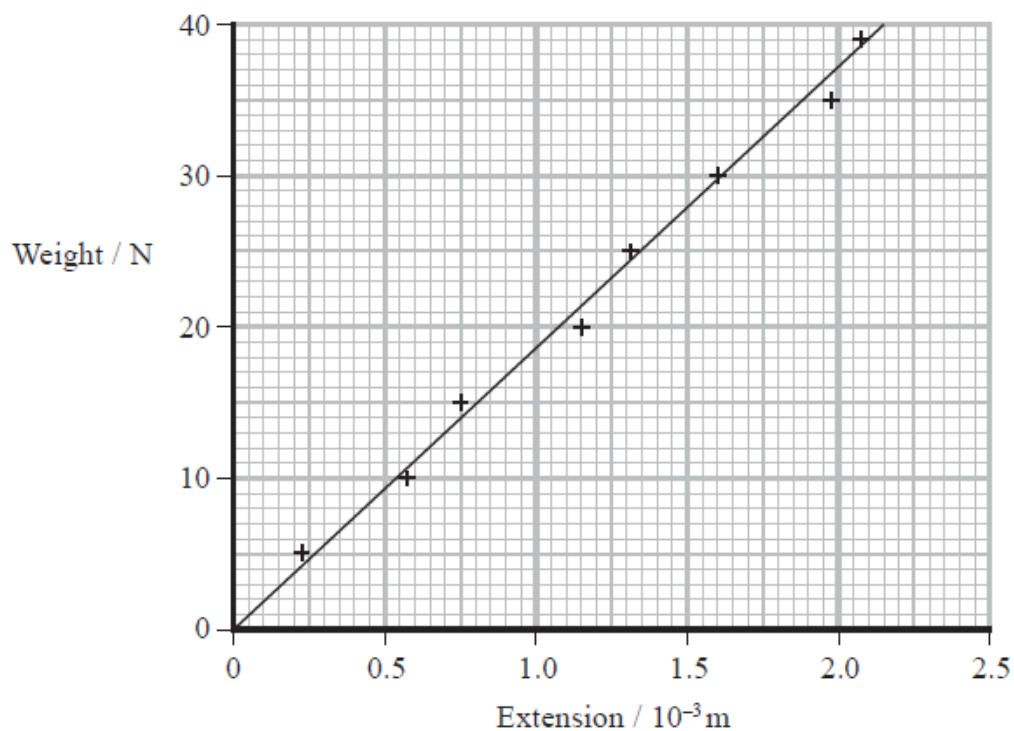
The wire had an unstretched length of 2.6 m. The diameter of the wire was 5.6×10^{-4} m.

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)

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



(i) Determine the gradient of the graph.

(2)

Gradient =

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

(3)

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.

(3)

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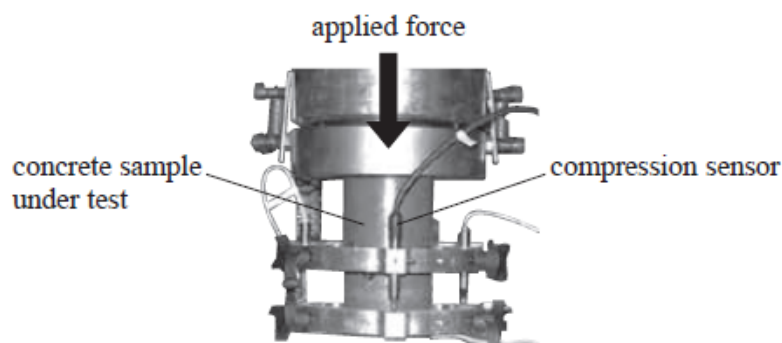
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(Total for question = 9 marks)

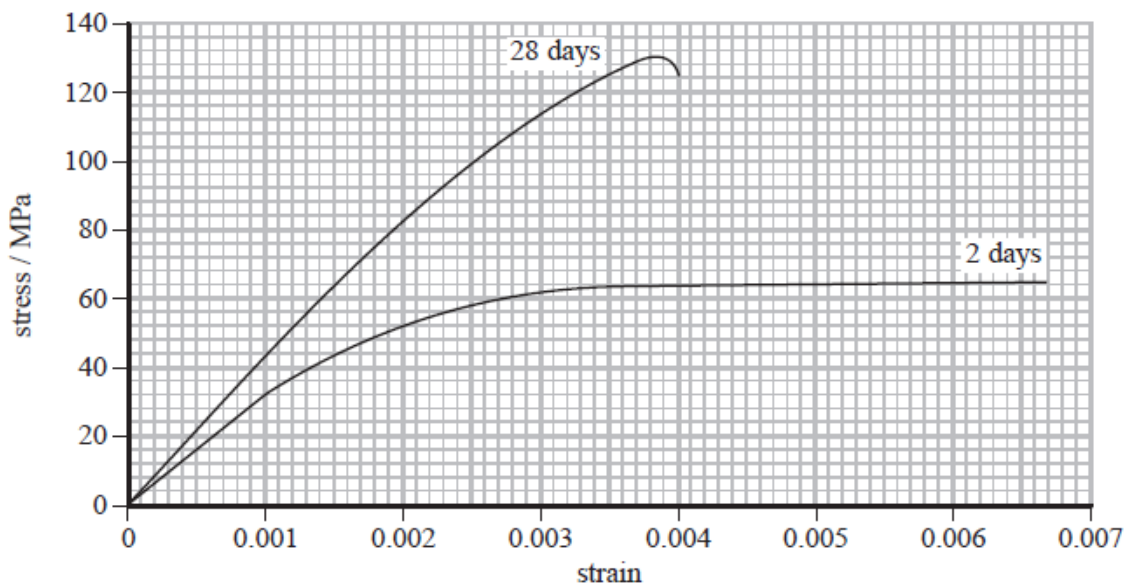
Q7.

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.

(4)

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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.

(3)

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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)

Q8.

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.

(2)

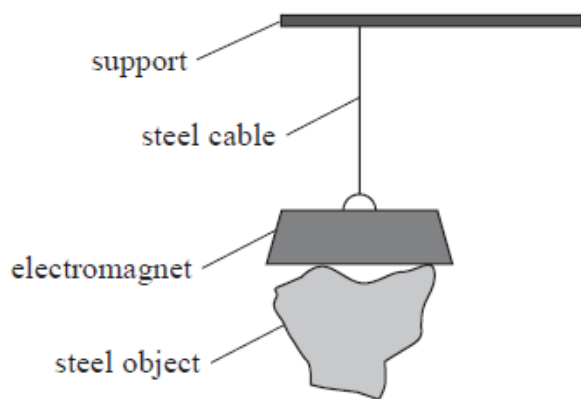
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(b) The electromagnet is suspended from a support by a steel cable, as shown.



(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 = $5.1 \times 10^{-4} \text{ m}^2$

unstretched length of cable = 3.8 m

stiffness of cable = $2.8 \times 10^7 \text{ N m}^{-1}$

(4)

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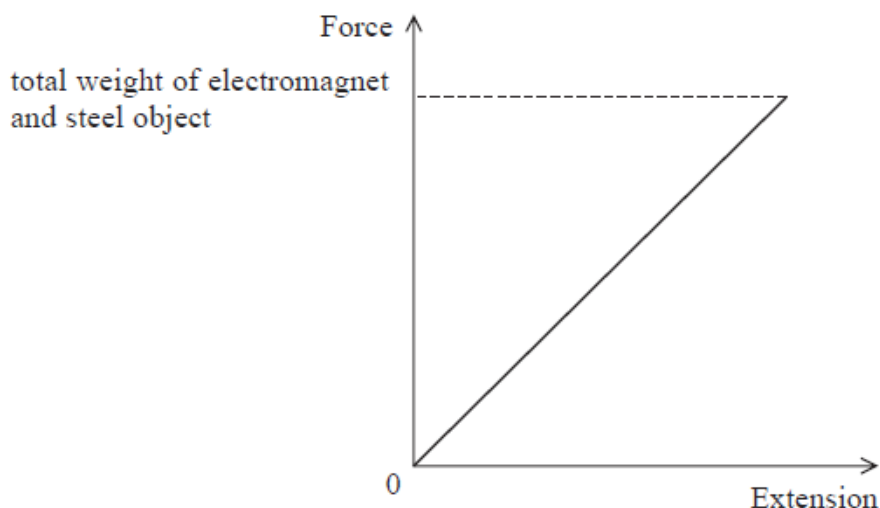
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Young modulus =

(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.

(5)

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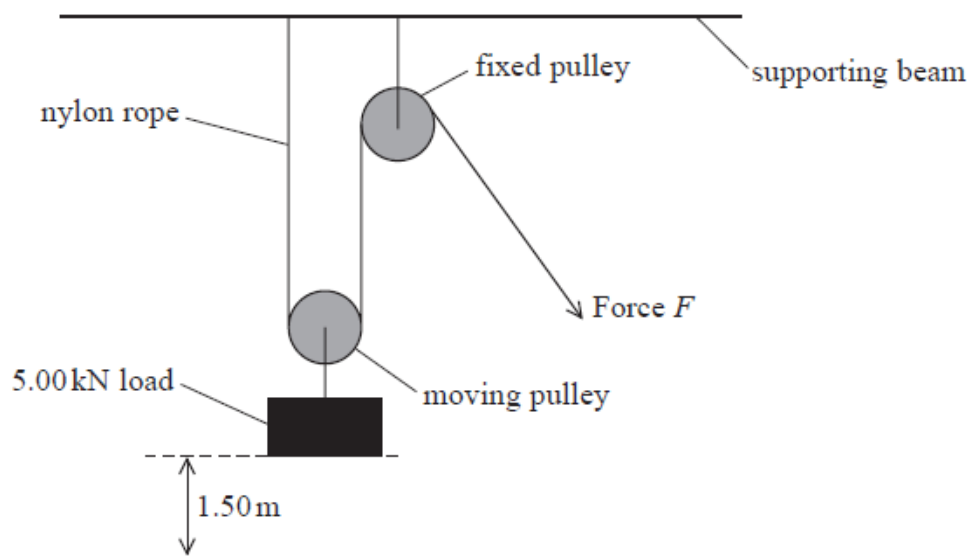
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(Total for question = 11 marks)

Q9.

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	$3.00 \times 10^{-4} \text{ m}^2$

(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 $1.4 \times 10^5 \text{ N m}^{-1}$.

(3)

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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.

(3)

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Extension of rope =

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

(2)

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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.

(2)

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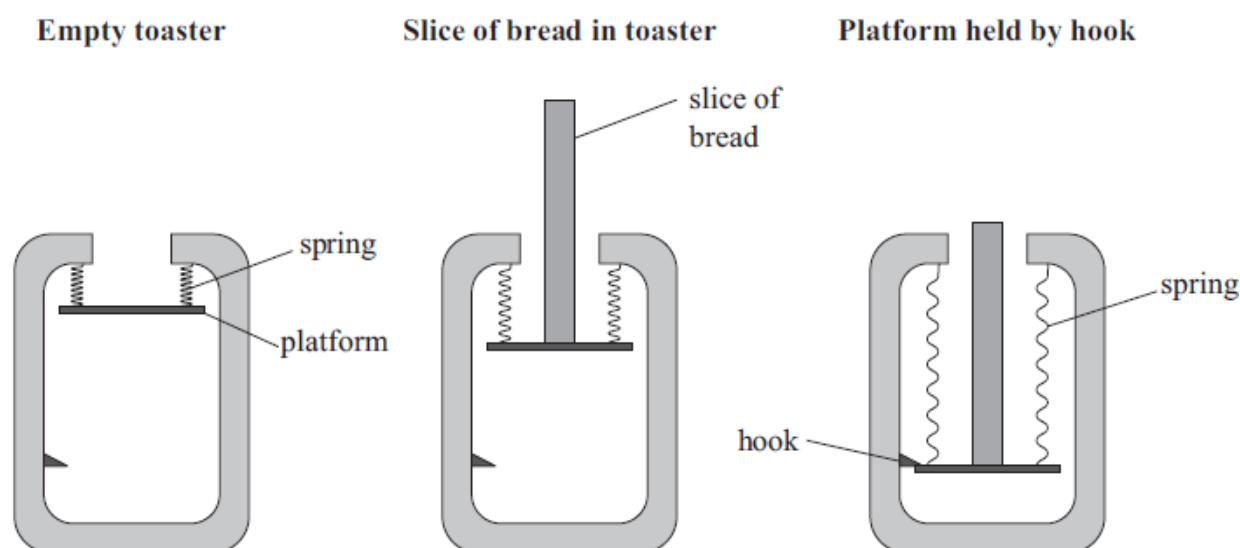
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(Total for question = 12 marks)

Q10.

A toaster is a device used to heat a slice of bread.

A platform in the toaster is supported by four springs. A slice of bread is placed in the toaster and a person pushes the platform downwards, stretching the springs. A hook then holds the platform in place, as shown.



(a) Explain how the elastic strain energy stored by the springs compares with the work done by the person to push the platform downwards.

(3)

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(b) The platform is supported by one spring at each corner. The 4 springs are identical.

A person places a slice of bread of weight 0.52 N in the toaster. The weight of the bread causes the platform to move 2.1 cm downwards.

(i) Show that the stiffness of each spring is about 6 N m^{-1} .

(3)

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(ii) The hook exerts a downwards force of 1.2 N on the platform.

The toaster heats the slice of bread and then releases the hook. The springs return to their unstretched length and the bread is launched upwards.

The mass of the platform is negligible.

Determine the speed of the bread at the instant the springs return to their unstretched length.

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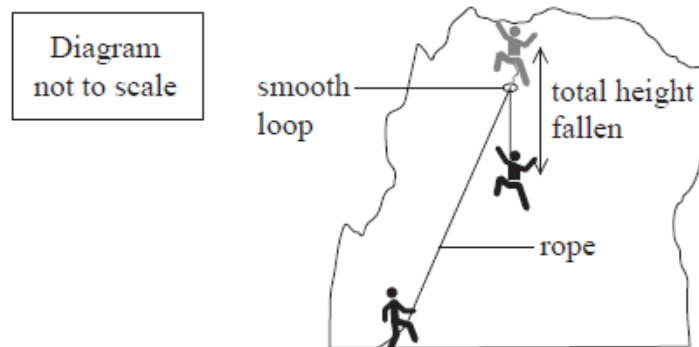
Speed =

(Total for question = 12 marks)

Q11.

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.



(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

(5)

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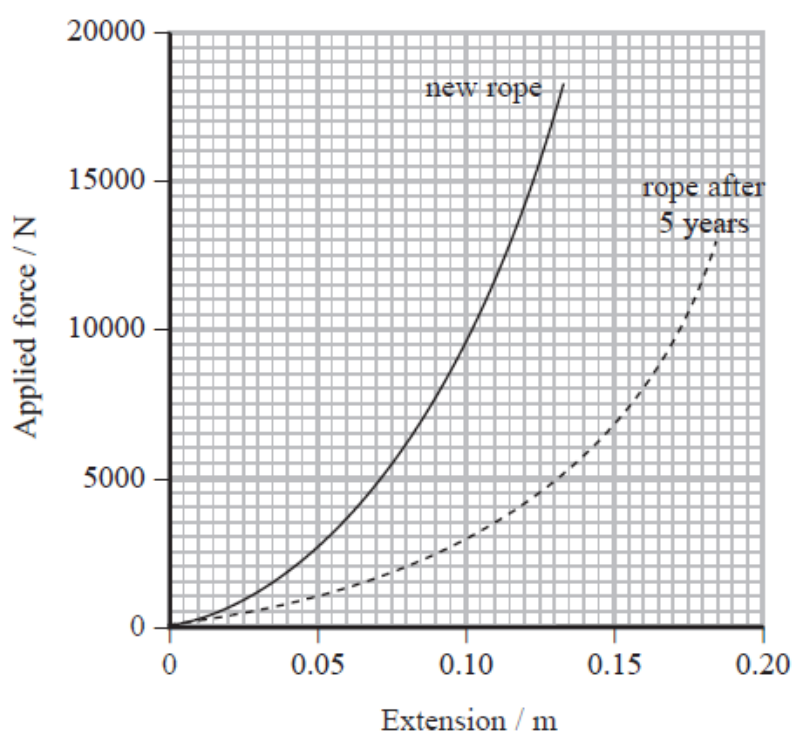
(ii) A new climber suggests using a longer length of rope between the loop and the climber, as this would absorb more energy after a fall.

Comment on this suggestion.

(2)

(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.

(6)

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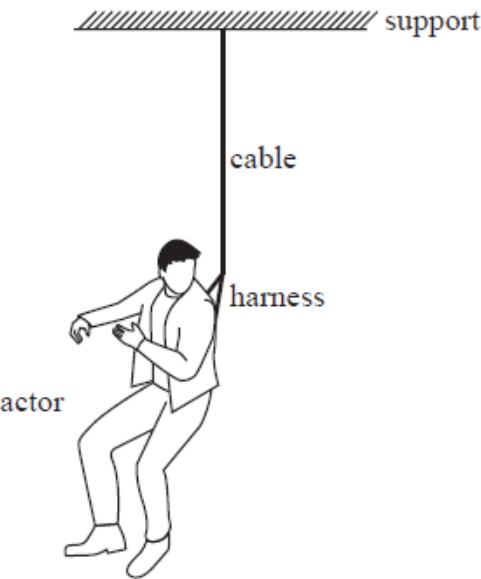
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(Total for question = 13 marks)

Q12.

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.

(2)

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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.

(3)

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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 $2.5 \times 10^8 \text{ Pa}$.

The diameter of the cable is $7.6 \times 10^{-3} \text{ m}$.

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

(4)

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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)