Materials AS Revision Pack

Name: ____________________

Class: ____________________

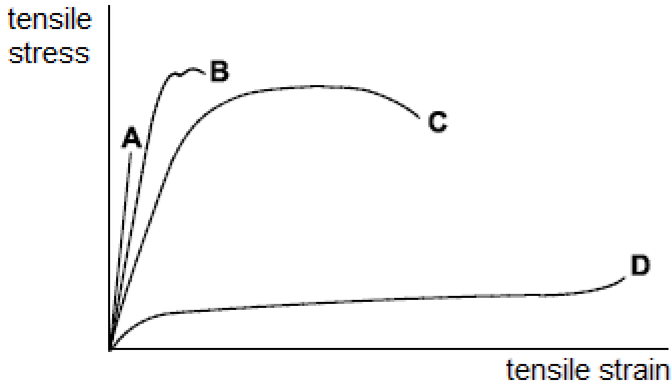
Date: ____________________

Time: **367 minutes**

Marks: **317 marks**

Comments:

1 The diagram below shows the tensile stress–tensile strain graphs for four materials, **A**, **B**, **C** and **D**, up to their breaking stress.



(a) State what is meant by tensile stress and tensile strain.

tensile stress ____

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tensile strain ____

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(2)

(b) Identify a property of material **A** using evidence from the graph to support your choice.

property ____

evidence ____

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(2)

(c) A cylindrical specimen of material **A** under test has a diameter of 1.5×10^{-4} m and a breaking stress of 1.3 GPa.

Calculate the tensile force acting on the specimen at its breaking point.

tensile force = ____________________ N

(3)

(d) Discuss which of the four materials shown on the graph is most suitable for each of the following applications:

- the cable supporting a lift in a tall building
- a rope or cable attached to a person doing a bungee jump.

For each application, you should discuss the reason for your choice and why you rejected the other materials.

(6)

(Total 13 marks)

2 (a) State the law of conservation of energy.

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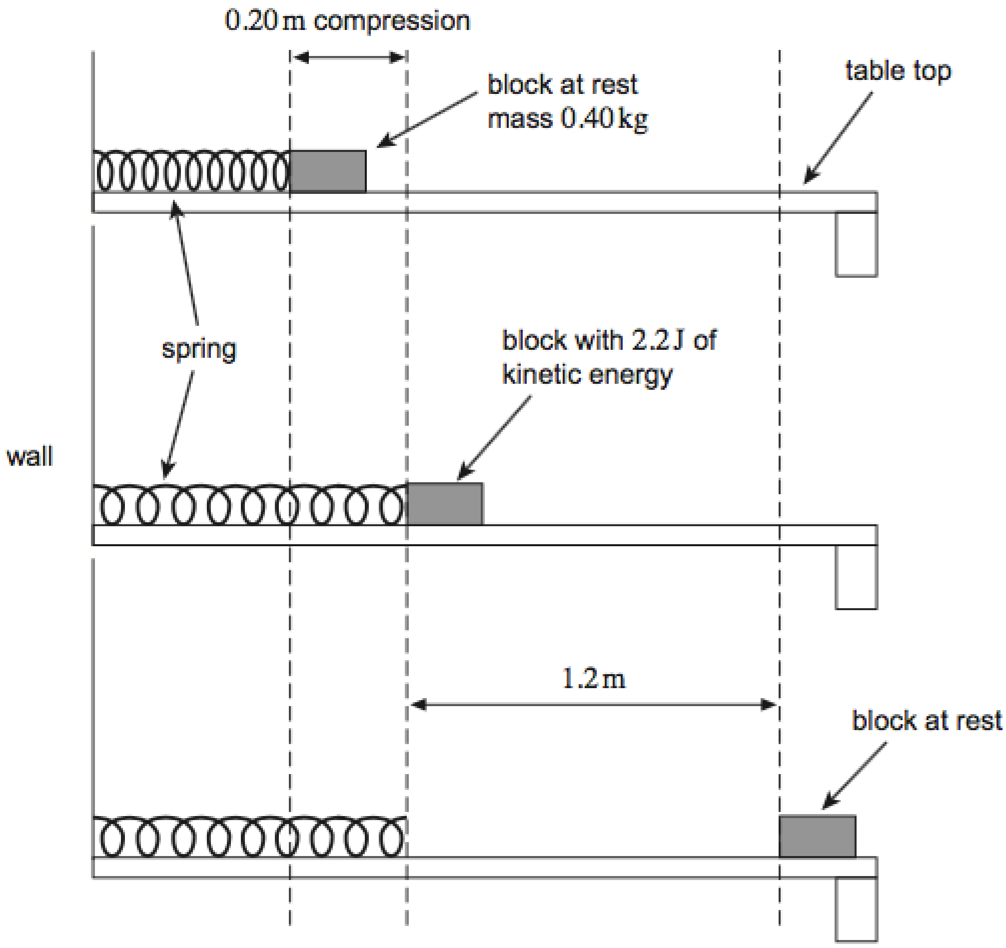
(2)

(b) The diagram shows a block on a horizontal table top initially held against a spring so that the spring is compressed. The other end of the spring is fixed to a wall. When released the block is pushed away by the spring. When the spring reaches its natural length the block leaves the spring and then slides along the table top. A constant frictional force acting between the moving block and the table top eventually brings the block to rest.



(i) When the block leaves the spring, the block has a kinetic energy of 2.2 J. The mass of the block is 0.40 kg.
Calculate the maximum velocity of the block.

maximum velocity = ____________________ m s^{-1}

(1)

(ii) The block travels 1.2 m after leaving the spring before coming to rest.
Show that the frictional force between the block and the table top is about 1.8 N.

(1)

(iii) The spring was initially compressed through 0.20 m. The constant frictional force acts on the block whenever it is moving.
Calculate the elastic potential energy in the spring when in its initial compressed position.
Assume the spring has negligible mass.
State an appropriate unit for your answer.

elastic potential energy = __________ unit = _________

(3)

(iv) The force exerted on the block by the spring is proportional to the compression of the spring.
Calculate the maximum force exerted on the block by the spring.

maximum force = ____________________ N

(1)

(Total 8 marks)

3 If lengths of rail track are laid down in cold weather, they may deform as they expand when the weather becomes warmer. Therefore, when rails are laid in cold weather they are stretched and fixed into place while still stretched. This is called pre-straining.

The following data is typical for a length of steel rail:

Young modulus of steel =	2.0×10^{11} Pa
cross sectional area of a length of rail =	7.5×10^{-3} m^2
amount of pre-strain =	2.5×10^{-5} for each kelvin rise in temperature the rail is expected to experience.

A steel rail is laid when the temperature is 8 °C and the engineer decides to use a pre-strain of 3.0×10^{-4}.

(a) Calculate the tensile force required to produce the pre-strain in the rail required by the engineer.

tensile force = ____________________ N

(3)

(b) Calculate the elastic strain energy stored in a rail of unstressed length 45 m when pre-strained as in part (a)

elastic strain energy = ____________________ J

(2)

(c) Calculate the temperature at which the steel rail becomes unstressed.

temperature = ____________________ °C

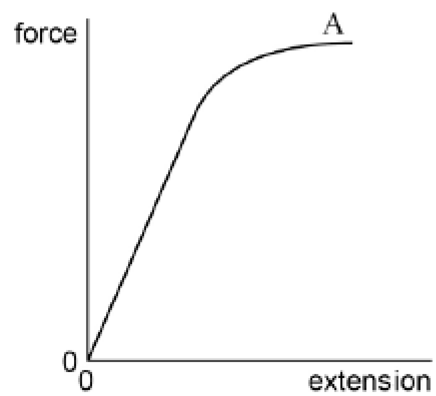
(2)

(d) Explain why the engineer does not use the highest observed temperature at the location of the railway track to determine the amount of pre-strain to use.

(2)

(Total 9 marks)

4 A student adds a series of masses to a vertical metal wire of circular cross–section and measures the extension of the wire produced. The figure below is a force-extension graph of the data.



(a) Mark on the figure the point P, the limit beyond which Hooke's law is no longer obeyed.

(1)

(b) Outline how the student can use these results and other measurements to determine the Young modulus of the wire.

(3)

(c) When the wire has been extended to A, the masses are removed one by one and the extension re-measured.

Draw, on the figure above, the shape of the graph that the student will obtain.

(1)

(d) Explain why the graph has the shape you have drawn.

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(2)

(e) The metal wire is used to make a cable of diameter 6.0 mm. The Young modulus of metal of the cable is 2.0×10^{11} Pa.

Calculate the force necessary to produce a strain of 0.20% in the cable.

force = ____________________ kN

(3)

(f) The cable is used in a crane to lift a mass of 600 kg.

Determine the maximum acceleration with which the mass can be lifted if the strain in the cable is not to exceed 0.20%.

acceleration = ____________________ m s^{-2}

(3)

(g) An engineer redesigns the crane to lift a 1200 kg load at the same maximum acceleration.

Discuss the changes that could be made to the cable of the crane to achieve this, without exceeding 0.20% strain.

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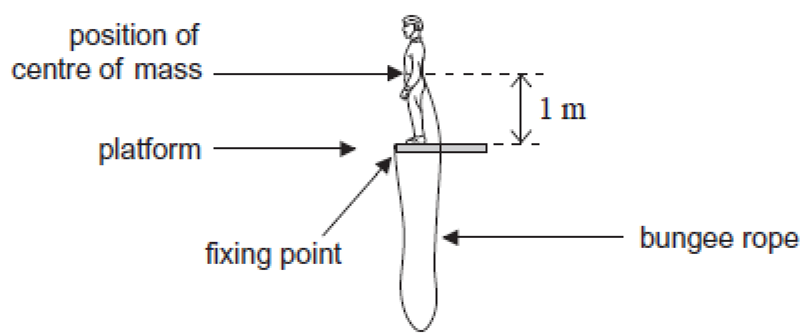
(3)

(Total 16 marks)

5 The diagram below shows a bungee jumper of mass 75 kg about to step off a raised platform. The jumper comes to a halt for the first time when his centre of mass has fallen through a distance of 31 m.

The bungee rope has an unextended length of 19 m and a stiffness of 380 N m^{-1}.

Ignore the effects of air resistance and the mass of the rope in this question.
Treat the jumper as a point mass located at the centre of mass.



(a) (i) Calculate the extension of the bungee rope when the centre of mass of the jumper has fallen through 31 m.

extension ____________________ m

(1)

(ii) Calculate the resultant force acting on the jumper when he reaches the lowest point in the jump.

resultant force ____________________ N

(2)

(b) Calculate the extension of the rope when the jumper's acceleration is zero.

extension ____________________ m

(2)

(c) The extension of the bungee rope is 5.0 m when the jumper's centre of mass has fallen through a distance of 25 m.

Use the principle of conservation of energy to calculate the speed of the jumper in this position.

speed ____________________ m s^{-1}

(4)

(d) The bungee jump operator intends to use a bungee rope of the same unextended length but with a much greater stiffness. The rope is to be attached in the same way as before.

Explain, with reference to the kinetic energy of the jumper, any safety concerns that may arise as the jumper is slowed down by the new rope.

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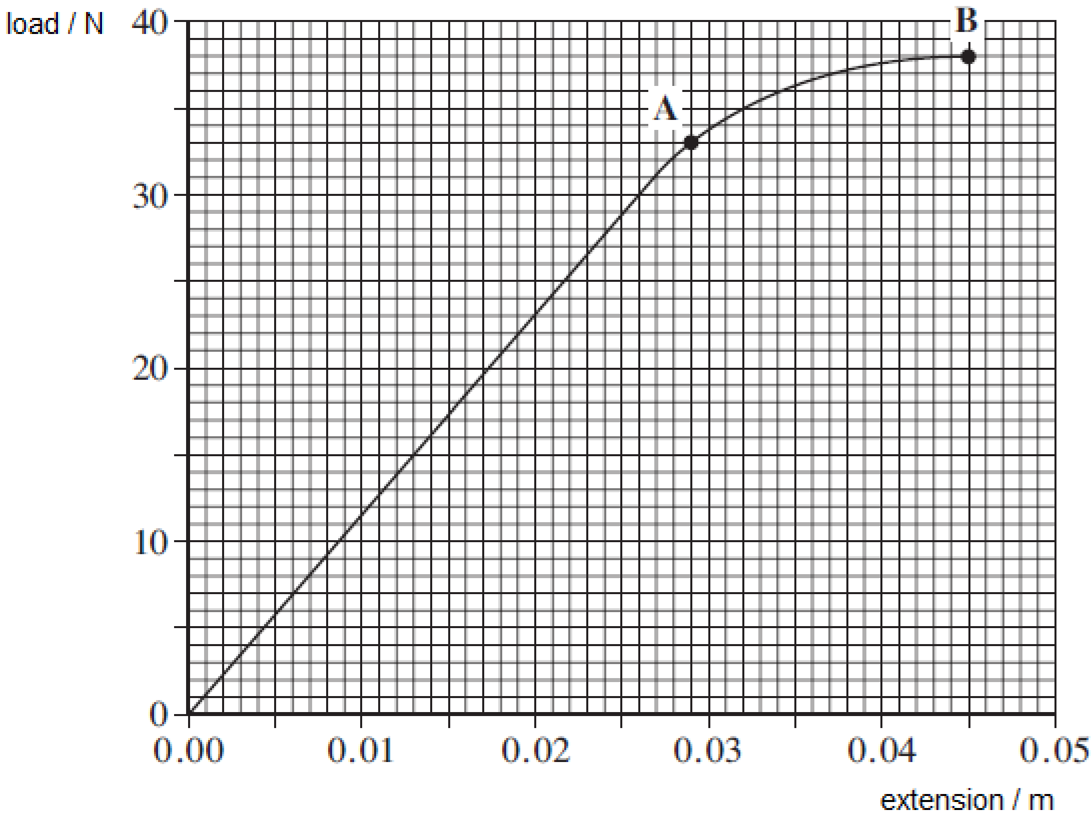
(3)

(Total 12 marks)

6 A manufacturer of springs tests the properties of a spring by measuring the load applied each time the extension is increased. The graph of load against extension is shown below.



(a) State Hooke's law.

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(2)

(b) Calculate the spring constant, *k*, for the spring. State an appropriate unit.

spring constant ____________________ unit __________

(3)

(c) Use the graph to find the work done in extending the spring up to point **B**.

work done ____________________ J

(3)

(d) Beyond point **A** the spring undergoes *plastic deformation*.

Explain the meaning of the term plastic deformation.

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(1)

(e) When the spring reaches an extension of 0.045 m, the load on it is gradually reduced to zero. On the graph above sketch how the extension of the spring will vary with load as the load is reduced to zero.

(2)

(f) Without further calculation, compare the total work done by the spring when the load is removed with the work that was done by the load in producing the extension of 0.045 m.

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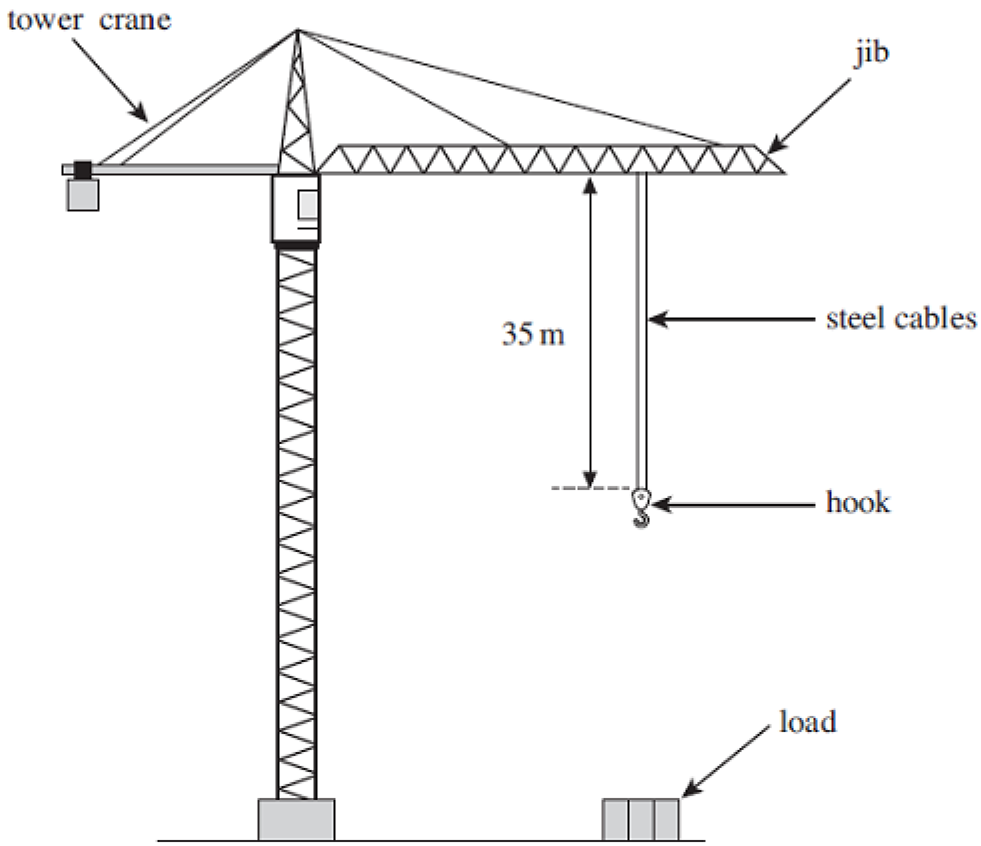
(1)

(Total 12 marks)

7 The diagram below shows a tower crane that has two identical steel cables. The length of each steel cable is 35 m from the jib to the hook.



(a) Each cable has a mass of 4.8 kg per metre. Calculate the weight of a 35 m length of one cable.

weight = ____________________ N

(2)

(b) The cables would break if the crane attempted to lift a load of 1.5×10^6 N or more. Calculate the breaking stress of **one** cable.

cross-sectional area of each cable = 6.2×10^{-4} m^2

breaking stress = ____________________ Pa

(2)

(c) When the crane supports a load **each** cable experiences a stress of 400 MPa. Each cable obeys Hooke's law. Ignore the weight of the cables.

Young modulus of steel = 2.1×10^{11} Pa

(i) Calculate the weight of the load.

weight = ____________________ N

(2)

(ii) The unstretched length of each cable is 35 m.

Calculate the extension of each cable when supporting the load.

extension = ____________________ m

(3)

(iii) Calculate the combined stiffness constant, *k*, for the **two** cables.

stiffness constant = ____________________ Nm^{-1}

(2)

(iv) Calculate the total energy stored in both stretched cables.

energy stored = ____________________ J

(2)

(Total 13 marks)

8 **Figure 1** shows car **A** being towed at a steady speed up a slope which is inclined at 5.0° to the horizontal. Assume that the resistive forces acting on car **A** are negligible.

Figure 1

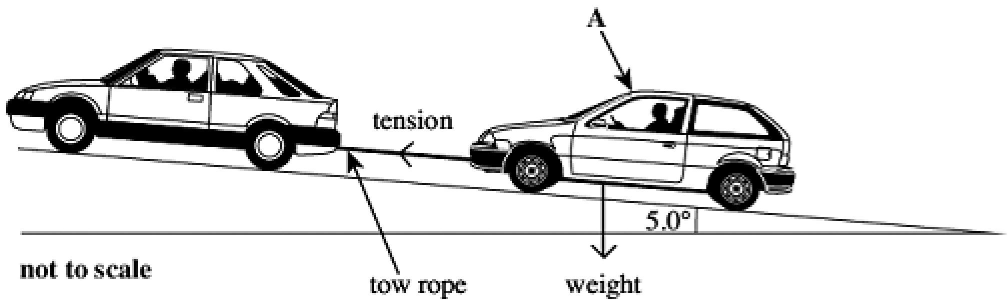
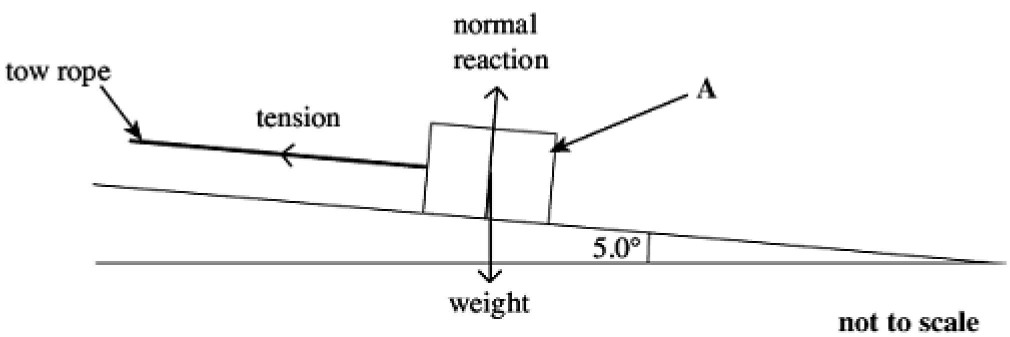


Figure 2 represents a simplified version of the forces acting on car **A** at the instant shown in **Figure 1**.

Figure 2



(a) (i) Car **A** has a mass of 970 kg. Show that the component of its weight that acts parallel to the slope is approximately 830 N.

(2)

(ii) Calculate the energy stored in the tow rope as car **A** is towed up the slope at a steady speed. The tow rope obeys Hooke's law and has a stiffness of 2.5×10^4 Nm^{-1}.

energy stored ____________________ J

(4)

(b) The tow rope is attached to a fixing point on car **A** using a metal hook. During the ascent of the slope the fixing point snaps and the metal hook becomes detached from car **A**. The metal hook gains speed due to the energy stored in the rope. State and explain how the speed gained by the hook would have changed if the rope used had a stiffness greater than 2.5×10^4 Nm^{-1}.

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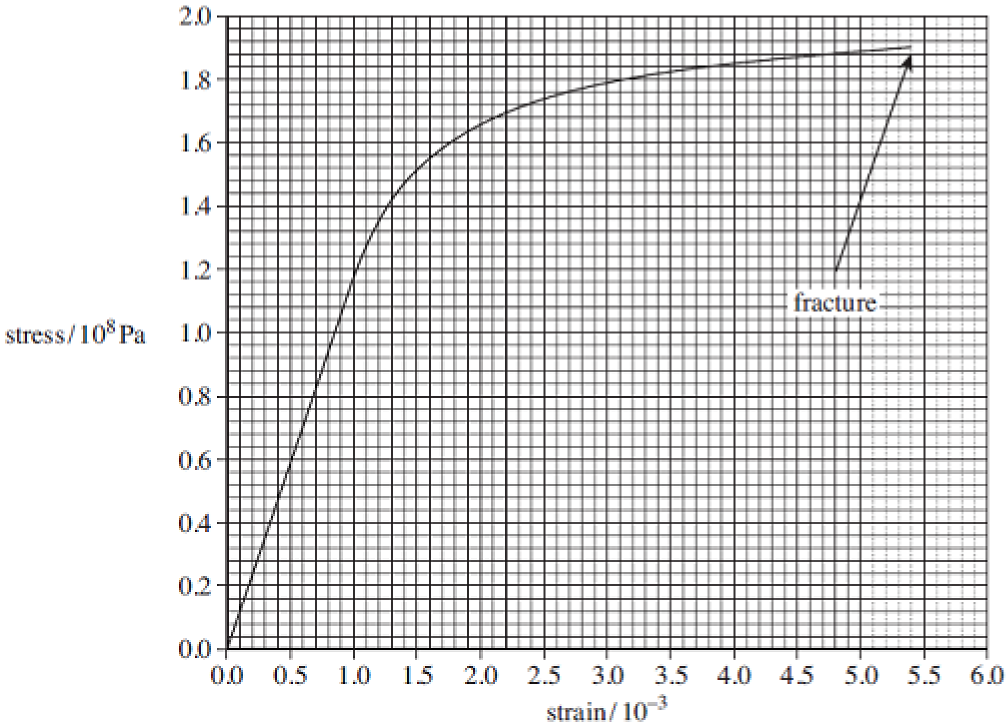
(3)

(Total 9 marks)

9 The figure below shows a stress-strain graph for a copper wire.



(a) Define tensile strain.

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(1)

(b) State the breaking stress of this copper wire.

answer = ______________________ Pa

(1)

(c) Mark on the figure above a point on the line where you consider plastic deformation may start.
Label this point **A**.

(1)

(d) Use the graph to calculate the Young modulus of copper. State an appropriate unit for your answer.

answer = ______________________

(3)

(e) The area under the line in a stress-strain graph represents the work done per unit volume to stretch the wire.

(i) Use the graph to find the work done per unit volume in stretching the wire to a strain of 3.0×10^{-3}.

answer = ______________________ J m^{-3}

(2)

(ii) Calculate the work done to stretch a 0.015 kg sample of this wire to a strain of 3.0×10^{-3}.

The density of copper = 8960 kg m^{-3}.

answer = ______________________ J

(2)

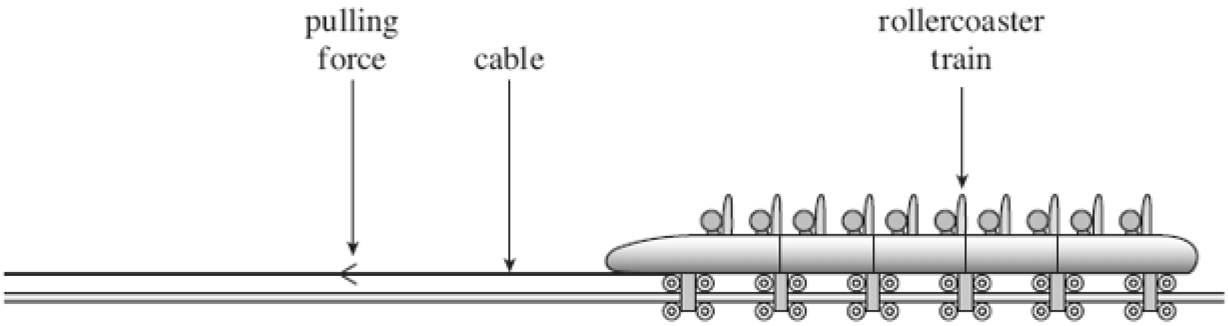
(f) A certain material has a Young modulus greater than copper and undergoes brittle fracture at a stress of 176 MPa.

On the figure above draw a line showing the possible variation of stress with strain for this material.

(2)

(Total 12 marks)

10 The figure below shows a rollercoaster train that is being accelerated when it is pulled horizontally by a cable.



(a) The train accelerates from rest to a speed of $58 ms^{-1}$ in 3.5 s. The mass of the fully loaded train is 5800 kg.

(i) Calculate the average acceleration of the train.

answer = ______________________ ms^{-2}

(2)

(ii) Calculate the average tension in the cable as the train is accelerated, stating an appropriate unit.

answer = ______________________

(3)

(iii) Calculate the distance the train moves while accelerating from rest to 58ms^{-1}.

answer = ______________________ m

(2)

(iv) The efficiency of the rollercoaster acceleration system is 20%.
Calculate the average power input to this system during the acceleration.

answer = ______________________ W

(3)

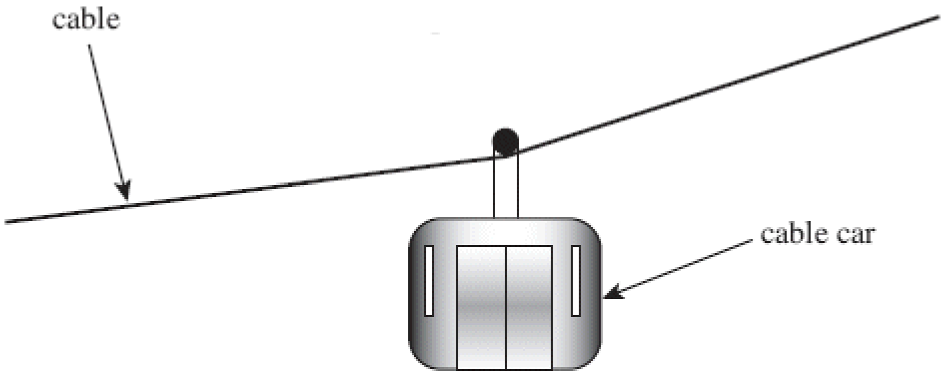
(b) After reaching its top speed the driving force is removed and the rollercoaster train begins to ascend a steep track. By considering energy transfers, calculate the height that the train would reach if there were no energy losses due to friction.

answer = ______________________ m

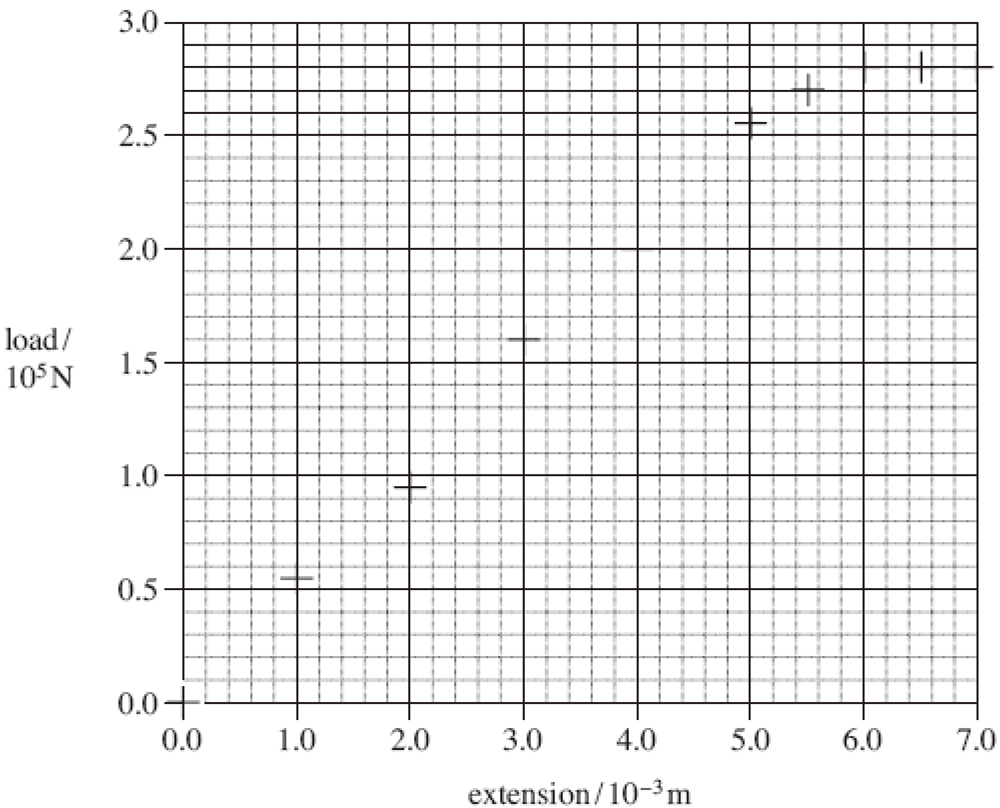
(3)

(Total 13 marks)

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



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



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

(2)

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

answer = ______________________ N m^{-1}

(2)

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

answer = ______________________

(3)

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

answer = ______________________m

(2)

(Total 9 marks)

12 A climber falls 2.3 m before being stopped by his climbing rope that is secured above him. The weight of the climber is 840 N.

(a) Calculate the loss in gravitational potential energy of the climber.

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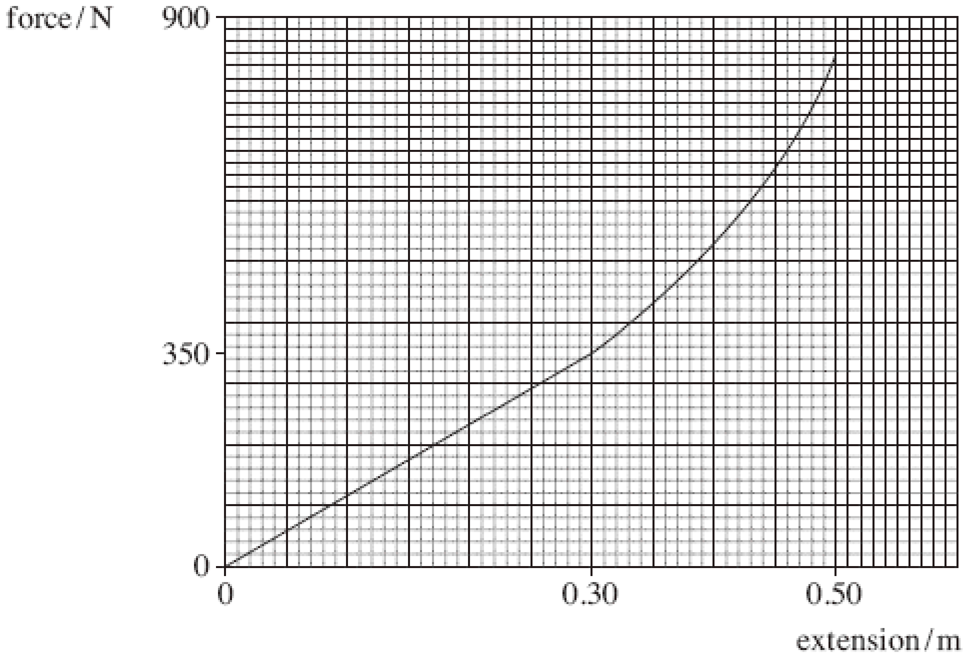
loss in potential energy ______________________ J

(2)

(b) The figure below shows a force-extension graph for the rope being used.



(b) (i) Use the figure above to find the stiffness of the rope when it is being used with forces up to 350 N. Give the appropriate unit.

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stiffness ______________________

unit ______________________

(4)

(ii) Use the figure above to determine the energy stored in the rope when it is stretched by 0.25 m.

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energy ______________________ J

(3)

(Total 9 marks)

13 A mountain walker of weight 750 N climbs a height of 300 m in 40 minutes.

(a) Calculate the average power required due to the gravitational force on the walker during the climb.

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average power ________________________ W

(3)

(b) The walker uses a spring loaded walking pole that changes in length by 15 mm when the full weight of the walker is applied to it.

Calculate the stiffness of the spring in the pole.
Give an appropriate unit for your answer.

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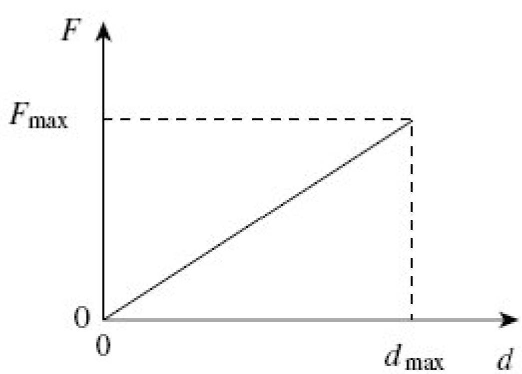
spring stiffness ________________________

unit ________________________

(3)
(Total 6 marks)

14 English longbows from the time of Henry VIII were found on board a sunken Tudor warship. The diagram below shows how the horizontal force, F, exerted by an archer on the bow string varies with the horizontal displacement, d, of the arrow as the bow is drawn.



(a) (i) Show that the energy stored in the bow is

$$\frac{1}{2} F_{max} d_{max}$$

where F_{max} is the maximum force in the bow and d_{max} is the maximum displacement of the bow string.

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(2)

(ii) Show that the maximum speed, v, with which an arrow can leave the bow is given by

$$v = \sqrt{\frac{F_{max} d_{max}}{m}}$$

where m is the mass of the arrow.

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(2)

(b) Each arrow had a mass of 0.060 kg and the bow string was displaced by a maximum of 0.60 m before releasing the arrow. The archers needed to exert a maximum force of 650 N.

(i) Show that the maximum speed of the arrow as it leaves the bow is about 80 m s^{-1}.

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(2)

(ii) State **one** reason why the speed of the arrow as it leaves the bow is likely to be less than 80 m s^{-1}.

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(1)

(c) The initial speed of an arrow as it leaves a bow is 65 m s^{-1}. When leaving the bow the arrow travels at an angle of 55° to the horizontal. Assume that the air resistance is negligible.

(i) Show that the vertical component of the initial speed of the arrow is about 53 m s^{-1}.

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(1)

(ii) The arrow is fired from ground level across a flat, level field.
Show that the arrow is in flight for about 11 s.

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(3)

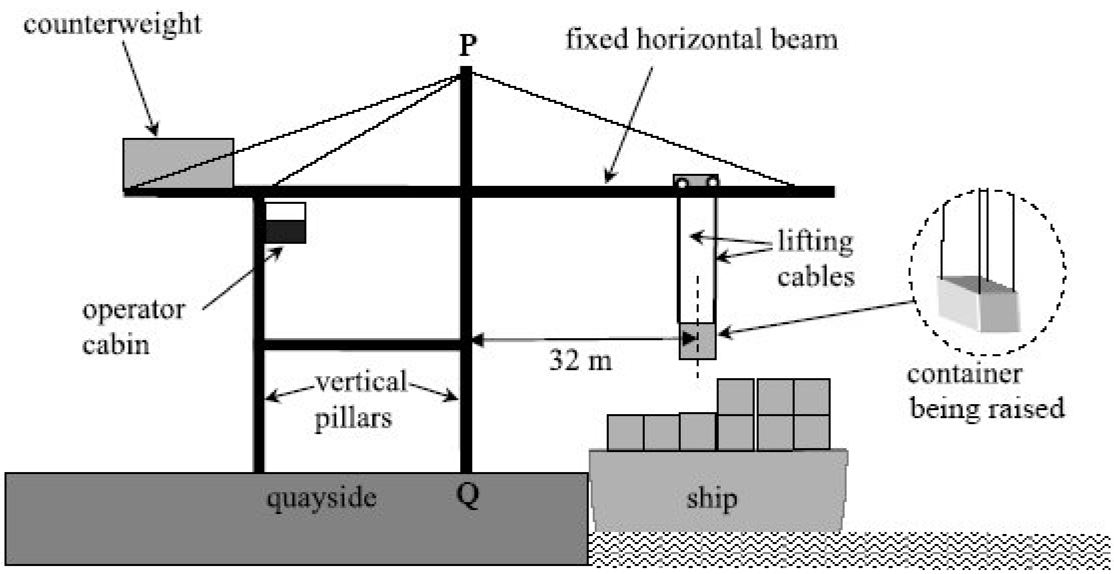
(iii) Calculate the horizontal distance travelled by the arrow when fired from level ground.

horizontal distance travelled ____________________ m

(2)

(Total 13 marks)

15 The diagram below shows a dockside crane that is used to lift a container of mass 22000 kg from a cargo ship onto the quayside. The container is lifted by four identical 'lifting' cables attached to the top corners of the container.



(a) When the container is being raised, its centre of mass is at a horizontal distance 32 m from the nearest vertical pillar **PQ** of the crane's supporting frame.

(i) Assume the tension in each of the four lifting cables is the same. Calculate the tension in each cable when the container is lifted at constant velocity.

answer ____________________ N

(2)

(ii) Calculate the moment of the container's weight about the point **Q** on the quayside, stating an appropriate unit.

answer ____________________

(3)

(iii) Describe and explain one feature of the crane that prevents it from toppling over when it is lifting a container.

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(2)

(b) Each cable has an area of cross–section of 3.8×10^{-4} m^2.

(i) Calculate the tensile stress in each cable, stating an appropriate unit.

answer ____________________

(3)

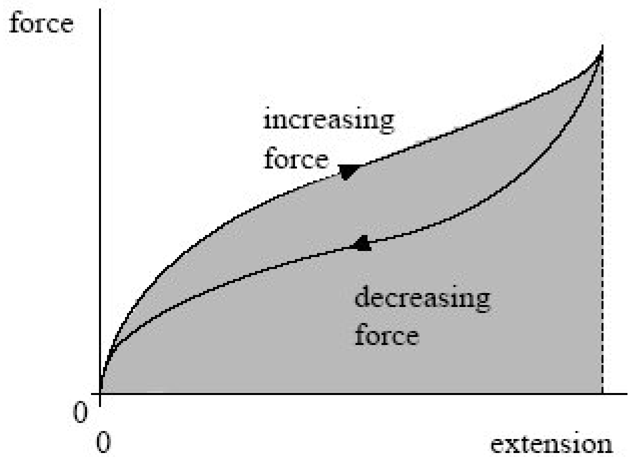
(ii) Just before the container shown in the diagram above was raised from the ship, the length of each lifting cable was 25 m. Show that each cable extended by 17 mm when the container was raised from the ship.

Young modulus of steel = 2.1×10^{11} Pa

(2)

(Total 12 marks)

16 A student investigated how the extension of a rubber cord varied with the force used to extend it. She measured the extension for successive increases of the force and then for successive decreases. The diagram below shows a graph of her results.



(a) (i) Give a reason why the graph shows the rubber cord does not obey Hooke's law.

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(1)

(ii) Give a reason why the graph shows the rubber cord does not exhibit plastic behaviour.

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(1)

(iii) What physical quantity is represented by the area shaded on the graph between the loading curve and the extension axis?

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(1)

(b) Describe, with the aid of a diagram, the procedure and the measurements you would make to carry out this investigation.

The quality of your written answer will be assessed in this question.

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(6)

(Total 9 marks)

17 (a) (i) Explain what is meant by the spring constant *k* of a spring.

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(ii) Give the unit of *k*.

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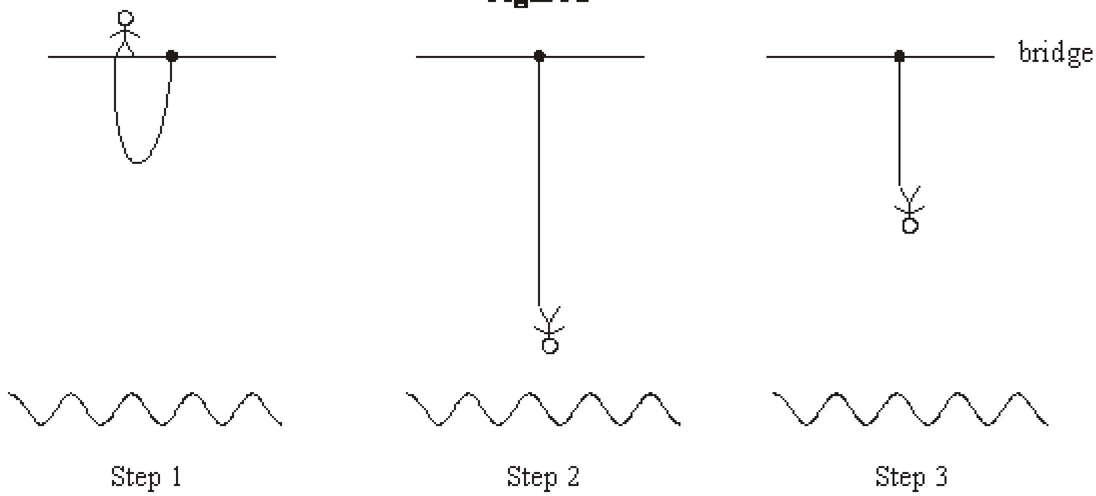
(2)

(b) The figure below shows the stages in a bungee jump.

Figure 5



In bungee jumping, the participant jumps from a high point attached to an elastic cord (step 1). After a period of free fall, the cord slows the fall of the jumper (step 2) with the system eventually undergoing oscillation (step 3).
A bungee jump is to be set up from a suspension bridge with the jumper of weight 700 N falling towards the river below. The roadway of the bridge is 76 m above the river surface. The bungee cord is adjusted so that the jumper just reaches the river surface at the bottom of the first oscillation.

The unstretched length of the elastic cord is to be 12 m.

(i) Calculate the time taken before the cord begins to stretch.

(ii) Show that, when jumping from the bridge to the river, the jumper loses about 53 kJ of gravitational potential energy.

(iii) Calculate the extension of the cord when the jumper is at the bottom of the first oscillation.

(iv) The gravitational potential energy is stored in the bungee cord.
Calculate the spring constant of the cord.

(v) Calculate the time period of oscillation of the jumper.

(12)

(c) (i) Calculate the tension in the cord when the jumper comes to rest for the first time.

(ii) Forces on astronauts and 'thrill seekers' are often specified in terms of the *g* force acting on the participants.

1*g* is equivalent to an acceleration of 9.8 m s^{-2}.

Calculate the maximum *g* force that acts on the jumper.

(iii) Hardened thrill seekers prefer their sports to generate 3*g* or more. Without carrying out detailed calculations, suggest the changes that would need to be made to the cord in order to produce a greater *g* force for the 700 N jumper.

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(6)

(Total 20 marks)

18 (a) (i) Describe the behaviour of a wire that obeys Hooke's law.

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(ii) Explain what is meant by the elastic limit of the wire.

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(iii) Define the Young modulus of a material and state the unit in which it is measured.

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(5)

(b) A student is required to carry out an experiment and draw a suitable graph in order to obtain a value for the Young modulus of a material in the form of a wire.
A long, uniform wire is suspended vertically and a weight, sufficient to make the wire taut, is fixed to the free end. The student increases the load gradually by adding known weights. As each weight is added, the extension of the wire is measured accurately.

(i) What other quantities must be measured before the value of the Young modulus can be obtained?

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(ii) Explain how the student may obtain a value of the Young modulus.

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(iii) How would a value for the elastic energy stored in the wire be found from the results?

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(6)

(Total 11 marks)

19 (a) State *Hooke's law* for a material in the form of a wire and state the conditions under which this law applies.

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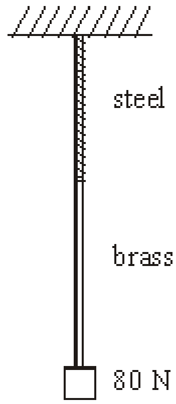
(2)

(b) A length of steel wire and a length of brass wire are joined together. This combination is suspended from a fixed support and a force of 80 N is applied at the bottom end, as shown in the figure below.



Each wire has a cross-sectional area of 2.4×10^{-6} m^2.

length of the steel wire = 0.80 m
length of the brass wire = 1.40 m
the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) Calculate the total extension produced when the force of 80 N is applied.

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(ii) Show that the mass of the combination wire = 4.4×10^{-2} kg.

density of steel = 7.9×10^3 kg m^{-3}
density of brass = 8.5×10^3 kg m^{-3}

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(7)

(c) A single brass wire has the same mass and the same cross-sectional area as the combination wire described in part (b). Calculate its length.

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(2)

(Total 11 marks)

20 (a) When determining the Young modulus for the material of a wire, a *tensile stress* is applied to the wire and the *tensile strain* is measured.

(i) State the meaning of

tensile stress ____

____

tensile strain ____

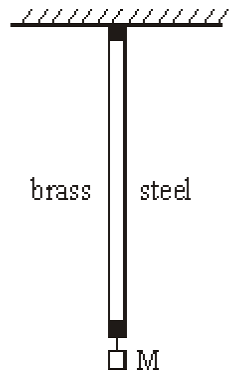
____

(ii) Define the Young modulus ____

____

(3)

(b) The diagram below shows two wires, one made of steel and the other of brass, firmly clamped together at their ends. The wires have the same unstretched length and the same cross-sectional area.
One of the clamped ends is fixed to a horizontal support and a mass M is suspended from the other end, so that the wires hang vertically.



(i) Since the wires are clamped together the extension of each wire will be the same. If E_S is the Young modulus for steel and E_B the Young modulus for brass, show that

$$\frac{E_S}{E_B} = \frac{F_S}{F_B},$$

where F_S and F_B are the respective forces in the steel and brass wire.

____

____

____

(ii) The mass M produces a total force of 15 N. Show that the magnitude of the force F_S = 10 N.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

____

____

____

____

(iii) The cross-sectional area of each wire is 1.4×10^{-6} m^2 and the unstretched length is 1.5 m. Determine the extension produced in either wire.

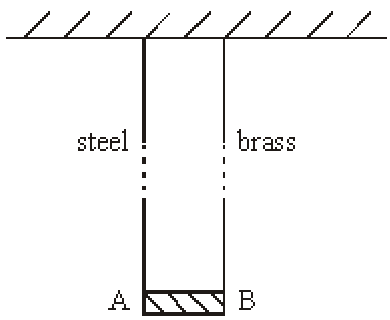
(6)

(Total 9 marks)

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

(2)

(b) A rigid bar AB of negligible mass, is suspended horizontally from two long, vertical wires as shown in the diagram. One wire is made of steel and the other of brass. The wires are fixed at their upper end to a rigid horizontal surface. Each wire is 2.5 m long but they have different cross-sectional areas.



When a mass of 16 kg is suspended from the centre of AB, the bar remains horizontal.

the Young modulus for steel = 2.0×10^{11} Pa
the Young modulus for brass = 1.0×10^{11} Pa

(i) What is the tension in each wire?

(ii) If the cross-sectional area of the steel wire is 2.8×10^{-7} m^2, calculate the extension of the steel wire.

(iii) Calculate the cross-sectional area of the brass wire.

___

___

___

(iv) Calculate the energy stored in the steel wire.

___

___

(7)

(c) The brass wire is replaced by a steel wire of the same dimensions as the brass wire. The same mass is suspended from the midpoint of AB.

(i) Which end of the bar is lower?

___

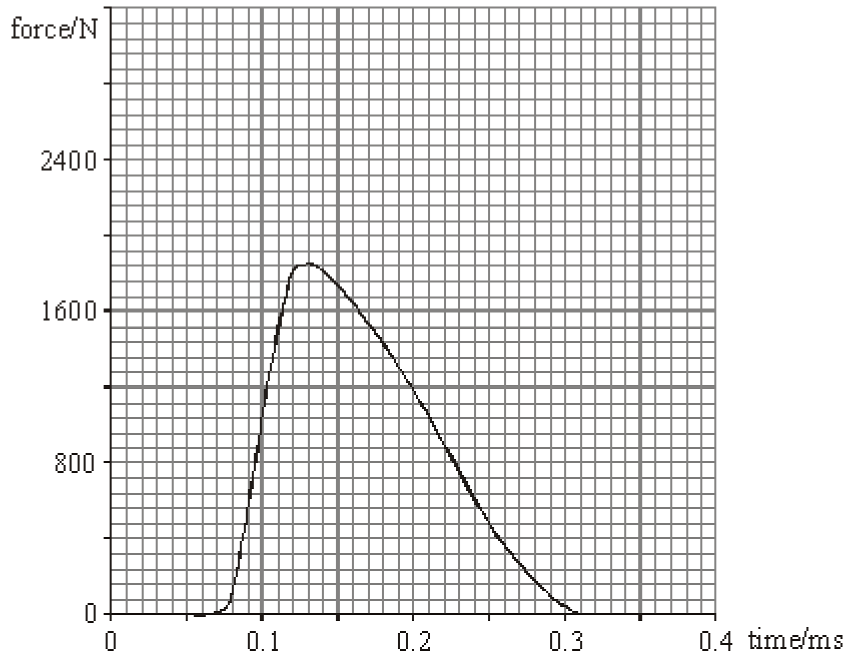
(ii) Calculate the vertical distance between the ends of the bar.

___

___

(2)
(Total 11 marks)

22 The diagram below shows how the impact force on the heel of a runner's foot varies with time during an impact when the runner is wearing cushioned sports shoes.



(a) Estimate the maximum stress on the cartilage pad in the knee joint as a result of this force acting on the cartilage pad over a contact area of 550 mm^2.

____

____

____

____

____

____

____

(4)

(b) On the diagram above, sketch the graph of force against time you would expect to see if a sports shoe with less cushioning had been used.

(3)

(Total 7 marks)

23 (a) Define the *density* of a material.

____

____

(1)

(b) Brass, an alloy of copper and zinc, consists of 70% **by volume** of copper and 30% **by volume** of zinc.

density of copper $= 8.9 \times 10^3$ kg m^{-3}
density of zinc $= 7.1 \times 10^3$ kg m^{-3}

(i) Determine the mass of copper and the mass of zinc required to make a rod of brass of volume 0.80×10^{-3} m^3.

(ii) Calculate the density of brass.

(4)
(Total 5 marks)

24 A uniform wooden beam of mass 35.0 kg and length 5.52 m is supported by two identical vertical steel cables **A** and **B** attached at either end, as shown in **Figure 1**.

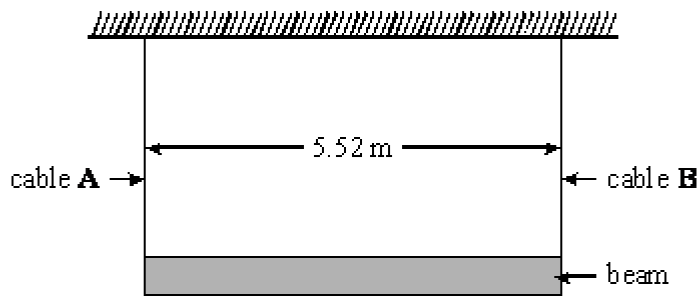


Figure 1

(a) Calculate

(i) the weight of the beam,

(ii) the tension in each cable.

(2)

(b) Each unstretched cable has a diameter of 8.26 mm and a length 2.50 m. Calculate the extension of each cable when supporting the beam.

The Young modulus for steel = 2.10×10^{11} Pa

____

____

____

____

(4)

(c) An object of mass 20.0 kg is hung from the beam 1.00 m from cable **A**, as shown in **Figure 2**.

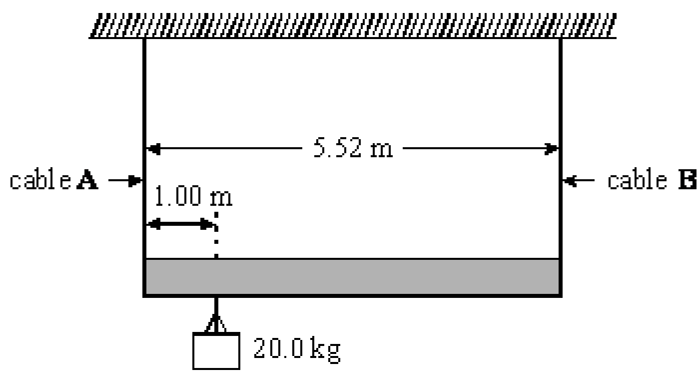


Figure 2

(i) Show that the new tension in cable **A** is 332 N.

____

____

____

____

____

____

____

____

(ii) Calculate the new tension in cable **B**.

____

____

____

(6)

(Total 12 marks)

25 (a) (i) Define the Young modulus for a material.

____

____

(ii) Explain what is meant by the *elastic limit* for a wire.

____

____

(2)

(b) A wire supported at its upper end, hangs vertically. The table shows readings obtained when stretching the wire by suspending masses from its lower end.

load / N	0	2.0	4.0	6.0	7.0	8.0	9.0	10.0	10.5
extension / mm	0	1.2	2.4	3.6	4.2	4.9	5.7	7.0	8.0

(i) Plot a graph of load against extension.

(One sheet of graph paper should be provided)

(ii) Indicate on your graph the region where Hooke's law is obeyed.

(iii) The unstretched length of the wire is 1.6 m and the area of cross-section 8.0×10^{-8} m^2. Calculate the value of the Young modulus of the material.

____

____

____

____

____

____

(8)

(c) (i) By considering the work done in stretching a wire, show that the energy stored is given by $\frac{1}{2}Fe$, where F is the force producing an extension e.

(ii) Calculate the energy stored in the wire in part (b) when the extension is 4.0 mm.

(4)

(Total 14 marks)

26 As part of a quality check, a manufacturer of fishing line subjects a sample to a tensile test. The sample of line is 2.0 m long and is of constant circular cross-section of diameter 0.50 mm. Hooke's law is obeyed up to the point when the line has been extended by 52mm at a tensile stress of 1.8×10^8 Pa.
The maximum load the line can support before breaking is 45 N at an extension of 88 mm.

(a) Calculate

(i) the value of the Young modulus,

(ii) the breaking stress (assuming the cross-sectional area remains constant),

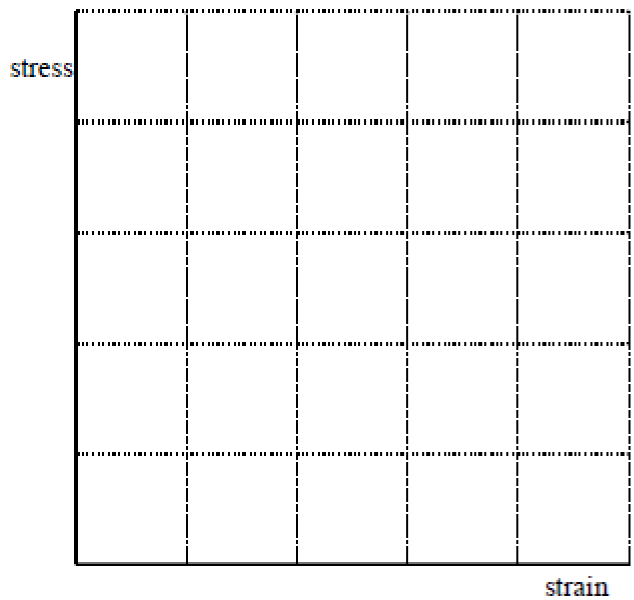
(iii) the breaking strain.

(5)

(b) Sketch a graph on the axes below to show how you expect the tensile stress to vary with strain. Mark the value of stress and corresponding strain at

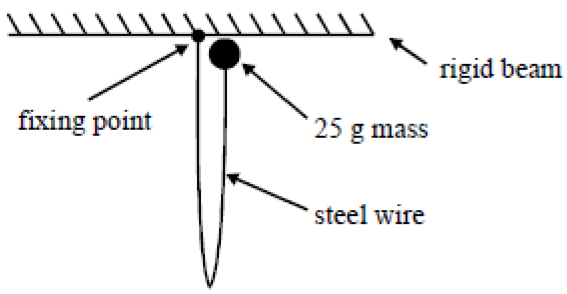
(i) the limit of Hooke's law,

(ii) the breaking point.



(4)
(Total 9 marks)

27 One end of a steel wire of length 1.2 m and 2.0 mm diameter is attached to a rigid beam. A 25 g mass is attached to the free end of the steel wire and placed against the underside of the beam as shown.



The 25 g mass is released and falls freely until the wire becomes taut. The kinetic energy of the falling mass is converted to elastic potential energy in the wire as the wire extends to a maximum of 1.0 mm. Energy converted to other forms is negligible.

For **maximum** extension of the wire, complete parts (a) to (e).

(a) Show that the elastic potential energy stored by the extended wire is 0.29 J.

___

___

(b) Calculate the tension in the wire.

(c) Calculate the stress in the wire.

(d) Calculate the strain of the wire.

(e) Hence, calculate the Young modulus for the steel of the wire.

(Total 9 marks)

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

tensile stress ______

tensile strain ______

(3)

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

quantity 1 ____

method of measurement ____

____

quantity 2 ____

method of measurement ____

____

(4)

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

(2)
(Total 9 marks)

29 (a) State what is meant by the *yield stress* of a material.

____

____

____

____

(3)

(b) A steel piano wire has a diameter of 1.8×10^{-3} m and a length of 1.55 m. When tightened to emit a note of the required frequency it extends by 1.3×10^{-3} m. The Young modulus of the steel is 2.1×10^{11} Pa.

(i) Calculate the force exerted on the frame of the piano by this wire.

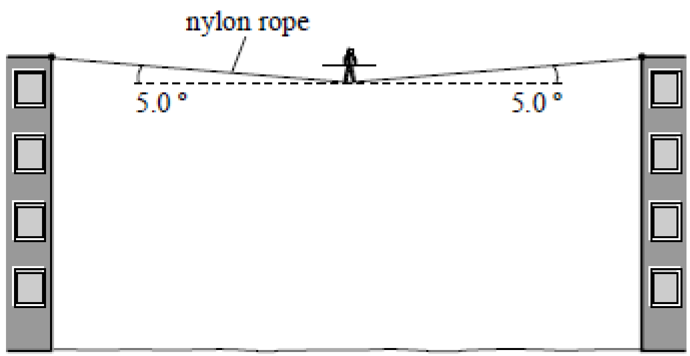
(3)

(ii) Calculate the strain energy stored in this stretched wire.

(2)

(Total 8 marks)

30 The figure below shows a person of weight 800 N, crossing the gap between two buildings on a nylon rope.



Before the crossing commenced the rope was horizontal and just taut. When the person is halfway across the rope sags by 5.0°.

(a) Explain briefly why, however taut the rope is, the rope must sag when the person is on it.

____

____

____

(1)

(b) By calculation or scale drawing, determine the tension in the rope when the person is half way across.

(3)

(c) The nylon rope has an ultimate tensile stress of 7.0×10^7 Pa. Calculate the minimum diameter of the rope that could be used.

(3)

(Total 7 marks)

Mark schemes

1 (a) tensile stress is the force exerted per/over <u>cross sectional area</u> ✓

can use equation but must define terms

1

tensile strain is the extension per/over <u>original length</u> ✓

NOT compared to

1

(b) material is brittle ✓

2nd mark dependent on first

1

shown on graph by little or no of plastic behaviour OR by linear behaviour/straight line to breaking stress ✓
OR
material has high Young modulus OR material is stiff ✓
shown on graph by large gradient/steep line (compared to other materials) ✓

1

(c) area = $\pi \times (1.5 \times 10^{-4})^2/4 = 1.77 \times 10^{-8}$ ✓

1

tensile force = 1.77×10^{-8} ✓

1

= 23 (N) ✓

1

if use diameter as radius −1

if use incorrect formula (d^2 $2\pi r$ etc. −2)

range 22.5 – 24

power of ten error −1

if calculated area incorrectly get following answers

diameter as radius = 92 (2 marks)

d^2 = 7.3 (1 mark)

$2\pi r$ = 610 000 (1 mark)

if use d for area then zero

(d) **The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist marking this question.**

Level 3
Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application and explanation why at least one other material would be rejected for **each** application.

6

Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application and explanation why at least one other material would be rejected for **one** application.

5

The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.

Level 2
Correct material selected for **one** application (B/C for lift and D for bungee). **One** reason for choice given for one application and explanation why at least one other material would be rejected for **one** application.

4

Correct material selected for **one** application (B/C for lift and D for bungee). **One** reason for choices given application.
OR
Correct materials selected for **each** application (B/C for lift and D for bungee). One reason for choices given for **each** application

3

The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.

Level 1
No correct material selected but at least **two** properties necessary for an application given.

2

No correct material selected but at least **one** property necessary for an application given.

1

The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.

Level 0
No correct material selected and no properties necessary for an application given
The student's presentation, spelling and grammar seriously obstruct understanding.

0

The following statements may be present for cable supporting a lift

material B/C is used for the lift because it has a high breaking stress and a high Young modulus

material A not chosen because lower breaking stress

material A not chosen because fails without warning

material C not chosen because has a lower breaking stress

material D not chosen as larger increase in strain for a given increase in stress

material D not chosen as low breaking stress.

material D a given stress produces a large strain meaning large extension

The following statements may be present for rope or cable used for bungee jump

material D chosen as due large strain for given stress
time taken to come to rest lengthens

material D is chosen because D can store a large amount of energy before failure

not A ,B or C because high Young Modulus so sudden stop resulting in large forces

not A as brittle and therefore limited strain and sudden failure

not C because requires a large strain before plastic behaviour

not C because if behaves plastically will not return to original length

[13]

2 (a) energy cannot be created or destroyed ✓
it can only be transferred / changed / converted from one form to another ✓

'Transformed' can be taken to mean transferred from one form to another.

2

(b) (i) (using $E_k = ½ mv^2$)
$2.2 = ½ \times 0.40 \times v^2$
$v = 3.3$ (ms^{-1}) ✓

Ignore errors in 3 sig fig.

Answer only can gain mark.

1

(ii) (using work done = $F \times s$) 2.2 = F × 1.2 ✓ (F = 1.83 N) or
(using $a = (v^2 – u^2) / 2 s$)
$a = (0^2 – 3.32^2) / 2 \times 1.2 = (-)\ 4.59$ (m s^{-1})
(F = ma) = 0.4 × 4.59 ✓ = (1.84 N)

A substitution of numbers are necessary for the mark

1

(iii) (work done in moving 0.2 m) = 1.8 × 0.2 (J) ✓ (= 0.36 J)
(allow ecf (bii) × 0.2)
total work done = 2.2 + 0.36 = 2.6 ✓ (same answer is achieved if F = 2N)
J or joule ✓

3

(iv) (use of energy = ½ F x)
2.6 = ½ F_{max} 0.2
F_{max} = 26 N ✓
(allow ecf 10 × (biii))

Allow mark for answer only even for ecf.

1

[8]

3

(a) Use of Young Modulus = $\frac{\text{tensile stress}}{\text{tensile strain}}$ ✓

The first mark is for calculating the tensile stress

1

To give tensile stress = 2 × 10^{11} × 3.0 × 10^{-4} = 6.0 × 10^{7} ✓

The second mark is substituting into the tensile force equation

1

Use of tensile stress = $\frac{\text{tensile force}}{\text{cross sectional area}}$

To give tensile force = 6.0 × 10^{7} × 7.5 × 10^{-3} = 4.5 × 10^{5} N ✓

The third mark is for the correct answer

1

(b) Use of strain = extension / original length

To give extension = 3.0 × 10^{-4} × 45 = 1.4 × 10^{-2} m

(1.35 × 10^{-2}) ✓

The first mark is for calculating the extension

1

Use of energy stored = ½ F e

To give

Energy stored = ½ × 4.5 × 10^5 × 1.4 × 10^{-2}

= 3.2 × 10^3 J ✓

(3.04 × 10^3)

The second mark is for the final answer

1

(c) Temperature change = pre-strain / pre-strain per K

= 3.0 × 10^{-4} / 2.5 × 10^{-5} = 12 K✓

The first mark is for the temperature change

1

Temperature = 8°C + 12 = 20 °C ✓

The second mark is for the final answer

1

(d) So that the rail is not always under stress✓

1

as the rail spends little time at the highest temperature✓

Or

To reduce the average stress the rail is under ✓

as zero stress will occur closer to average temperature / the rail will be under compressive / tensile stress at different times✓

1

[9]

4 (a) P at the end of linear section ✓

1

(b) Measure original length and diameter ✓

1

Determine gradient of linear section to obtain F / extension ✓

1

$$E = \frac{F}{e} \times \frac{length}{\pi\left(\frac{d}{2}\right)^2}$$ ✓

1

Alternative:

Convert to stress–strain graph and determine gradient.

(c) Line from A

Parallel to straight section of original

Ending at horizontal axis ✓

1

(d) Plastic deformation has produced permanent extension / re-alignment of bonds in material hence intercept non-zero ✓

1

Gradient is same because after extension identical forces between bonds ✓

1

(e) 0.2% is a strain of 0.002

Stress = $2.0 \times 10^{11} \times 0.002$ =

1

4×10^{8} ✓

$$Force\left(=\frac{\pi\left(6\times10^{-3}\right)^2}{4}\times 4\times 10^{8}\right)$$ ✓

1

= 11.3 kN ✓

1

(f) Maximum force = 11300 N

Weight of mass = 600 x 9.81 = 5886 N ✓

1

Accelerating force must be less than

11300 – 5886 = 5423 N ✓

1

a (= F / m = 5423 / 600)

= 9.0 m s^{-2} ✓

1

(g) To lift double the load at the same acceleration, would require double the force, ✓

The first mark is for discussing the effect on the force

1

To produce the same strain either use:

- double the diameter of wire – so the stress stays the same and therefore the strain is the same for the same wire, ✓

1

- a wire with double the Young modulus – so that double the stress produces the same strain for the same diameter. ✓

1

The other two are for discussing the two alternative methods of keeping the strain the same

[16]

5 (a) (i) 11 (m)

B1

1

(ii) Use of $F = k\Delta L$ or $W = mg$

Allow use of $\Delta L = 12$ *m*

C1

3400 (N)

A1

2

(b) Sets $mg = k\Delta L$

C1

1.9 (m)

A1

2

(c) Correct use of $W = ½k\Delta L^2$ or $½F\Delta L$

ΔL = 5 m

C1

Correct use of $\Delta GPE = mg\Delta h$

Δh = 25 m

C1

States or uses $(mg\Delta h) – (½ k\Delta L^2) = ½mv^2$

C1

19 (m s^{-1}) cnao

A1

4

(d) Same kinetic energy when rope begins to stretch

B1

More work done per unit extension / stops in shorter distance

"Shorter time" gets no credit

B1

Increases force on jumper (increasing the risk of injury)

B1

3

[12]

6 (a) Force proportional to extension ✓

up to the limit of proportionality (accept elastic limit) ✓ dependent upon award of first mark

Symbols must be defined
Accept word equation
allow 'F=kΔL (or F ∝ ΔL) up to the limit of proportionality ' ***for the second mark only***
allow stress ∝ strain up to the limit of proportionality' ***for the second mark only***

2

(b) Gradient clearly attempted / use of $k=F/\Delta L$ ✓

k = 30 / 0.026 = 1154
or 31 / 0.027 = 1148

correct values used to calculate gradient with appropriate 2sf answer given (1100 or 1200)

1100 or 1200 with no other working gets 1 out of 2

OR 1154 ± 6 seen

Do not allow 32/0.0280 or 33/0.0290 (point A) for second mark.

AND load used >= 15 ✓ (= 1100 or 1200 (2sf))

32 / 0.028 is outside tolerance. 32/0.0277 is just inside.

Nm^{-1} / N / m (newtons per metre) ✓ (not n / m, n / M, N / M)

3

(c) any area calculated or link energy with area / use of 1 / 2FΔL ✓

(or 0.001 Nm for little squares)

35 whole squares, 16 part gives 43 ± 1.0
OR equivalent correct method to find whole area ✓

0.025 Nm per (1cm) square × candidates number of squares and correctly evaluated
OR (= 1.075) = 1.1 (J) (1.05 to 1.10 if not rounded) ✓

3

(d) permanent deformation / permanent extension ✓

Allow: 'doesn't return to original length'; correct reference to 'yield'
*e.g. allow '**extension beyond the yield point**'*
do not accept: 'does not obey Hooke's law' or 'ceases to obey Hooke's law',

1

(e) any line from B to a point on the x axis from 0.005 to 0.020 ✓

straight line from B to x axis (and no further) that reaches x axis for 0.010<=ΔL<= 0.014 ✓

2

(f) work done by spring < work done by the load

Accept 'less work' or 'it is less' (we assume they are referring to the work done by spring)

1

[12]

7 (a) ($W = mg$)
= 4.8 × 35 × 9.81 ✓
=1600 (1648 N) ✓

Allow g=10 : 1680 (1700 N)
g = 9.8 → 1646 N
max 1 for doubling or halving.
Max 1 for use of grammes

2

(b) (stress = tension / area)

For first mark, forgive absence of or incorrect doubling / halving.

= (0.5 ×) 1.5 × 10^6 / 6.2 × 10^{-4} OR = 1.5 × 10^6 / (2 ×) 6.2 × 10^{-4} ✓
= 1.2 × 10^9 (1.21 GPa) ✓

Forgive incorrect prefix if correct answer seen.

2

(c) (i) (weight = stress × area)

max 1 mark for incorrect power of ten in first marking point

= 400 ×(10^6) × 6.2 × 10^{-4} (= 248 000 N)✓

max 1 mark for doubling or halving both stress and area

(× 2 =) 5.0 × 10^5 (496 000 N)✓

Forgive incorrect prefix if correct answer seen.Look out for YM ÷ 400k Pa which gives correct answer but scores zero.

2

(ii) $\Delta L = \frac{F\ L}{A\ E}$ **OR** correct substitution into a correct equation (forgive incorrect doubling or halving for this mark only ✓

OR alternative method:
strain = stress / E
then ΔL = L × strain

$= \frac{(\text{Ans 4ci}/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}}$ **OR** $\frac{\text{Ans 4ci} \times 35}{2 \times 6.2\times10^{-4} \times 2.1\times 10^{11}}$ ✓ ecf from 4ci

If answer to 4ci is used, it must be halved, unless area is doubled, for this mark

$(= \frac{(4.96\times10^5/2) \times 35}{6.2\times10^{-4} \times 2.1\times 10^{11}} =)$ 6.7×10^{-2} (6.667×10^{-2} m) ✓ ecf from 4ci

Any incorrect doubling or halving is max 1 mark.
Allow 0.07

3

(iii)

$(k = \frac{F}{\Delta L})$

$= \frac{2 \times 248\ 000}{6.667\times10^{-2}}$ OR correct substitution into *F=kΔL* ✓ ecf ci and cii (answer 4c(i) ÷ answer 4c(ii))

Allow halving extension for force on one cable

= 7.4(4)× 10^6 ✓(Nm^{-1})

Correct answer gains both marks

2

(iv) $\left(E = \frac{1}{2}F\Delta L \text{ or } E = \frac{1}{2}k\Delta L^2 \right)$

Correct answer gains both marks

$= ½ \times 496\ 000 \times 6.667 \times 10^{-2}$ OR $½ \times 7.4(4) \times 10^{6} \times (6.667 \times 10^{-2})^2$ ✓ ecf ci, cii, ciii

$= 1.6(5) \times 10^{4}$ (J)✓

Forgive incorrect prefix if correct answer seen.

Doubling the force gets zero.

2

[13]

8 (a) (i) uses trigonometry *(mg sin*5 *or mg cos*85 seen)

B1

829.3 / 828.5 (N) at least 3 sf

B1

2

(ii) tension = 830 (N)

C1

E= ½ *F*Δ*L* **and** *F* = *k* Δ*L* identified / or combined to *E*= ½ (F^2/k)

C1

correct sub condone power 10 error

C1

13.8 (J) range 13.9 to 13.7

A1

4

(b) lower speed

B1

less extension

B1

less energy stored (in rope)

B1

3

[9]

9 (a) extension divided by its **original** length ✓

do not allow symbols unless defined ✓

1

(b) 1.9×10^8 (Pa) ✓

1

(c) point on line **marked 'A'** between a strain of 1.0×10^{-3} and 3.5×10^{-3} ✓

1

(d) clear evidence of gradient calculation for **straight section**
eg $1.18\ (1.2) \times 10^8/1.0 \times 10^{-3}$ ✓

= 120 GPa **and stress used ≥ 0.6×10^8 Pa** ✓ allow range 116 − 120 GPa

Pa or Nm^{-2} or N/m^2 ✓

3

(e) (i) clear attempt to calculate correct area (evidence on graph is sufficient) ✓

(32 whole squares + 12 part/2 = 38 squares)

(38 × 10000 =) 380000 ($J\ m^{-3}$) ✓ allow range 375000 to 400000

2

(ii) $V = m/\rho$ **or** 0.015/8960 **or** 1.674×10^{-6} (m^3) ✓

$380\ 000 \times 1.674 \times 10^{-6} = 0.64$ (0.6362 J) ✓ ecf from ei

2

(f) straight line passing through origin (small curvature to the right only above 160 MPa is acceptable) end at 176 MPa ✓ (allow 174 to 178)

straight section to the left of the line for copper (steeper gradient) ✓

2

[12]

10 (a) (i) $(a = \frac{v-u}{t}) = \frac{58}{3.5}$ ✓ = 17 ($m\ s^{-2}$) ✓

2

(ii) (F = ma) = 5800 × 16.57 ecf (a)(i) ✓

= 96000 ✓

allow 98600 or 99000 for use of 17

N ✓

3

(iii) $(s = \frac{1}{2}(u + v)t) = \frac{1}{2} \times 58 \times 3.5$ ✓

= 100 (101.50, 102, accept 101 m) ✓

or use of $v^2 = u^2 + 2as$ (= 101 m. 98.9 for use of 17) 2

or $s = ut + \frac{1}{2}at^2$ (= 101.7, use of 17 gives 104) (ecf from (a)(i))

2

(iv) ($W = Fs$) (a)(ii) × (a)(iii) or use of $\frac{1}{2}mv^2$ ✓ (= 13.6 to 14.7)

$\left(P = \frac{Fs}{t}\right) = \frac{96106 \times 101.5}{3.5}$ ✓ = 2.8M (W) ecf (a)(ii), (a)(iii)

or use of $P = \frac{Fv}{2}$ their answer × 5 ✓ = 14,000,000 = 14 M (W)

3

(b) $\frac{1}{2}(m)v^2 = (m)g(\Delta)h$ **or** (loss of) KE = (gain in) PE ✓

allow their work done from (iv) used as KE

$h = \frac{1}{2}\frac{v^2}{g}$ **or** $h = \frac{1}{2} \times \frac{58^2}{9.81}$ ✓

accept use of kinematics equation

= 170 ✓

3

[13]

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

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

2

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

= 5.1 × 10^7

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

allow error in calculation ± 2%

2

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

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

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

3

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

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

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

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

2

[9]

12 (a) 840 × 2.3

C1

1900 (J)/1930 (J)

A1

2

(b) (i) uses gradient

C1

data extraction correct –350 N, 0.3 m

C1

1170

A1

N m^{-1}

B1

4

(ii) uses area

B1

6.5 to 7.0 squares or 1 square is equivalent to
5 J/area is ½ base × height

B1

32.5 to 35 (J)

B1

3

[9]

13 (a) conversion to seconds seen (60 × 40)
or velocity = 300/40 seen
or energy gain in 40 mins = 750 × 300 = 2.25×10^5 (J)

C1

use of $p = Fv$
power = 750 × (300)/(2400)
or 750 × their velocity (eg seen 750 × 300/40)

C1

94 (93.8) (W) cnao

A1

3

(b) $k = \frac{750}{15 \times 10^{-3}}$ (allow use of m or mm) use of $k = F/\Delta L$

C1

5.0×10^4

A1

N m^{-1} (allow if calculation not attempted or incomplete)

A1

3

[6]

14 (a) (i) area under graph = energy stored

B1

area = ½ base × height

B1

or quotes ½ $F\Delta l$ **and** identifies F as F_{max} and Δl as d_{max}

B1

2

(ii) equates ½ $F\Delta l$ and ½ mv^2 clearly

M1

$v^2 = F_{max}d_{max}/m$ shown

A1

2

(b) (i) √650*0.60/0.060

M1

81(80.6) (m s^{-1})

A1

2

(ii) **max 1 from**

friction between arrow and bow during release

B1

bow moves during release so absorbs some energy in kinetic form flight feathers provide drag

B1

uneven stretch/distortion in bow during draw

B1

1

(c) (i) 65cos (35°) = 53.2 (m s^{-1})

B1

1

(ii) 0 = 53.2 – 9.8 × t seen condone sign errors

B1

t = 5.4 s to top of motion

B1

in air for 10.8/10.9 s

B1

or 0 = 53t – ½ × 9.8 × t^2 seen

condone sign errors

B1

53t = ½ × 9.8 × t^2

sign working must be correct

B1

in air for 10.8 s

must be from correct working

B1

3

(iii) s = 65 × cos (55°) × 10.8

C1

400 (m) 2 sf/405 (m) sf/410 m from 11 s

A1

2

[13]

15 (a) (i) weight of container (= mg = 22000 × 9.8(1)) = 2.16 × 10^5 (N) **(1)**

tension (= ¼ *mg*) = (5.39) 5.4 × 10^4 (N) or divide a weight by 4 **(1)**

(ii) moment (= force × distance) = 22000 *g* × 32 **(1)** ecf weight in (a) (i)

= 6.9 or 7.0 × 10^6 **(1)** **N m** or correct base units **(1)** not J, nm, NM

(iii) the counterweight **(1)**

provides a (sufficiently large) anticlockwise moment (about Q) or moment in opposite direction (to that of the container to prevent the crane toppling clockwise) **(1)**

or
left hand pillar pulls (down) **(1)**
and provides anticlockwise moment

or
the centre of mass of the crane(‘s frame and the counterweight) is between the two pillars **(1)**

which prevents the crane toppling **clockwise**/to right **(1)**

7

(b) (i) (tensile) stress $\left(= \frac{\text{tension}}{\text{csa}}\right) = \frac{5.4 \times 10^4}{3.8 \times 10^{-4}}$ ecf (a) (i) **(1)**

$= 1.4(2) \times 10^8$ **(1) Pa** (or N m^{-2}) **(1)**

(ii) extension = $\frac{\text{length} \times \text{stress}}{E}$ or $\frac{FL}{EA}$ **(1)**

$= \frac{25 \times 1.4 \times 10^8}{2.1 \times 10^{11}}$ and (= 1.7×10^{-2} m) = 17 (mm) **(1)**

5

[12]

16 (a) (i) the lines are not straight (owtte) **(1)**

(ii) there is no permanent extension **(1)**
(or the overall/final extension is zero or the unloading curve returns to zero extension)

(iii) (area represents) **work done** (on or energy transfer to the rubber cord) or **energy** (stored) **(1)** not heat/thermal energy

3

(b) the mark scheme for this part of the question includes an overall assessment for the Quality of Written Communication

QWC	descriptor	mark range
good-excellent	The candidate provides a comprehensive and coherent description which includes nearly all the necessary procedures and measurements in a logical order. The descriptions should show awareness of how to apply a variable force. They should know that measurements are to be made as the force is increased then **as it is decreased**. In addition, they should know how to calculate/measure the extension of the cord. **At least five different masses/'large number' of masses are used. Minimum 7 masses to reach 6 marks**. The diagram should be detailed.	**5-6**
modest-adequate	The description should include most of the necessary procedures including **how to apply a variable force** and should include the necessary measurements. They may not have described the procedures in a logical order. They may not appreciate that measurements are also to be made as the cord is unloaded. They should know **that the extension** of the cord must be found and name a **suitable measuring instrument (or seen in diagram – label need not be seen)/how to calculate**. The diagram may lack some detail.	**3-4**
poor-limited	The candidate knows that the **extension or cord length** is to be measured for **different forces –** may be apparent from the diagram. They may not appreciate that measurements are also to be made as the cord is unloaded. They may not state how to calculate the extension of the cord. The diagram may not have been drawn.	**1-2**
incorrect, inappropriate or no response	No answer at all or answer refers to unrelated, incorrect or inappropriate physics.	**0**

The explanation expected in a competent answer should include a coherent selection of the following physics ideas.

diagram showing rubber cord fixed at one end supporting a weight at the other end or pulled by a force **(1)**

means of applying variable force drawn or described (eg use of standard masses or a newtonmeter) **(1)**

means of measuring cord drawn or described **(1)**

procedure

measured force applied (or known weights used) **(1)**

cord extension measured or calculated **(1)**

repeat for increasing then decreasing length (or force/weight) **(1)**

extension calculated from cord length – initial length **(1)**

[9]

17 (a) (i) k = *force/extension* **(1)**

(ii) N m^{-1} **(1)**

2

(b) (i) $s = ut + ½ at^2$ or alt used **(1)**

t^2 – 12/4.9 **(1)**

1.6 s **(1)**

(ii) weight × height change seen **(1)**

53200 J **(1)**

(iii) 76 – 12 = 64 m **(1)**

12

(iv) $½ kx^2$ = *energy stored* seen **(1)**

$k = 2 \times 53200 /(64)^2$ **(1)**

25.9 N **(1)**

(v) $T = 2\pi\sqrt{(k/m)}$ seen **(1)**

subst **(1)**

1.2 s **(1)**

(c) (i) $F = kx$ seen **(1)**

$= 25.9 \times 64 = 1660$ N **(1)**

(ii) 1660/700 seen **(1)**

2.4 *g* **(1)**

(iii) stiffer cord **(1)**

less elongation so longer natural length **(1)**

6

[20]

18 (a) (i) the extension produced (by a force) in a wire is directly proportional to the force applied **(1)**
applies up to the limit of proportionality **(1)**

(ii) elastic limit: the maximum amount that a material can be stretched (by a force) and still return to its original length (when the force is removed) **(1)**
[or correct use of permanent deformation]

(iii) the Young modulus: ratio of tensile stress to tensile strain **(1)**
unit: Pa or Nm^{-2} **(1)**

5

(b) (i) length of wire **(1)**
diameter (of wire) **(1)**

(ii) graph of force vs extension **(1)**
reference to gradient **(1)**

gradient = $E\frac{A}{l}$ **(1)**

[or graph of stress vs strain, with both defined
reference to gradient
gradient = *E*]

area under the line of F vs ΔL **(1)**
[or energy per unit volume = area under graph of stress vs strain]

6

[11]

19 (a) Hooke's law: the extension is proportional to the force applied **(1)**
up to the limit of proportionality or elastic limit
[or for small extensions] **(1)**

2

(b) (i) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $\Delta L_s = \frac{80 \times 0.8}{2.0 \times 10^{11} \times 2.4 \times 10^{-6}}$ **(1)**

$= 1.3 \times 10^{-4}$ (m) **(1)** (1.33×10^{-4} (m))

$\Delta L_b = \frac{80 \times 1.4}{1.0 \times 10^{11} \times 2.4 \times 10^{-6}} = 4.7 \times 10^{-4}$ (m) **(1)** (4.66×10^{-4} (m))

total extension = 6.0×10^{-4} m **(1)**

(ii) $m = \rho \times V$ **(1)**
$m_s = 7.9 \times 10^3 \times 2.4 \times 10^{-6} \times 0.8 = 15.2 \times 10^{-3}$ (kg) **(1)**
$m_b = 8.5 \times 10^3 \times 2.4 \times 10^{-6} \times 1.4 = 28.6 \times 10^{-3}$ (kg) **(1)**
(to give total mass of 44 or 43.8×10^{-3} kg)

7

(c) (use of $m = \rho A l$ gives) $l = \frac{44 \times 10^{-3}}{8.5 \times 10^3 \times 2.4 \times 10^{-6}}$ **(1)**

= 2.2 m **(1)** (2.16 m)

(use of mass = 43.8×10^{-3} kg gives 2.14 m)

2

[11]

20 (a) tensile stress: force/tension per unit cross-sectional area or $\frac{F}{A}$
with *F* and *A* defined **(1)**
tensile strain: extension per unit length or $\frac{\Delta L}{l}$ with *e* and *l* defined **(1)**

the Young modulus: $\frac{\text{tensile stress}}{\text{tensile strain}}$ **(1)**

3

(b) (i) $E_S = \frac{F_s}{A}\frac{l}{\Delta L}$ **(1)** and $E_B = \frac{F_B}{A}\frac{l}{\Delta L}$ **(1)** hence $\frac{E_S}{E_B} = \frac{F_S}{F_B}$

(ii) $\frac{E_S}{E_B} = 2$ **(1)**

$\therefore F = 2F_B$ **(1)**

$F_S + F_B = 15$ N **(1)** gives $F_S = 10$ N

[or any alternative method]

(iii) $\left(E = \frac{F}{A}\frac{l}{\Delta L} \text{ gives}\right)$ $e = \left(\frac{F}{A}\frac{l}{E}\right) = \frac{10 \times 1.5}{1.4 \times 10^{-6} \times 2.0 \times 10^{11}}$ **(1)**

$= 5.36 \times 10^{-5}$m **(1)**

6

[9]

21 (a) extension proportional to the applied force **(1)**
up to the limit of proportionality
[or provided the extension is small] **(1)**

2

(b) (i) 8 × 9.81 = 78 (5) N **(1)**

(allow C.E. in (ii), (iii) and (iv) for incorrect value)

(ii) (use of $E = \frac{F}{A}\frac{l}{\Delta L}$ gives) $2.0 \times 10^{11} = \frac{78.5}{2.8 \times 10^{-7}} \times \frac{2.5}{\Delta L}$ **(1)**

$\Delta L = 3.5 \times 10^{-3}$ m **(1)**

(iii) similar calculation **(1)**
to give $A_S = 5.6 \times 10^{-7}$ m^2 **(1)**
[or $A_B = 2A_S$ **(1)** and correct answer **(1)**]

(iv) (use of energy stored = ½ *Fe* gives) energy stored
= ½ × 78.5 × 3.5 × 10^{-3} **(1)**
= 0.14 J **(1)**

7

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

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

2

[11]

22 (a) maximum force (from graph) = 1840 (N) (±100 N) **(1)**

max stress $\left(= \frac{\text{force}}{\text{contact area}}\right) = \frac{1840(\text{N})}{550 \times 10^{-6}(\text{m}^2)}$ **(1)**
(for correct denominator) **(1)**

= 3.3 × 10^6 N m^{-2} **(1)**

4

(b) using shoes without cushioning:
impact time would be less **(1)**
maximum impact force would be greater **(1)**
area under the curve the same **(1)**

3

[7]

23 (a) density = $\frac{\text{mass}}{\text{volume}}$ **(1)**

1

(b) (i) volume of copper = $\frac{70}{100} \times 0.8 \times 10^{-3}$ (= 0.56×10^{-3} m^3)

(volume of zinc = 0.24×10^{-3} m^3)

m_c (= $\rho_c V_c$) = $8.9 \times 10^3 \times 0.56 \times 10^{-3}$ = 5.0 kg **(1)** (4.98 kg)

$m_z = \frac{30}{100} \times 0.8 \times 10^{-3} \times 7.1 \times 10^3$ = 1.7 (kg) **(1)**

(allow C.E. for incorrect volumes)

(ii) m_b (= 5.0 +1.7) = 6.7 (kg) **(1)**

(allow C.E. for values of m_c and m_z)

$\rho_b = \frac{6.7}{0.8 \times 10^{-3}} = 8.4 \times 10^3$ kg m^{-3} **(1)**

(allow C.E. for value of m_b)

[or ρ_b = (0.7 × 8900) + (0.3 × 7100) **(1)** = 8.4×10^3 kg m^{-3} **(1)**]

max 4

[5]

24 (a) (i) (35 × 9.81) = 343 N

(ii) tension in each cable $\left(= \frac{mg}{2}\right)$ = 172 N **(1)**

2

(b) area of cross-section $\left(= \frac{\pi d^2}{4}\right) = \frac{\pi (8.26 \times 10^{-3})^2}{4} = 5.36 \times 10^{-5}$ (m^2)

$e = \frac{Fl}{EA}$ **(1)**

$= \frac{172 \times 2.5}{5.36 \times 10^{-5} \times 2.1 \times 10^{11}}$

$= 3.8 \times 10^{-5}$ m **(1)**

4

(c) (i) moments about T_2, (cable B) gives

5.52 T_1 **(1)** = 343 × 2.76 **(1)** + 196 × 4.52 **(1)**

$T_1 = \left(\frac{1833}{5.52}\right)$ **(1)** (= 332 N)

(ii) $T_1 + T_2 = 343 + 196 = 539$ (N) **(1)**
$T_2 = 539 – 332 = 207$ N **(1)**

(allow C.E. for. value of T_1, from (i))

[or moments about T_1 gives 5.52 T_2 = (343 × 2.76) + (196 × 1.) **(1)**

T_2 =1143/5.52 = 207 N **(1)**

6

[12]

25 (a) (i) the Young modulus: tensile stress / tensile strain **(1)**

(ii) maximum force or load which can be applied without wire being permanently deformed
[or point beyond which (when stress removed,) material does not regain original length] **(1)**

2

(b) (i) graph: suitable scale **(1)**
correct points **(1)** **(1)**
best straight line followed by curve **(1)**

(ii) indication of region or range of Hooke's law **(1)**

(iii) (use of $E = \frac{Fl}{Ae}$)

values of F and e within range or correct gradient **(1)**

to give $E = \frac{67}{4 \times 10^{-3}} \times \frac{1.6}{8.0 \times 10^{-8}}$ **(1)**

$= 3.3(5) \times 10^{10}$ Pa **(1)**

8

(c) (i) work done = force × distance **(1)**
= <u>average</u> force × extension (= ½Fe) **(1)**
[or use work done = area under graph
area = ½ base × height]

(ii) energy stored = $\frac{67 \times 4 \times 10^{-3}}{2}$ **(1)**

$= 13.(4) \times 10^{-3}$ J **(1)**

4

[14]

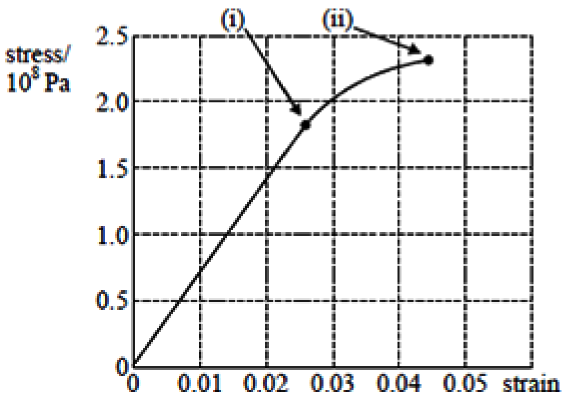
26 (a) (i) strain = 0.026 **(1)**
$E = 6.92 \times 10^9$ Pa **(1)**

(ii) $A = 1.96 \times 10^{-7}$ (m^2) **(1)**
stress = 230×10^8 Pa **(1)**

(iii) breaking strain = 0.044 **(1)**

5

(b)



shape overall **(1)**

(i) straight line **(1)**
0 to (0.026, 1.8) **(1)**

(ii) curve **(1)**
to (0.044, 2.3) **(1)**

max 4

[9]

27 (a) appropriate discussion of energy conservation **(1)**
Δ p.e. = $2.5 \times 10^{-2} \times 9.8 \times 1.2$ **(1)** (= 0.29 J)

(b) $F = \frac{2E_p}{e}$ **(1)** = 590 N **(1)**

(c) $A = 3.1 \times 10^{-6}$ (m^2) **(1)**
stress = 1.9×10^8 Pa **(1)**

(d) strain = $\frac{e}{L} = \frac{0.001}{1.2}$ = 8.3×10^{-4} **(1)**

(e) $E = \frac{\text{stress}}{\text{strain}} = \frac{1.9 \times 10^8}{8.3 \times 10^{-4}}$ **(1)** = 2.3×10^{11} Pa **(1)**

[9]

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

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

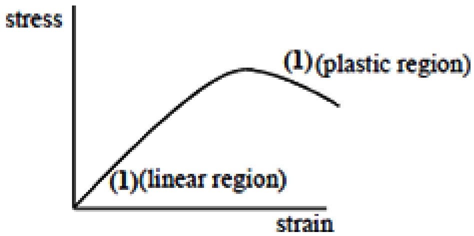
mention of tensile **and** original **(1)**

(3)

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

(max 4)

(c)



(2)

[9]

29 (a) The force per unit area

B1

at which the material extends considerably / a lot / plastically /
or strain increases considerably etc
NOT doesn't return to its original shape / permanently deformed

B1

for no (or a small) increase in) force / stress

B1

(3)

(b) (i) strain = 8.4×10^{-4} (1.3×10^{-3} / 1.55 seen) (allow if in $E = FL / A\Delta L$)

B1

or area of cross section = 2.54×10^{-6}
or $\pi (0.9 \times 10^{-3})^2$
stress = E × strain (explicit or numerically) and
stress = F / A or $E = FL / AL$

C1

force = 440 – 450 N(cao)

A1

(3)

(ii) Energy = ½ $F \Delta l$ or ½ stress × strain × volume

C1

0.29 J ecf for F from (b)(i)

A1

(2)

[8]

30 (a) rope has to provide an upward force to balance that of the weight down

B1

(1)

(b) reasonable attempt to resolve vertical forces
T sin 5 or T cos 85 seen in a calculation but **not** T cos 5
or some progress in use of scale diagram
C1

2 T sin 5 = 800 **or** well drawn scale diagram with scale indicated
C1

T = 4590 N (4600N)
or 4500 to 4700 by scale drawing
A1
(3)

(c) UTS = maximum force / area
or force / minimum area
C1

area = 6.6×10^{-5} m^2
or their (b) / 7×10^7
C1

d = 0.0091 m
{$1.35 \times 10^{-40} \times \sqrt{(b)(i)}$}
A1
(3)
[7]