Young's Modulus Past Paper Questions

Jan 2002 to Jan 2009

6 (a) (i) Draw and label suitable apparatus required for measuring the Young modulus of a material in the form of a long wire.

Q6 Jan 2002

(ii) List the measurements you would make when using the apparatus described in part (i).

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(iii) Describe briefly how the measurements listed in part (ii) would be carried out.

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(iv) Explain how you would calculate the Young modulus from your measurements.

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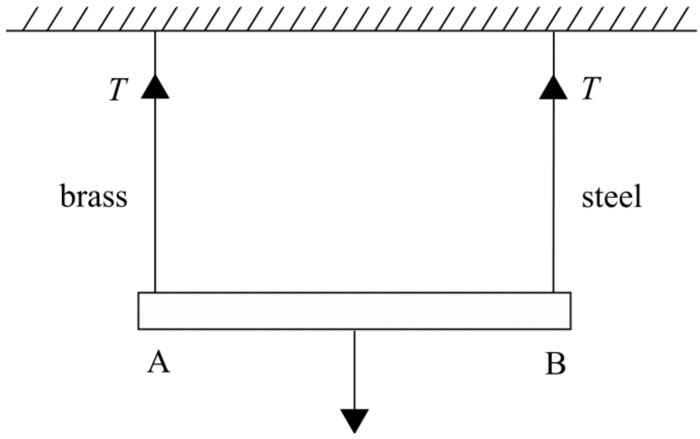
(13 marks)

(b) A uniform heavy metal bar of weight 250 N is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown.



One wire is made of brass and the other of steel. The cross-sectional area of each wire is $2.5 \times 10^{-7}\,\text{m}^2$ and the unstretched length of each wire is 2.0 m.

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

(i) If the tension, T, in each wire is 125 N, calculate the extension of the steel wire.

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(ii) Estimate how much lower the end A will be than the end B.

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(3 marks)

Q5 June 2002

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

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

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(2 marks)

(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 on the grid 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 $8.0 \times 10^{-8}\,\text{m}^2$. Calculate the value of the Young modulus of the material.

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(8 marks)

(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.

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

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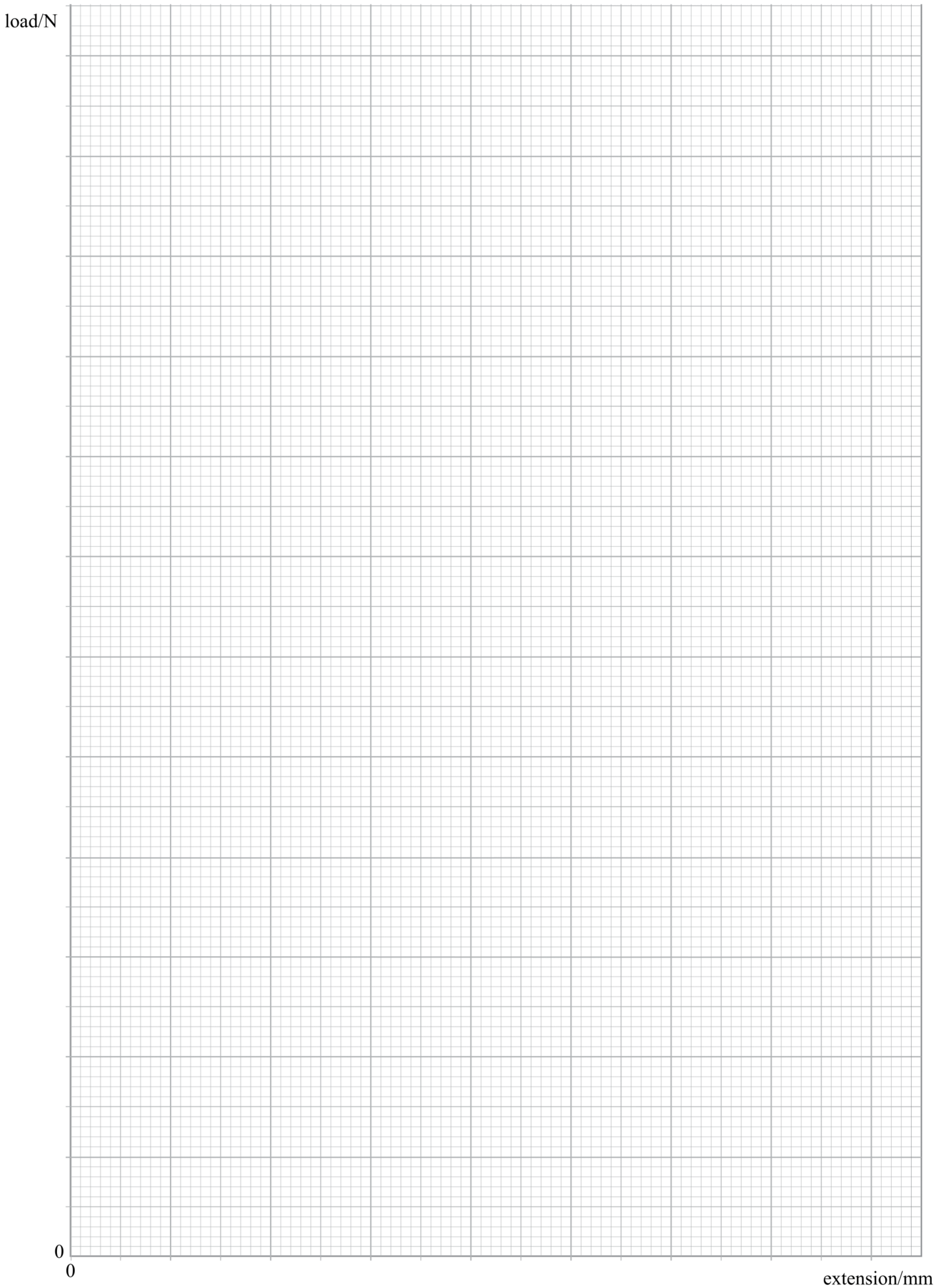
(4 marks)


load/N
0
0
extension/mm

Q6 Jan 2003

6 A material in the form of a wire, 3.0 m long and cross-sectional area = $2.8 \times 10^{-7}\,\text{m}^2$ is suspended from a support so that it hangs vertically. Different masses may be suspended from its lower end. The table shows the extension of the wire when it is subjected to an increasing load and then a decreasing load.

load / N	0	24	52	70	82	88	94	101	71	50	16	0
extension / mm	0	2.2	4.6	6.4	7.4	8.2	9.6	13.0	10.2	8.0	4.8	3.2

(a) Plot, on the grid opposite, a graph of load (on *y* axis) against extension (on *x* axis) both for increasing and decreasing loads.

(4 marks)

(b) Explain what the shape of the graph tells us about the behaviour of the material in the wire.

You may be awarded marks for the quality of written communication in your answer.

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(4 marks)

(c) Using the graph, determine a value of the Young modulus for the material of the wire.

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(3 marks)

(d) State how the graph can be used to estimate the energy stored during the loading process.

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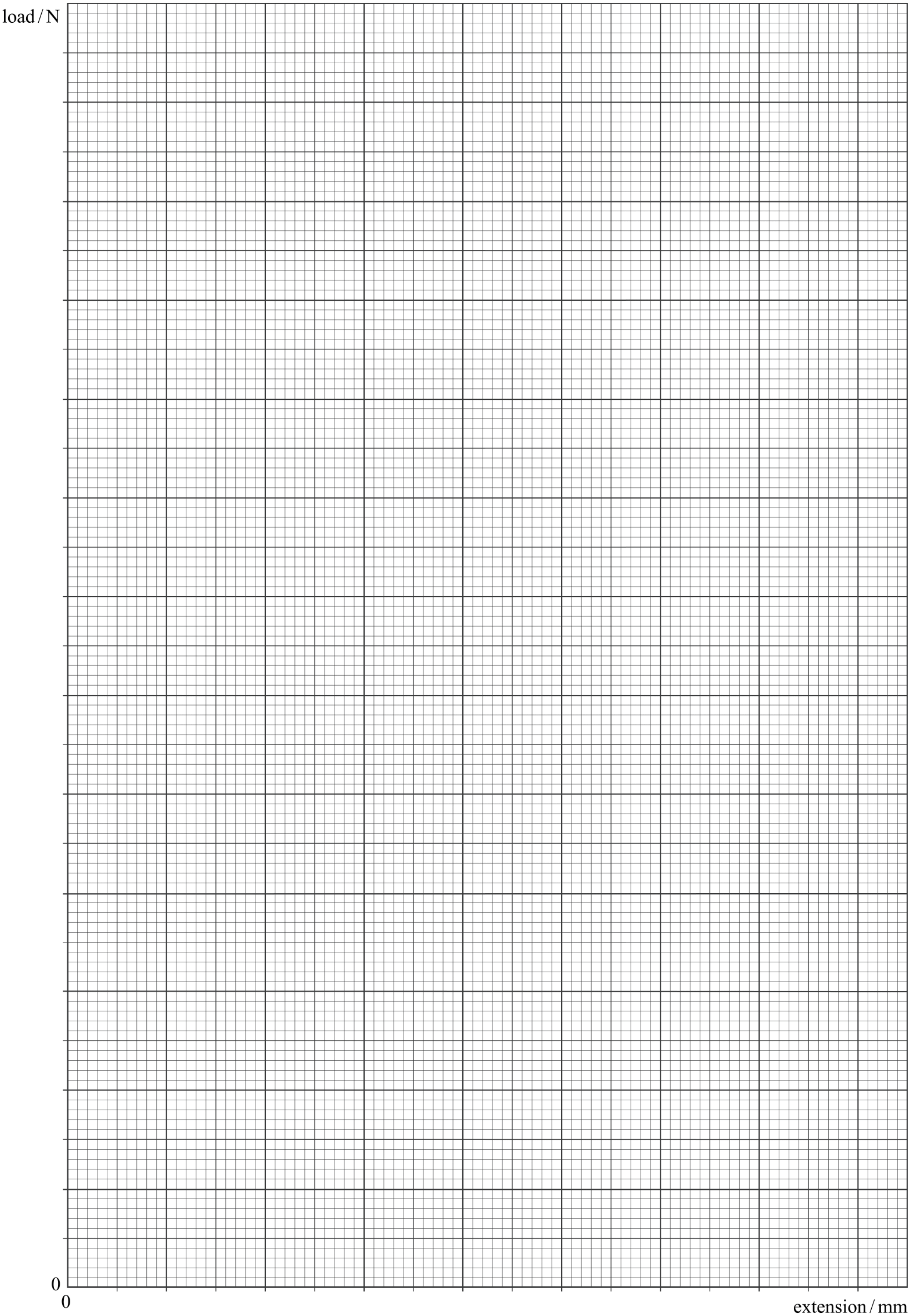
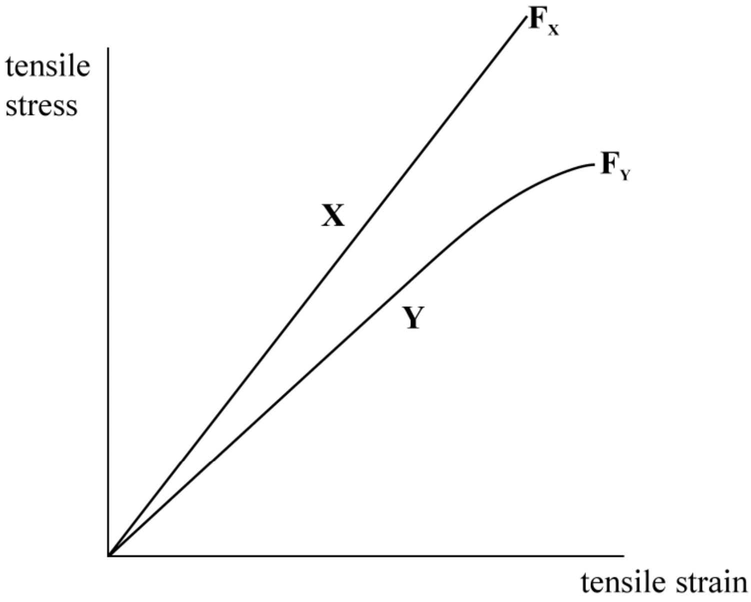
(1 mark)


load / N
0
0
extension / mm

5 (a) The graph shows the variation of *tensile stress* with *tensile strain* for two wires **X** and **Y**, having the same dimensions, but made of different materials. The materials fracture at the points $\mathbf{F_X}$ and $\mathbf{F_Y}$ respectively.

Q6 Jun 2003



You may be awarded marks for the quality of written communication provided in your answer to the following questions.

State, with a reason for each, which material, **X** or **Y**,

(i) obeys Hooke's law up to the point of fracture,

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(ii) is the weaker material,

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(iii) is ductile,

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(iv) has the greater elastic strain energy for a given tensile stress.

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(8 marks)

(b) An elastic cord of unstretched length 160 mm has a cross-sectional area of 0.64 mm^2. The cord is stretched to a length of 190 mm. Assume that Hooke's law is obeyed for this range and that the cross-sectional area remains constant.

the Young modulus for the material of the cord = 2.0×10^7 Pa

(i) Calculate the tension in the cord at this extension.

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(ii) Calculate the energy stored in the cord at this extension.

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(5 marks)

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

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tensile strain. ....

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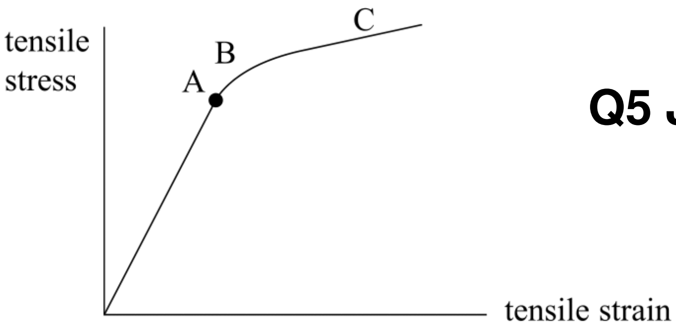
(2 marks)

(b) A long thin metallic wire is suspended from a fixed support and hangs vertically. Weights are added to increase the load on the free end of the wire until the wire breaks. The graph below shows how the tensile strain in the wire increases as the tensile stress increases.



Q5 Jan 2004

With reference to the graph, describe the behaviour of the wire as the load on the free end is increased. To assist with your answer refer to the point A, and regions B and C.

You may be awarded marks for the quality of written communication in your answer.

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(5 marks)

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

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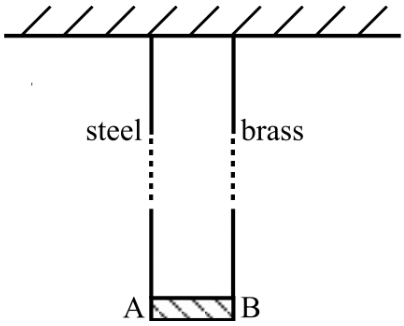
(2 marks)

(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.



Q6 Jun 2004

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

the Young modulus for steel $= 2.0 \times 10^{11}$ Pa
the Young modulus for brass $= 1.0 \times 10^{11}$ Pa

(i) What is the tension in each wire?

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

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

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

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(7 marks)

(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?

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

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(2 marks)

6 (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...

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tensile strain...

....

(ii) Define the Young modulus...

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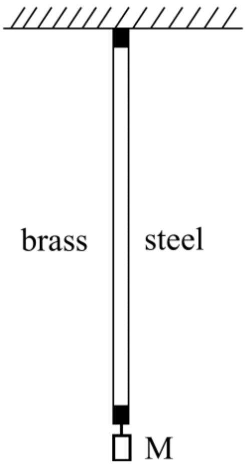
(3 marks)

(b) **Figure 7** 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.



Q6 Jan 2005

Figure 7

(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.

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(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 $= 2.0 \times 10^{11}$ Pa
the Young modulus for brass $= 1.0 \times 10^{11}$ Pa

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

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(6 marks)

5 (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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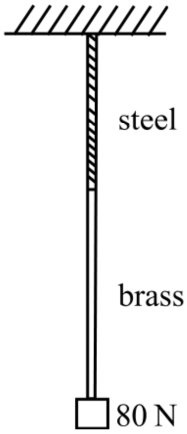
(2 marks)

(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 **Figure 5**.



Q5 Jun 2005

Figure 5

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 = $7.9 \times 10^{3}\,\text{kg m}^{-3}$
density of brass = $8.5 \times 10^{3}\,\text{kg m}^{-3}$

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(7 marks)

(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 marks)

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress, ...

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tensile strain. ....

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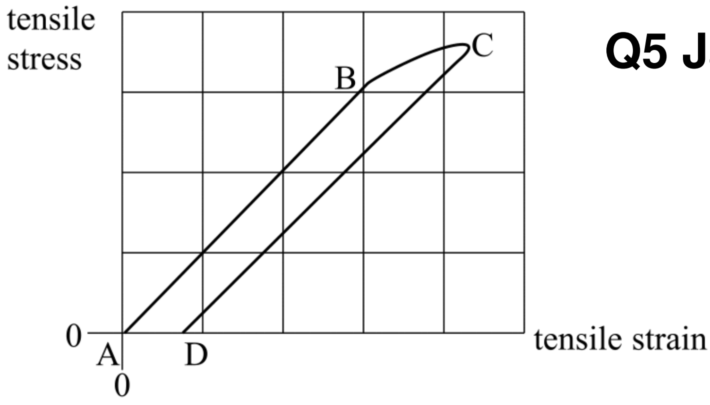
(2 marks)

(b) A long, thin metal wire is suspended from a fixed support and hangs vertically. Masses are suspended from its lower end.

As the load on the lower end is increased from zero to a certain value, and then decreased again to zero, the variation of the resulting tensile strain with the applied tensile stress is shown in the graph.



Q5 Jan 2006

(i) Describe the behaviour of the wire during this process. Refer to the points A, B, C and D in your answer.
You may be awarded marks for the quality of written communication in your answer.

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(ii) State, with a reason, whether the material of the wire is ductile or brittle.

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(iii) What does AD represent?

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(iv) State how the Young modulus for the material may be obtained from the graph.

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(v) State how the energy per unit volume stored in the wire during the loading process may be estimated from the graph.

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(9 marks)

(c) The wire described in part (b) has an unstretched length of 3.0 m and cross-sectional area 2.8×10^{-7} m^2. At a certain stage between the points A and B on the graph, the wire supports a load of 75 N. Calculate the extension produced in the wire by this load.

the Young modulus for the material of the wire = 2.1×10^{11} Pa

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(2 marks)

5 (a) (i) Describe the behaviour of a wire that obeys Hooke's law. **Q5 Jun 2006**

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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 marks)

(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 marks)

5 A material in the form of a long wire is suspended from a support so that it hangs vertically with a mass holder attached to the lower end. Masses, up to a certain value, are added to the holder and then removed again, until only the mass holder remains. The extension of the wire is measured as each mass is added and again as they are removed.
The table shows the extension of the wire as the masses are added and removed.

load/N	0	26	50	73	93	108	118	90	51	0
extension/mm	0	2.4	4.6	6.8	8.6	10.4	13.6	10.8	7.0	2.0

(a) On the grid opposite, plot a graph of load against extension for both increasing and decreasing loads. *(5 marks)*

(b) With reference to the graph, describe the behaviour of the wire as the load is increased and then decreased.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

Q5 Jan 2007

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(3 marks)

Question 5 continues on the next page

(c) The wire described in the first paragraph of the question has an original length of 2.5 m and a cross-sectional area of 2.8×10^{-7} m^2. At an extension corresponding to a load of 82 N (when the load is being increased), calculate for the wire,

(i) the tensile stress,

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(ii) the tensile strain,

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(iii) the Young modulus for the material of the wire,

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(iv) the energy stored in the wire.

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(4 marks)

6 (a) (i) Describe an experiment a student would carry out to determine the Young modulus of the material of a long uniform wire of known cross-sectional area. You may draw a diagram of the apparatus, if necessary.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

Q6 Jun 2007

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(ii) Explain how the value of the Young modulus could be determined from the measurements made using a suitable graph.

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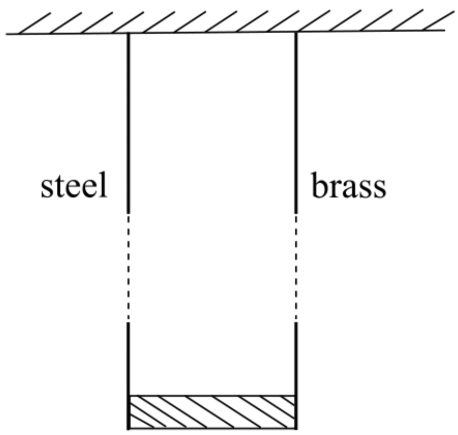
(8 marks)

(b) A uniform heavy metal bar is suspended by two vertical wires, supported at their upper ends from a horizontal surface, as shown in **Figure 12**. One of the wires is brass and the other steel. Each wire has the same original length and both extend by the same amount, thus making the metal bar horizontal.

Figure 12



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

(i) Explain why the brass wire has the greater cross-sectional area.

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(ii) The unstretched length of each wire is 2.5 m and the extension produced is 4.8×10^{-3} m. If the cross-sectional area of the steel wire is 1.6×10^{-7} m^2, calculate the tension in the steel wire.

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(4 marks)

5 (a) When a *tensile stress* is applied to a wire, a *tensile strain* is produced in the wire. State the meaning of

tensile stress ....

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tensile strain ....

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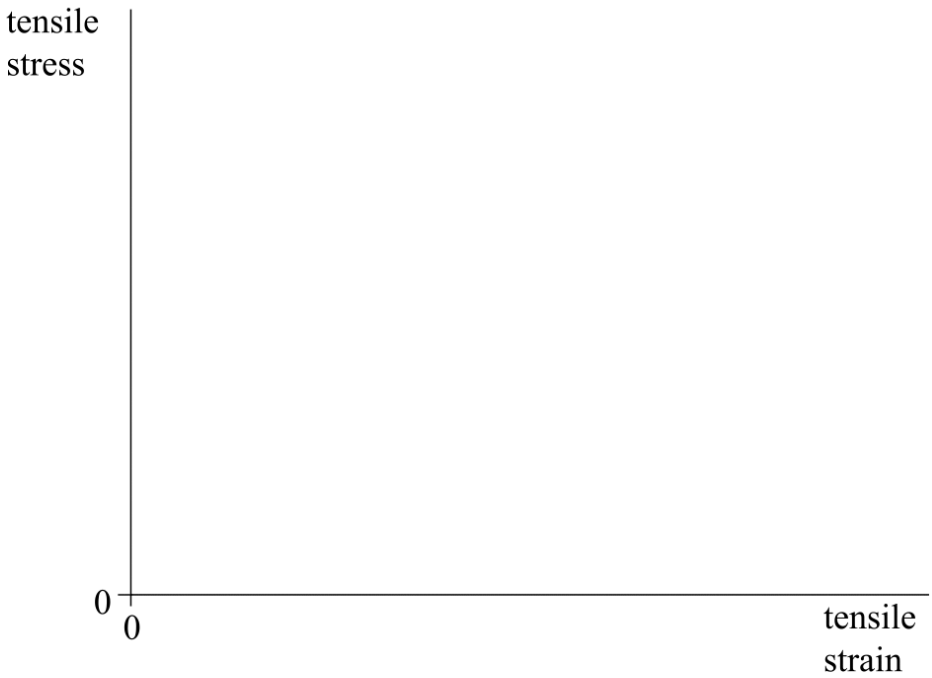
(2 marks)

(b) Two wires, **A** and **B**, of equal length and diameter are to be compared. Each of the two wires is subjected, in turn, to an increasing tensile stress until the wire breaks.

Wire **A** is made from a brittle material and wire **B** from a ductile material. The Young modulus for the brittle material is greater than that for the ductile material.

(i) On the axes provided, sketch the graphs you would expect for each wire. Label the graphs **A** and **B** respectively.

Q5 Jan 2008



(ii) Describe how the behaviour of each wire relates to the shape of each graph.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

graph **A** ....

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graph **B** ....

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(8 marks)

(c) A uniform wire of length 1.5 m and cross-sectional area 2.4×10^{-6} m^2, hangs vertically from a fixed support. A mass of 10 kg is suspended from its lower end.

Calculate the extension of the wire.

the Young modulus for the material of the wire = 2.0×10^{11} Pa

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(2 marks)

6 (a) The Young modulus, E, for a material in the form of a wire is given by $E = \frac{Fl}{Ae}$.
State what each symbol represents.

F ....

l ....

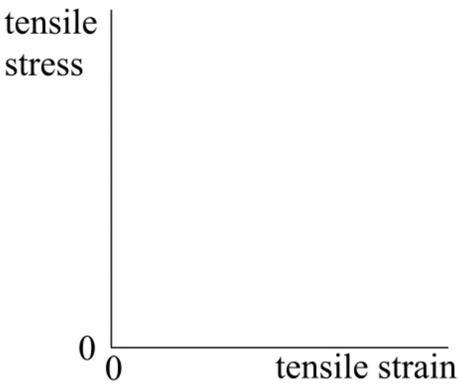
A ....

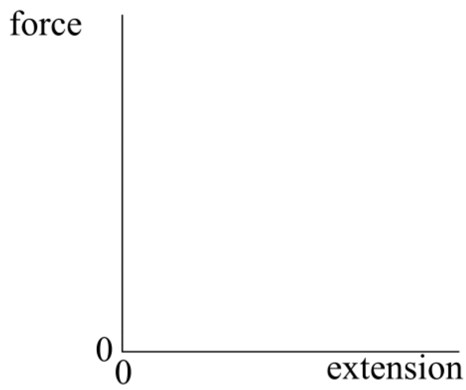
e ....

(1 mark)

6 (b) (i) A wire, **P**, is subjected to an increasing tensile stress by application of a force.
This results in a tensile strain being produced in the wire.
On each set of axes provided, sketch a graph which represents the behaviour of the wire up to its elastic limit.

Q6 Jun 2008





6 (b) (ii) A wire, **Q**, is made from the same material as wire **P** and is the same length as **P**, but the cross-sectional area of wire **Q** is half that of **P**.
On the same set of axes, sketch the corresponding graphs for wire **Q** over the same range of tensile stress.
Label clearly which graph represents **Q** and which represents **P**.

6 (b) (iii) Explain the graphs you have drawn for wire **Q**, with reference to their position relative to the graphs for wire **P**.

tensile stress vs *tensile strain* graph: ....

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6 (b) (iii) *force* vs *extension* graph: ....

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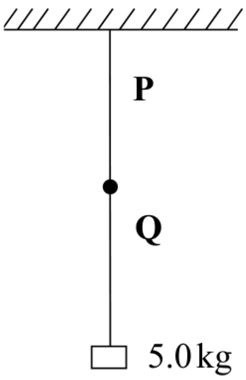
(7 marks)

6 (c) The two wires, **P** and **Q**, are joined together and fixed to a horizontal support. A mass of 5.0 kg is suspended from the free end, as shown in **Figure 10**.

Figure 10



length of each wire = 1.8 m
cross-sectional area of wire **P** = $2.0 \times 10^{-7}\,m^2$
the Young modulus of the material of the wires = 4.6×10^{11} Pa

Calculate the total extension of the combined wire.

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(3 marks)

2 (a) (i) State the difference between a scalar quantity and a vector quantity.

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(1 mark)

2 (a) (ii) State **two** examples of a scalar quantity and **two** examples of a vector quantity.

scalar quantities ....

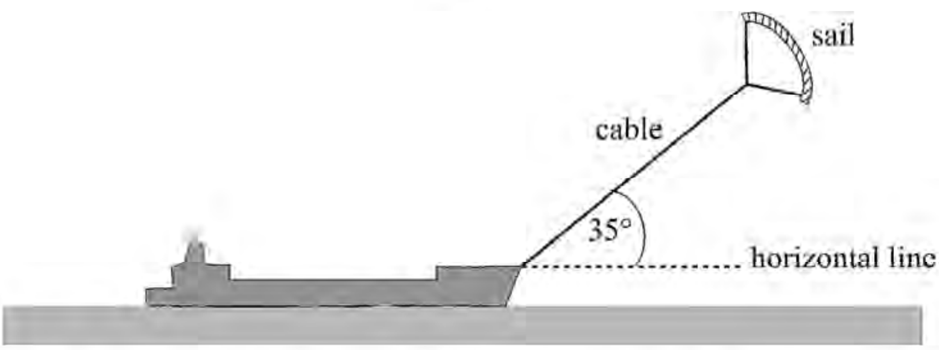
vector quantities ....

(3 marks)

2 (b) **Figure 1** shows a ship fitted with a sail attached to a cable. The force of the wind on the sail assists the driving force of the ship's propellors.

Q2 Jan 2008

Figure 1



The cable exerts a steady force of 2.8 kN on the ship at an angle of 35° above a horizontal line.

2 (b) (i) Calculate the horizontal and vertical components of this force.

horizontal component of force .... kN

vertical component of force .... kN

(2 marks)

2 (b) (ii) The ship is moving at a constant velocity of $8.3\,m\,s^{-1}$ and the horizontal component of the force of the cable on the ship acts in the direction in which the ship is moving.
Calculate the power provided by the wind to this ship, stating an appropriate unit.

Answer ....
(3 marks)

2 (c) The cable has a diameter of 0.014 m. Calculate the tensile stress in the cable when it exerts a force of 2.8 kN on the ship, stating an appropriate unit.
Assume the weight of the cable is negligible.

Answer ....
(5 marks)