CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Unit 6: Elasticity, Stress and Strain

Past Papers 2021 – 2025

QUESTION PAPER 24 Questions

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Question 1

A spring is extended by a force. The variation with extension x of the force F is shown in Fig. 3.1.

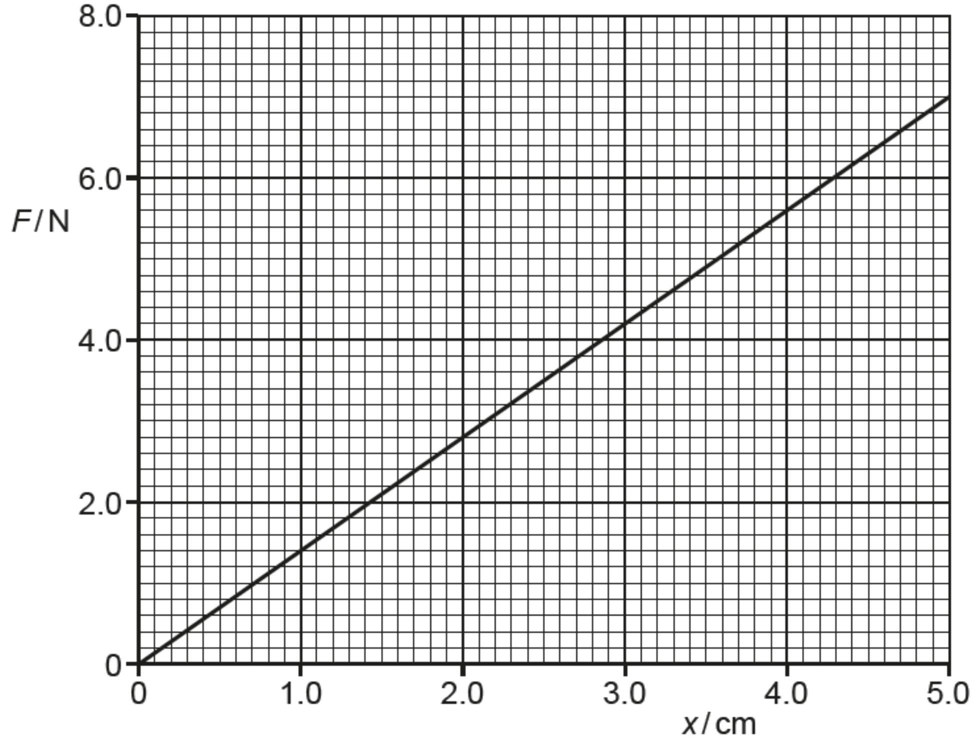


Fig. 3.1

(a) State the name of the law that relates the force and extension of the spring shown in Fig. 3.1.

.... [1]

(b) Determine:

(i) the spring constant, in $N\,m^{-1}$, of the spring

spring constant = ... $N\,m^{-1}$ [2]

(ii) the strain energy (elastic potential energy) in the spring when the extension is 4.0 cm.

strain energy = ... J [2]

(b) Determine:

(i) the spring constant, in $N\,m^{-1}$, of the spring

spring constant = ... $N\,m^{-1}$ [2]

(ii) the strain energy (elastic potential energy) in the spring when the extension is 4.0 cm.

strain energy = ... J [2]

(c) One end of the spring is attached to a fixed point. A cylinder that is submerged in a liquid is now suspended from the other end of the spring, as shown in Fig. 3.2.

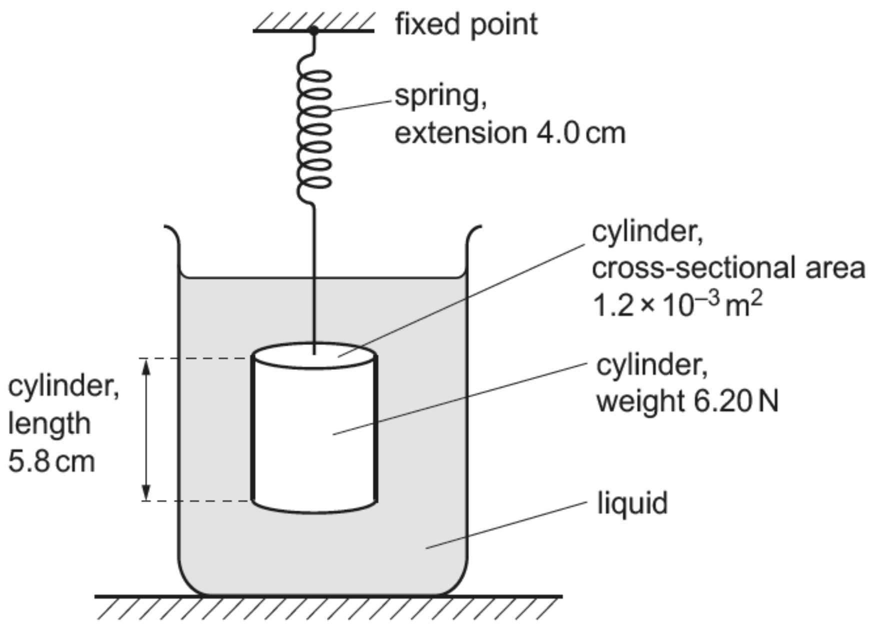


Fig. 3.2

The cylinder has length 5.8 cm, cross-sectional area $1.2 \times 10^{-3}\,m^2$ and weight 6.20 N. The cylinder is in equilibrium when the extension of the spring is 4.0 cm.

(i) Show that the upthrust acting on the cylinder is 0.60 N.

[1]

(ii) Calculate the difference in pressure between the bottom face and the top face of the cylinder.

difference in pressure = ... Pa [2]

(iii) Calculate the density of the liquid.

density = ... $kg\,m^{-3}$ [2]

(d) The liquid in **(c)** is replaced by another liquid of greater density.

State the effect, if any, of this change on:

(i) the upthrust acting on the cylinder

.... [1]

(ii) the extension of the spring.

.... [1]

[Total: 12]

Question 2

(a) A uniform metal bar, initially unstretched, has sides of length w, x and y, as shown in Fig. 3.1.

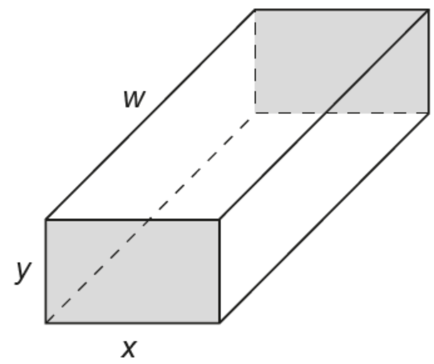


Fig. 3.1

The bar is now stretched by a tensile force F applied to the shaded ends. The changes in the lengths x and y are negligible. The bar now has sides of length x, y and z, as shown in Fig. 3.2.

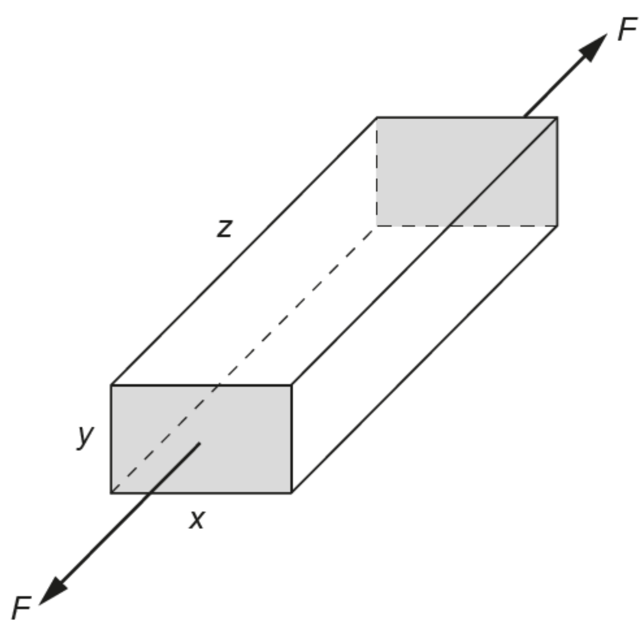


Fig. 3.2

Determine expressions, in terms of some or all of F, w, x, y and z, for:

(i) the stress σ applied to the bar by the tensile force

σ = ... [1]

(ii) the strain ε in the bar due to the tensile force

ε = ... [1]

(iii) the Young modulus E of the metal from which the bar is made.

E = ... [2]

(b) A copper wire is stretched by a tensile force that gradually increases from 0 to 280 N. The variation with extension of the tensile force is shown in Fig. 3.3.

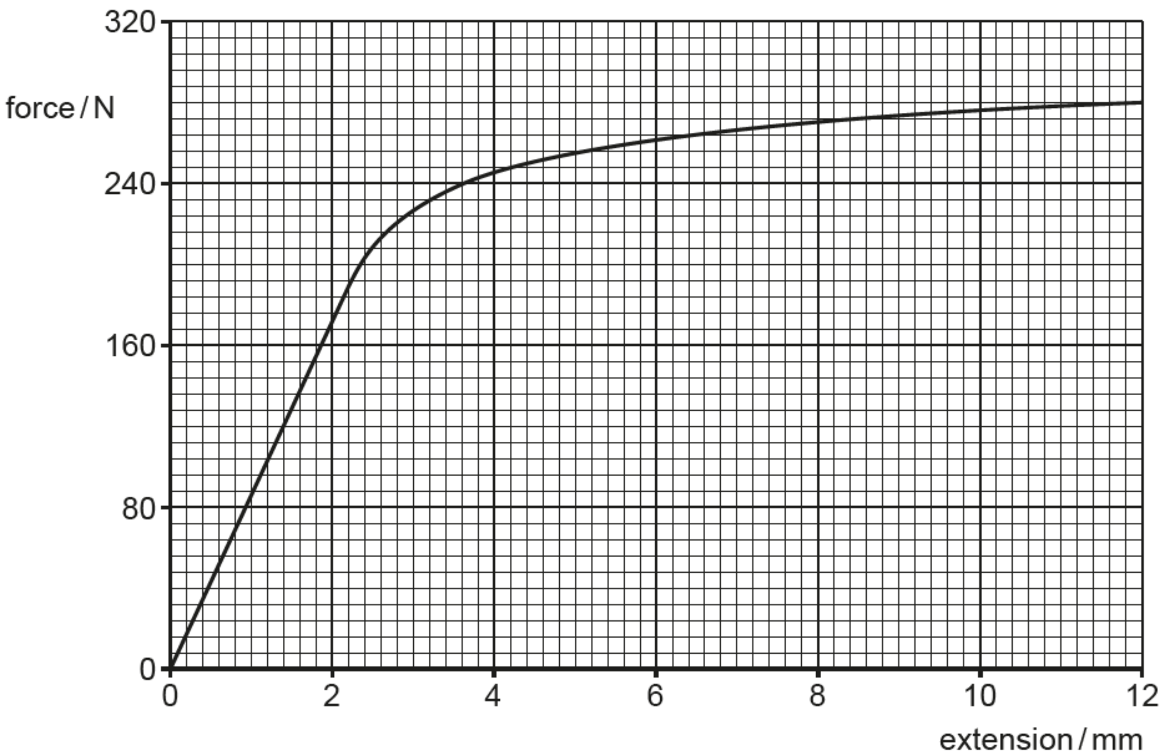


Fig. 3.3

(i) State the maximum extension of the wire for which it obeys Hooke's law.

extension = ... mm [1]

(ii) Use Fig. 3.3 to determine the strain energy in the wire when the tensile force is 120 N.

strain energy = ... J [3]

(iii) Explain why the work done in stretching the wire to an extension of 12 mm is not equal to the energy recovered when the tensile force is removed.

....

....

.... [2]

[Total: 10]

Question 3

(a) A solid cylinder of weight 24 N is made of material of density 850 kg m^{-3}. The cylinder has a length of 0.18 m, as shown in Fig. 1.1.

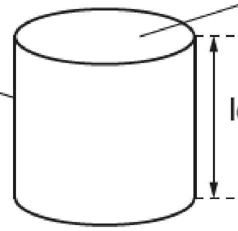


Fig. 1.1

Show that the cross-sectional area *A* of the cylinder is 0.016 m^2.

[3]

(b) The cylinder in **(a)** is attached by a spring to the bottom of a rigid container of liquid, as shown in Fig. 1.2.

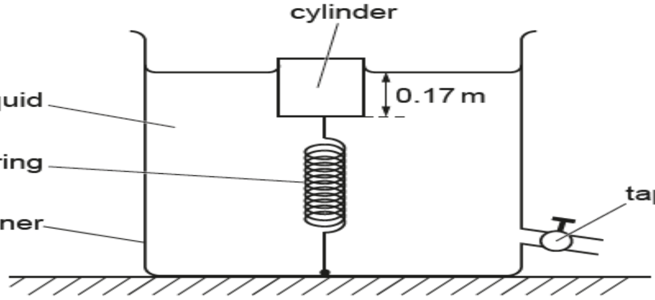


Fig. 1.2 (not to scale)

The cylinder is in equilibrium with its bottom face at a depth of 0.17 m below the surface of the liquid. The tension in the spring is 8.0 N.

(i) Show that the upthrust acting on the cylinder due to the liquid is 32 N.

[1]

(b) The cylinder in **(a)** is attached by a spring to the bottom of a rigid container of liquid, as shown in Fig. 1.2.

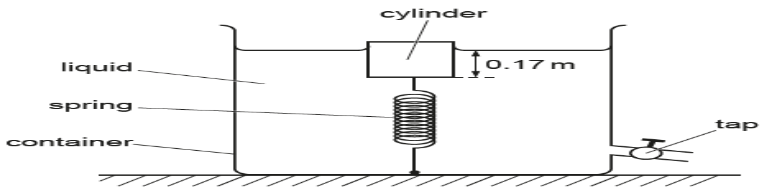


Fig. 1.2 (not to scale)

The cylinder is in equilibrium with its bottom face at a depth of 0.17 m below the surface of the liquid. The tension in the spring is 8.0 N.

(i) Show that the upthrust acting on the cylinder due to the liquid is 32 N.

[1]

(ii) Calculate the density of the liquid.

density = ... $kg\,m^{-3}$ [3]

(c) Fig. 1.3 shows the variation of the tension *F* with the length of the spring in **(b)**.

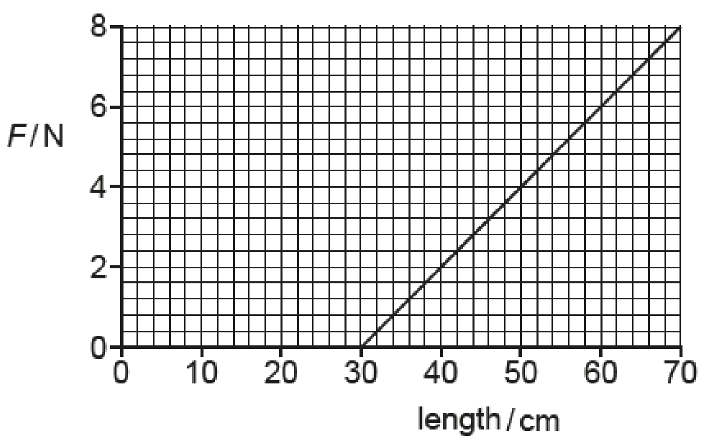


Fig. 1.3

(i) The tap at the bottom of the container is opened so that a fixed amount of liquid flows out of the container. The cylinder moves downwards so that the tension in the spring changes from 8.0 N to 4.0 N.

Determine the change in the elastic potential energy of the spring.

change in elastic potential energy = ... J [3]

(ii) More liquid is let out of the container until the upthrust on the cylinder becomes 24 N.

For the upthrust of 24 N, determine the length of the spring.

length = ... cm [1]

[Total: 11]

Question 4

A child moves down a long slide, as shown in Fig. 4.1.

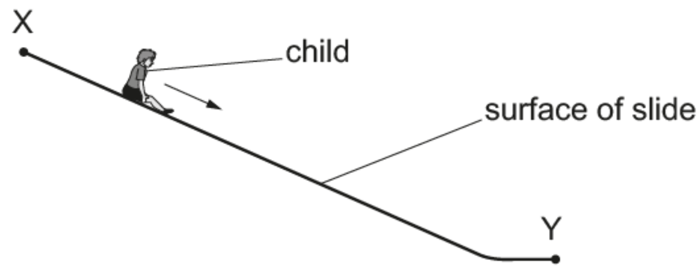


Fig. 4.1 (not to scale)

The child moves from rest at the top end X of the slide. An average resistive force of 76 N opposes the motion of the child as they move to the lower end Y of the slide. The kinetic energy of the child at Y is 300 J. The decrease in gravitational potential energy of the child as it moves from X to Y is 3200 J.

(a) Determine the ratio

$$\frac{\text{kinetic energy of the child at Y when the resistive force is 76 N}}{\text{kinetic energy of the child at Y if there is no resistive force}}.$$

ratio = ... [1]

(b) Use the answer in **(a)** to calculate the ratio

$$\frac{\text{speed of the child at Y when the resistive force is 76 N}}{\text{speed of the child at Y if there is no resistive force}}.$$

ratio = ... [2]

(c) Calculate the length of the slide from X to Y.

length = ... m [2]

(d) At end Y of the slide, the child is brought to rest by a board, as shown in Fig. 4.2.

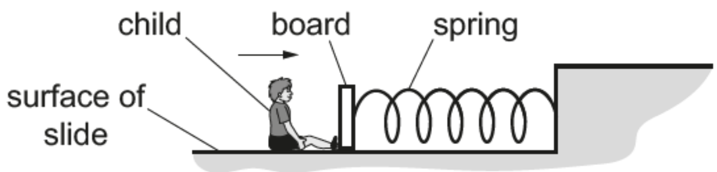


Fig. 4.2 (not to scale)

A spring connects the board to a fixed point. The spring obeys Hooke's law and has a spring constant of 63 N m^{-1}. The child hits the board so that it moves to the right and compresses the spring. The speed of the child becomes zero when the elastic potential energy of the spring has increased to its maximum value of 140 J.

(i) Calculate the maximum compression of the spring.

maximum compression = ... m [2]

(ii) Calculate the percentage efficiency of the transfer of the kinetic energy of the child to the elastic potential energy of the spring.

percentage efficiency = ... % [1]

(iii) The maximum compression of the spring is x_0. On Fig. 4.3, sketch a graph to show the variation of the elastic potential energy of the spring with its compression x from $x = 0$ to $x = x_0$. Numerical values are not required.

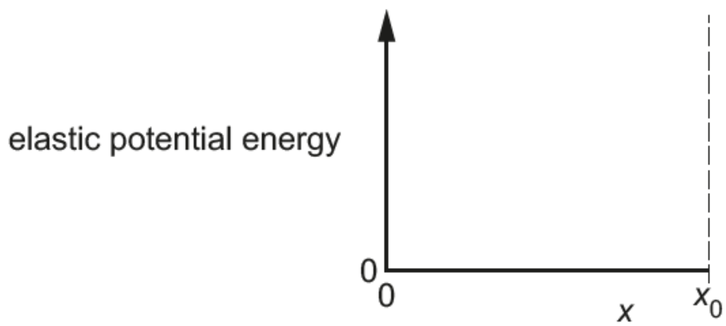


Fig. 4.3

[2]

[Total: 10]

Question 5

A spring is suspended from a fixed point at one end and a vertical force is applied to the other end, as shown in Fig. 4.1.

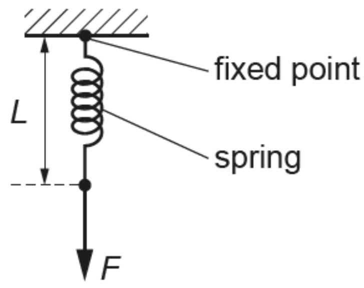


Fig. 4.1

The variation of the applied force F with the length L of the spring is shown in Fig. 4.2.

The variation of the applied force F with the length L of the spring is shown in Fig. 4.2.

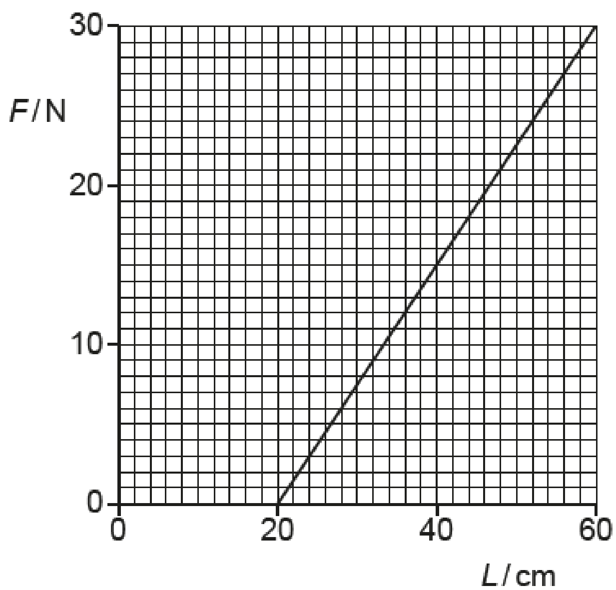


Fig. 4.2

(a) Determine the spring constant k of the spring.

k = ... $N\,m^{-1}$ [2]

(b) Determine the elastic potential energy in the spring when the applied force F is 15 N.

elastic potential energy = ... J [3]

[Total: 5]

Question 6

A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

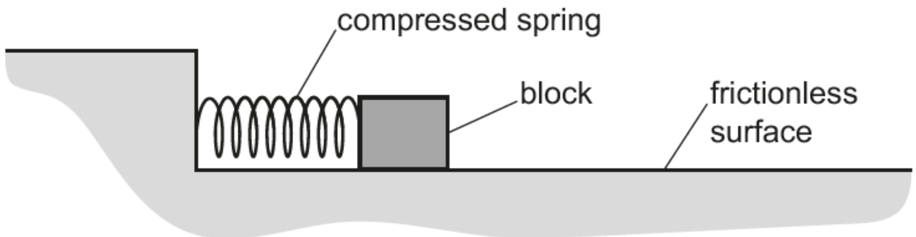


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,\mathrm{m\,s^{-1}}$, as shown in Fig. 4.2.

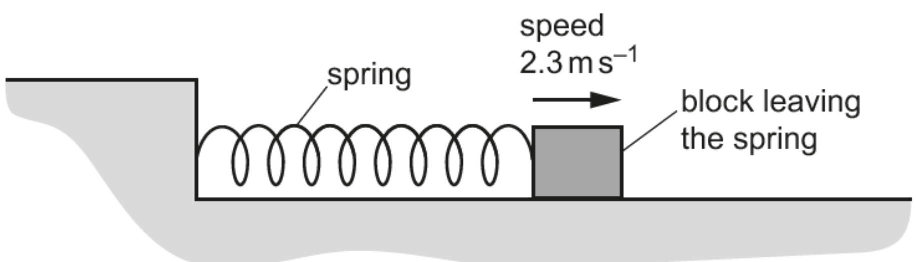


Fig. 4.2

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

(a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

(b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

(c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of $2.3\,\text{m}\,\text{s}^{-1}$. The block then rebounds at a speed of $1.5\,\text{m}\,\text{s}^{-1}$ and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s.

Calculate:

(i) the change in momentum of the block during the collision

change in momentum = ... N s [2]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

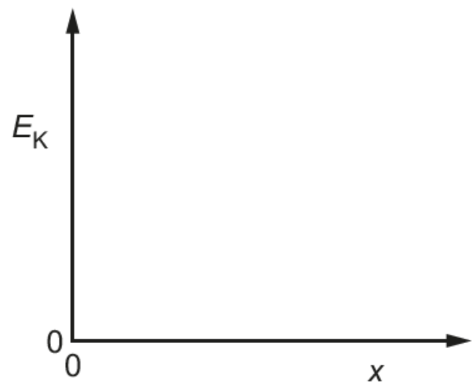


Fig. 4.3

[1]

[Total: 8]

Question 7

(b) The ball is projected by means of a compressed spring which is attached to a fixed block as shown in Fig. 2.2.

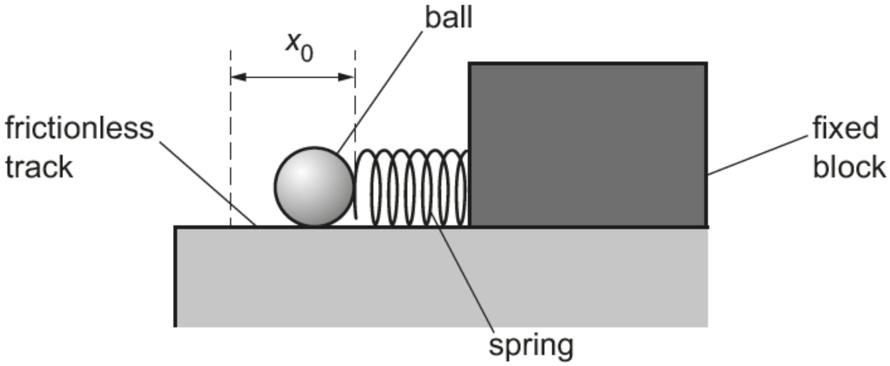


Fig. 2.2

The ball is placed on a frictionless track in front of the spring. The ball is then pulled back so that the spring has compression x_0.

When the spring is released, the ball is projected horizontally as shown in Fig. 2.3.

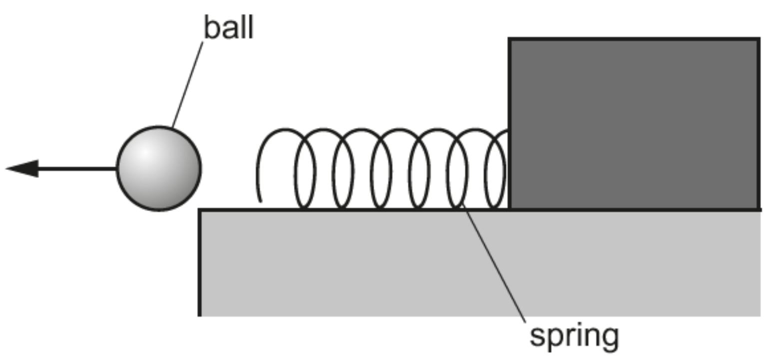


Fig. 2.3

The variation with compression *x* of the applied force *F* for the spring is shown in Fig. 2.4.

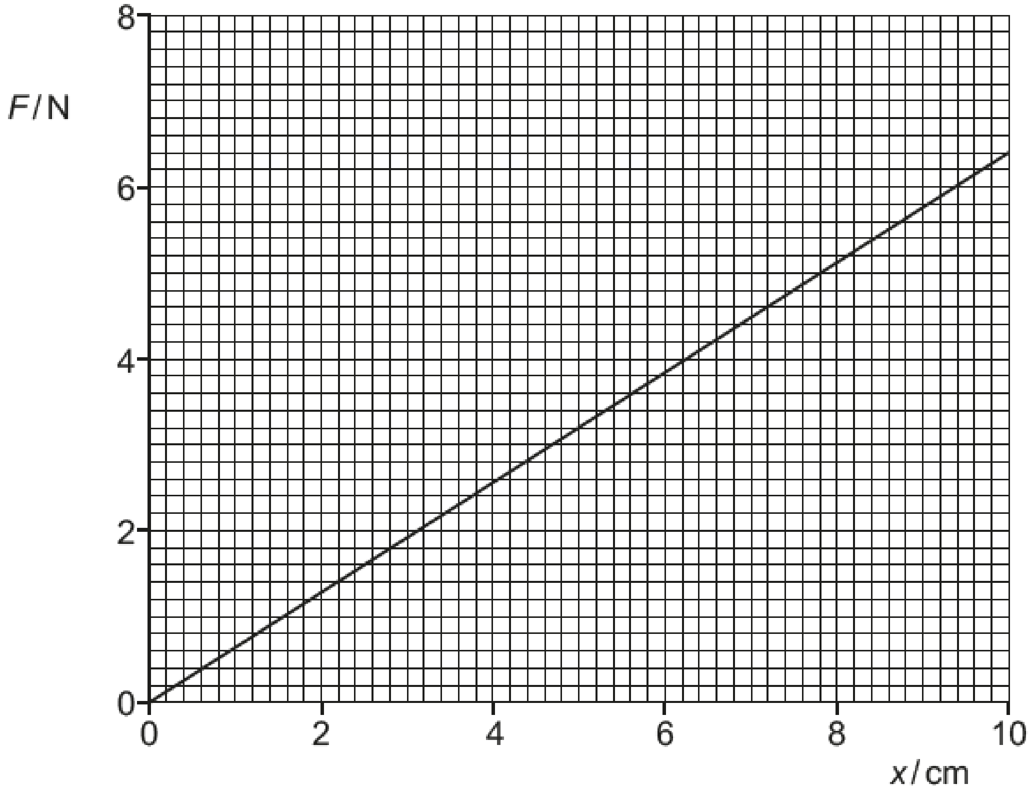


Fig. 2.4

The ball is a uniform sphere of steel of diameter 0.016 m and mass 0.017 kg.

(i) Calculate the density of the steel.

density = ... $kg\,m^{-3}$ [3]

(ii) All of the elastic potential energy in the spring is converted into kinetic energy of the ball. The speed of the ball as it leaves the spring is $4.9\,\mathrm{m\,s^{-1}}$.

Show that the maximum elastic potential energy of the spring is 0.20 J.

[2]

(iii) Use Fig. 2.4 to determine the spring constant k of the spring.

k = ... $\mathrm{N\,m^{-1}}$ [2]

(iv) Use your answer in **(b)(iii)** and the value of energy given in **(b)(ii)** to determine the compression x_0 of the spring.

x_0 = ... m [2]

(c) The steel ball is replaced by a polystyrene ball of the same diameter but of much lower mass. The spring is given compression x_0 and is then released.

Air resistance on this ball is **not** negligible after it leaves the spring.

Explain:

(i) why this ball leaves the spring with a greater speed than that of the steel ball

....

....

.... [1]

(ii) why this ball takes a longer time to reach the ground than the steel ball.

....

....

.... [1]

[Total: 17]

Question 8

A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

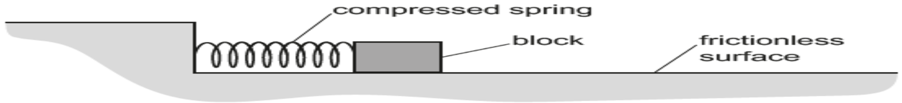


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,\mathrm{m\,s^{-1}}$, as shown in Fig. 4.2.

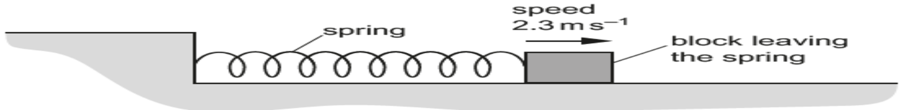


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of $420\,\mathrm{N\,m^{-1}}$.

A horizontal spring is fixed at one end. A block is pushed against the other end of the spring so that the spring is compressed, as shown in Fig. 4.1.

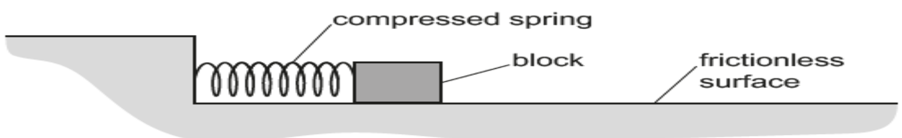


Fig. 4.1

The block is released and accelerates along a horizontal frictionless surface as the spring returns to its original length. The block leaves the end of the spring with a speed of $2.3\,\mathrm{m\,s^{-1}}$, as shown in Fig. 4.2.

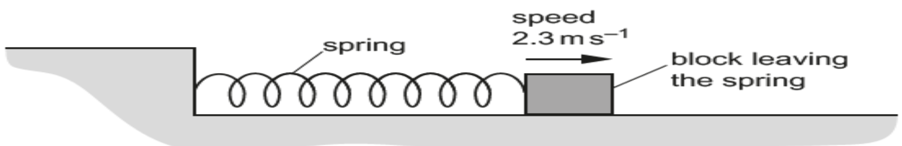


Fig. 4.2

The block has a mass of 250 g and the spring has a spring constant of $420\,\mathrm{N\,m^{-1}}$.

Assume that the spring always obeys Hooke's law and that all the elastic potential energy of the spring is transferred to the kinetic energy of the block.

(a) Calculate the kinetic energy of the block as it leaves the spring.

kinetic energy = ... J [2]

(b) Calculate the compression of the spring immediately before the block is released.

compression = ... m [2]

(c) After leaving the spring, the block moves along the surface until it hits a barrier at a speed of $2.3\,\text{m}\,\text{s}^{-1}$. The block then rebounds at a speed of $1.5\,\text{m}\,\text{s}^{-1}$ and moves back along its original path. The block is in contact with the barrier for a time of 0.086 s.

Calculate:

(i) the change in momentum of the block during the collision

change in momentum = ... N s [2]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

Fig. 4.3

[1]

[Total: 8]

(ii) the average resultant force exerted on the block during the collision.

average resultant force = ... N [1]

(d) The maximum compression x of the spring is now varied in order to vary the kinetic energy E_K of the block as it leaves the spring. Assume that all the elastic potential energy in the spring is always transferred to the kinetic energy of the block.

On Fig. 4.3, sketch a graph to show the variation with x of E_K.

Fig. 4.3

[1]

[Total: 8]

Question 9

(b) A hollow plastic sphere is attached at one end of a bar. The sphere is partially submerged in water and the bar is attached to a fixed vertical support by a pivot P, as shown in Fig. 3.1.

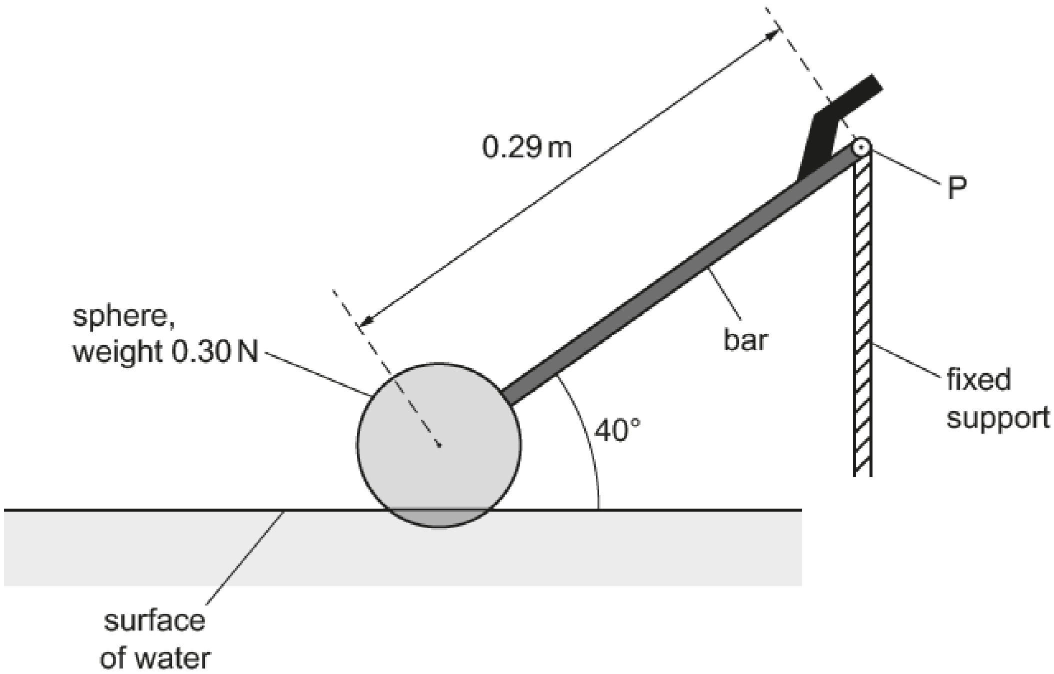


Fig. 3.1 (not to scale)

The sphere has weight 0.30 N. The distance from P to the centre of gravity of the sphere is 0.29 m. Assume that the weight of the bar is negligible.

Calculate the moment of the weight of the sphere about P.

moment = ... N m [2]

(c) The system shown in Fig. 3.1 is part of a mechanism that controls the amount of water in a tank.

Water enters the tank and causes the sphere to rise. This results in the bar becoming horizontal. Fig. 3.2 shows the system in its new position.

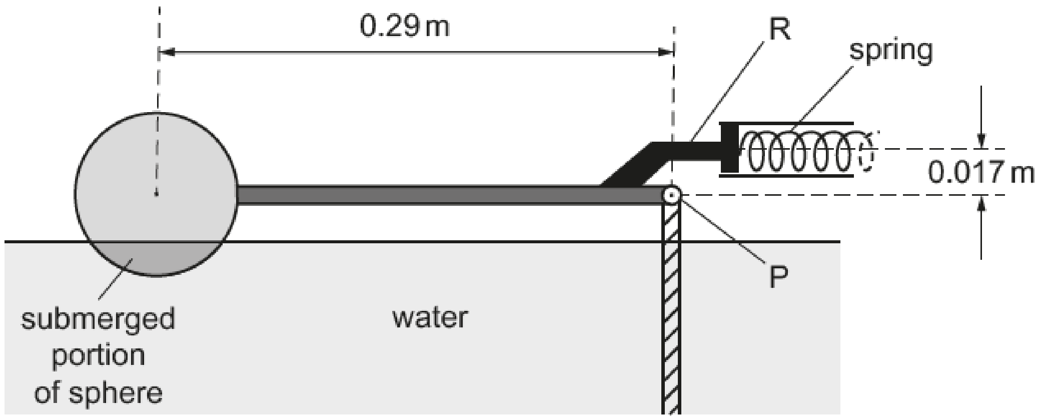


Fig. 3.2 (not to scale)

In this position the rod R exerts a force to compress a horizontal spring that controls the water supply to the tank. R is positioned at a perpendicular distance of 0.017 m above P.

The variation of the force *F* applied to the spring with compression *x* of the spring is shown in Fig. 3.3.

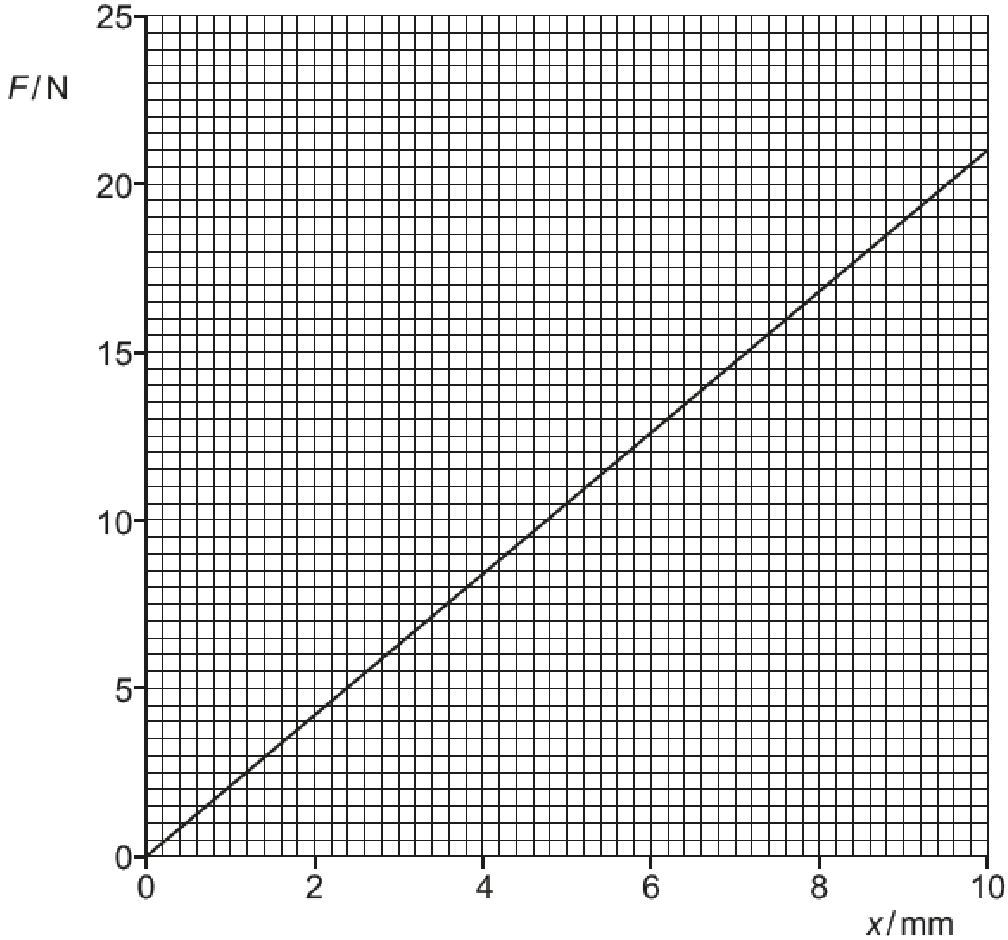


Fig. 3.3

(i) Use Fig. 3.3 to calculate the spring constant *k* of the spring.

k = ... $N\,m^{-1}$ [2]

(ii) At the position shown in Fig. 3.2, the system is stationary and in equilibrium.

The radius of the sphere is 0.0480 m and 26.0% of the volume of the sphere is submerged.
The density of water is $1.00 \times 10^3\,kg\,m^{-3}$.

Show that the upthrust on the sphere is 1.18 N.

[2]

(iii) By taking moments about P, determine the force exerted on the spring by the rod R.

force = ... N [2]

(iv) Calculate the elastic potential energy E_P of the compressed spring.

E_P = ... J [2]

(d) When the sphere moves from the position shown in Fig. 3.1 to the position shown in Fig. 3.2, the upthrust on the sphere does work.
Assume that resistive forces are negligible.

Explain why the work done by the upthrust is not equal to the gain in elastic potential energy of the spring.

....

.... [1]

[Total: 13]

Question 10

A beaker in air contains a liquid. The base of the beaker is in contact with the liquid and has area A, as shown in Fig. 4.1.

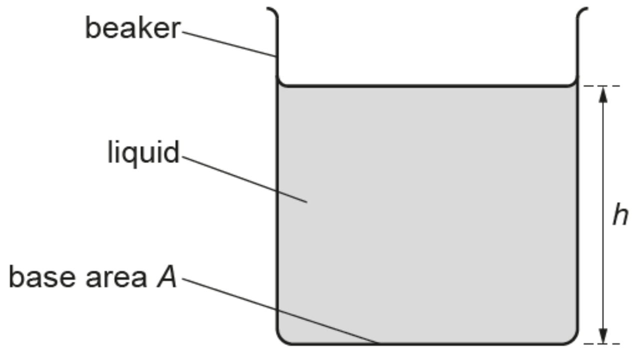


Fig. 4.1

The liquid has density ρ and fills the beaker to a depth h.

(a) By using the definitions of pressure and density, show that

$$p = \rho g h$$

where p is the pressure due to the liquid that is exerted on the base of the beaker and g is the acceleration of free fall.

[3]

(b) Suggest why the equation in **(a)** does not give the total pressure on the base of the beaker.

....

.... [1]

(c) Fig. 4.2 shows the variation of the total pressure inside the liquid with depth x below the surface.

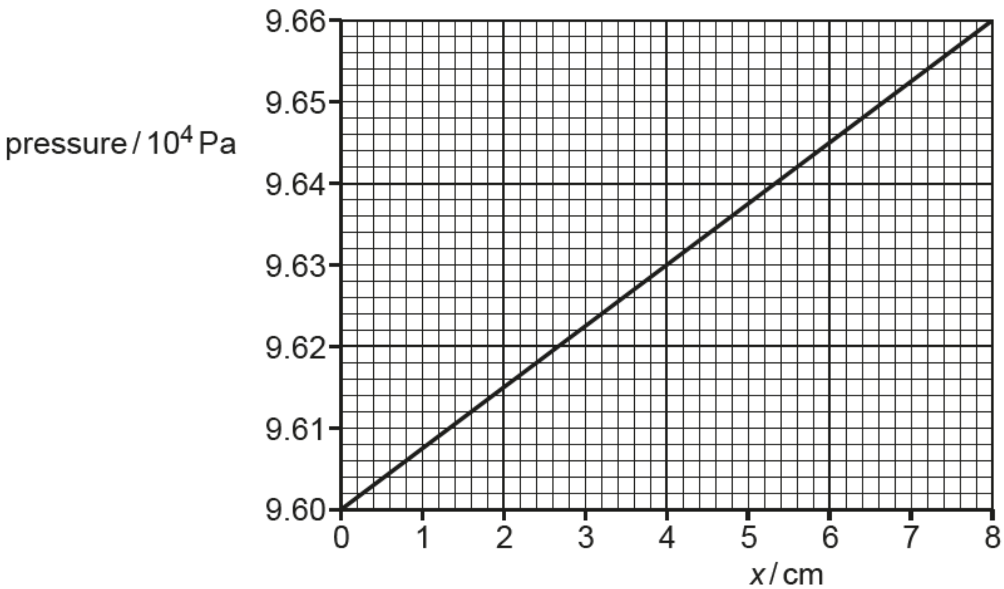


Fig. 4.2

Determine the density of the liquid.

density = ... $kg\,m^{-3}$ [2]

(d) A solid cylinder is held stationary by a wire so that the base of the cylinder is level with the surface of the liquid, as shown in Fig. 4.3.

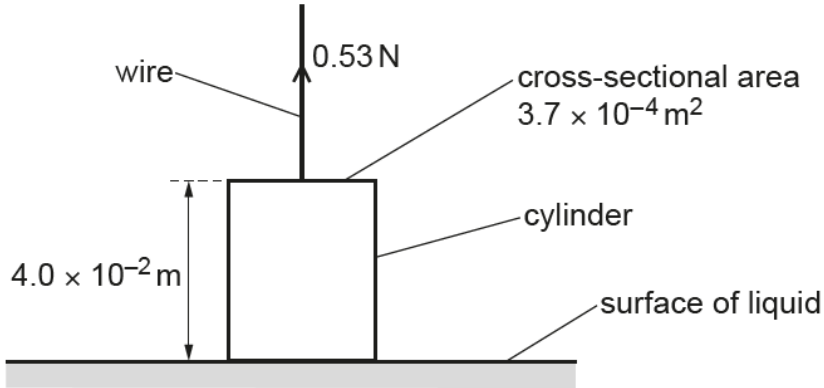


Fig. 4.3 (not to scale)

The cylinder has length 4.0×10^{-2} m and cross-sectional area $3.7 \times 10^{-4}\,m^2$. The tension in the wire is 0.53 N.

The cylinder is now lowered and then held stationary by the wire so that the top of the cylinder is level with the surface of the liquid.

Calculate the new tension in the wire.

tension = ... N [2]

[Total: 8]

Question 11

A spring is suspended from a fixed point at one end. The spring is extended by a vertical force applied to the other end. The variation of the applied force F with the length L of the spring is shown in Fig. 4.1.

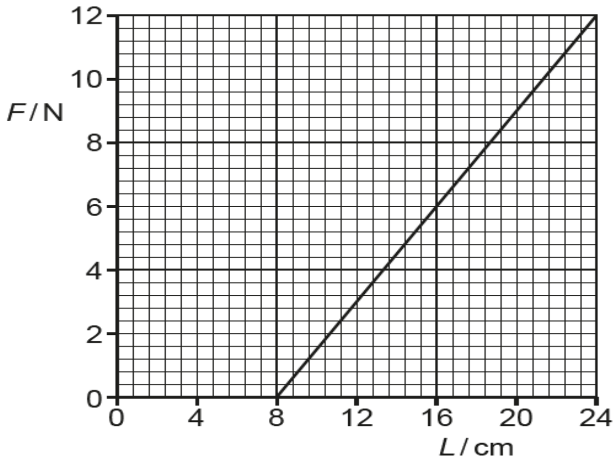
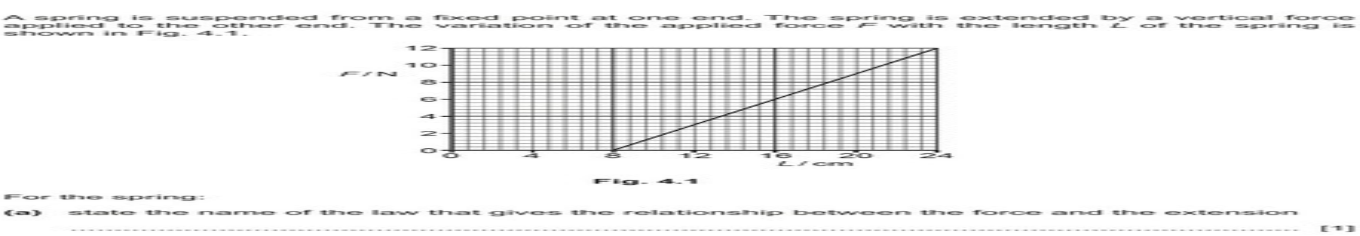


Fig. 4.1

For the spring:

(a) state the name of the law that gives the relationship between the force and the extension

.... [1]


A spring is suspended from a fixed point at one end. The spring is extended by a vertical force applied to the other end. The variation of the applied force F with the length L of the spring is shown in Fig. 4.1.
Fig. 4.1
For the spring:
(a) state the name of the law that gives the relationship between the force and the extension
[1]

(b) determine the spring constant, in $N\,m^{-1}$

spring constant = ... $N\,m^{-1}$ [2]

(c) determine the elastic potential energy when $F = 6.0\,\text{N}$.

elastic potential energy = ... J [2]

[Total: 5]

Question 12

A vertical rod is fixed to the horizontal surface of a table, as shown in Fig. 3.1.

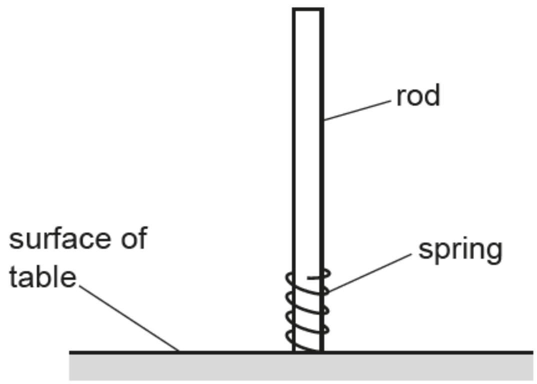


Fig. 3.1 (not to scale)

A spring of mass 7.5 g is able to slide along the full length of the rod.

The spring is first pushed against the surface of the table so that it has an initial compression of 2.1 cm. The spring is then suddenly released so that it leaves the surface of the table with a kinetic energy of 0.048 J and then moves up the rod.

Assume that the spring obeys Hooke's law and that the initial elastic potential energy of the compressed spring is equal to the kinetic energy of the spring as it leaves the surface of the table. Air resistance is negligible.

(a) By using the initial elastic potential energy of the compressed spring, calculate its spring constant.

spring constant = ... $N\,m^{-1}$ [2]

(b) Calculate the speed of the spring as it leaves the surface of the table.

speed = ... $m\,s^{-1}$ [2]

(c) The spring rises to its maximum height up the rod from the surface of the table. This causes the gravitational potential energy of the spring to increase by 0.039 J.

(i) Calculate, for this movement of the spring, the increase in height of the spring after leaving the surface of the table.

increase in height = ... m [2]

(ii) Calculate the average frictional force exerted by the rod on the spring as it rises.

average frictional force = ... N [2]

(d) The rod is replaced by another rod that exerts negligible frictional force on the moving spring. The initial compression x of the spring is now varied in order to vary the maximum increase in height Δh of the spring after leaving the surface of the table. Assume that the spring obeys Hooke's law for all compressions.

On Fig. 3.2, sketch a graph to show the variation with x of Δh. Numerical values are not required.

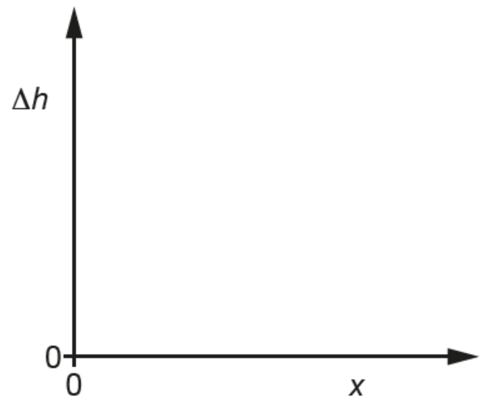


Fig. 3.2

[2]

[Total: 10]

Question 13

Fig. 4.1 shows the variation with extension x of the tensile force F for two wires, G and H, made from the same material.

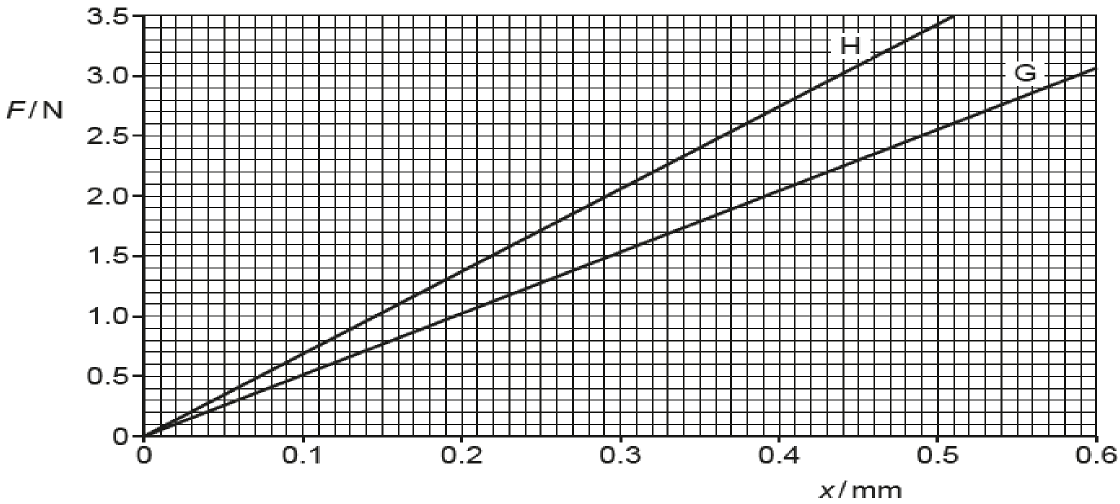


Fig. 4.1

The elastic limit has not been exceeded for G or H.

(a) For the lines in Fig. 4.1:

(i) state what is represented by the gradient

.... [1]

Fig. 4.1 shows the variation with extension x of the tensile force F for two wires, G and H, made from the same material.

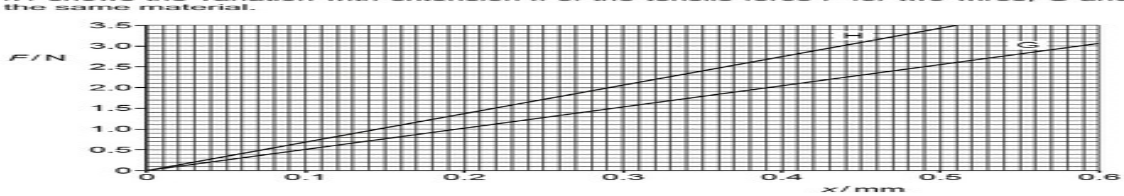


Fig. 4.1

The elastic limit has not been exceeded for G or H.

(a) For the lines in Fig. 4.1:

(i) state what is represented by the gradient

.... [1]

(ii) explain why the area under the line represents the elastic potential energy of the wire.

....

....

....

.... [2]

(b) Wires G and H are joined together end-to-end to form a composite wire of negligible weight. The composite wire hangs vertically from a fixed support.

A block of weight of 2.0 N is attached to the end of the wire, as shown in Fig. 4.2.

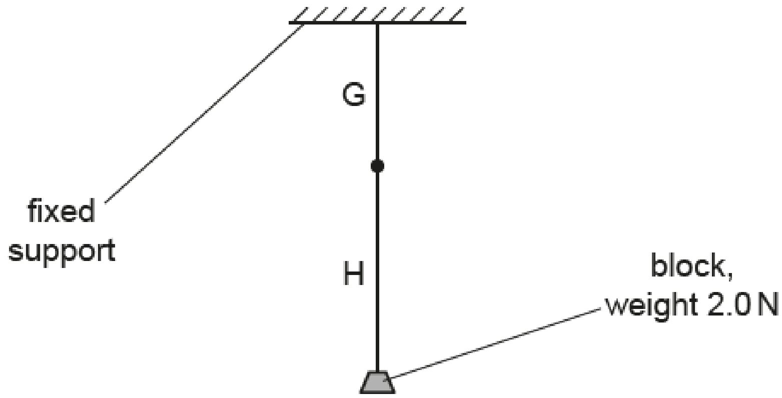


Fig. 4.2

(i) Use Fig. 4.1 to determine:

- the extension x_G of wire G

x_G = ... mm

- the extension x_H of wire H.

x_H = ... mm
[1]

(ii) Calculate the total elastic potential energy E_P of the composite wire due to the weight of the block.

E_P = ... J [2]

(iii) The original length of wire G is L and the original length of wire H is $1.5\,L$.

Calculate the ratio

$$\frac{\text{cross-sectional area of wire G}}{\text{cross-sectional area of wire H}}.$$

ratio = ... [3]

[Total: 9]

Question 14

A thin metal wire X, of diameter 1.2×10^{-3} m, is used to suspend a model planet, as shown in Fig. 3.1.

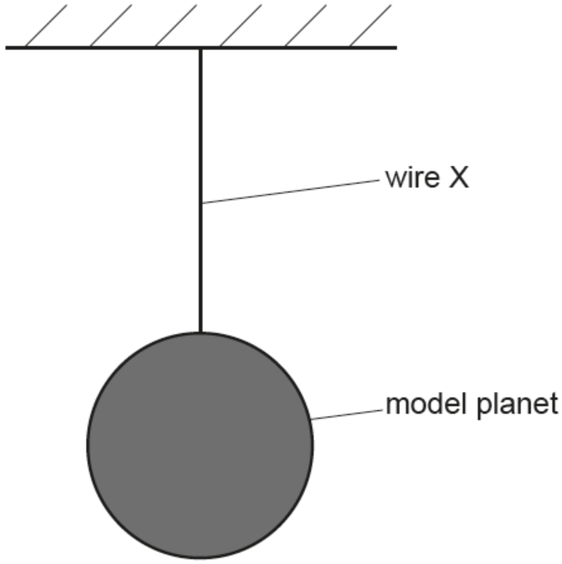


Fig. 3.1 (not to scale)

The variation with strain of the stress for wire X is shown in Fig. 3.2.

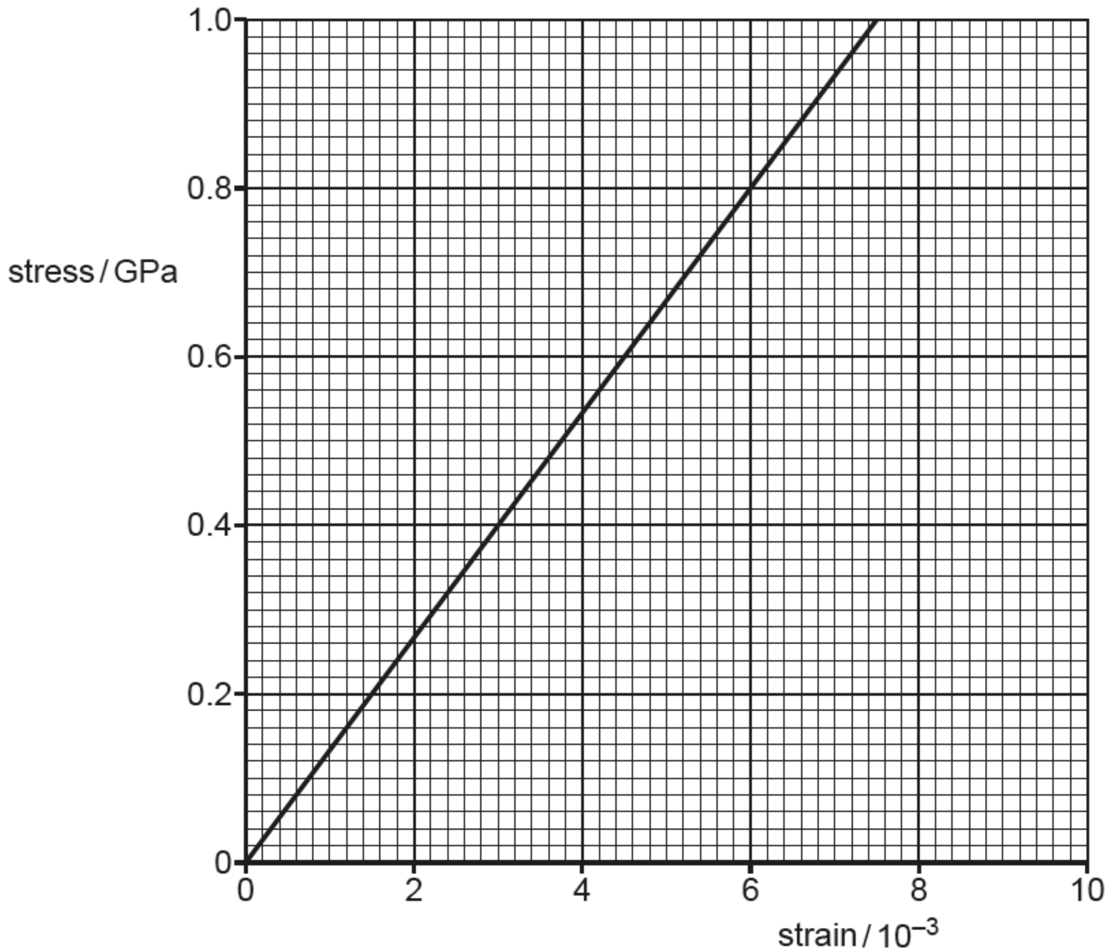


Fig. 3.2

(a) The strain in X is 5.4×10^{-3}.

(i) Use Fig. 3.2 to calculate the force exerted on the wire by the model planet.

force = ... N [3]

(ii) The elastic potential energy of X is 0.31 J.

Calculate the original length of the wire before the model planet was attached.

original length = ... m [3]

(b) Wire X is replaced by a new wire, Y, with the same original length and diameter but double the Young modulus of X. Wire Y also obeys Hooke's law.

On Fig. 3.2, draw a line representing the variation with strain of the stress for Y. [2]

[Total: 8]

Question 15

(a) Define strain.

....

.... [1]

(b) A copper wire of length 4.0 m has a uniform cross-sectional area of $4.5 \times 10^{-7}\,m^2$.

A tensile force of 18 N is applied to the wire. This causes the wire to extend by 1.4 mm up to its limit of proportionality.

(i) Calculate the Young modulus of the wire.

Young modulus = ...Pa [3]

(ii) On Fig. 4.1, draw a line to show how the stress varies with the strain for the wire up to its limit of proportionality.

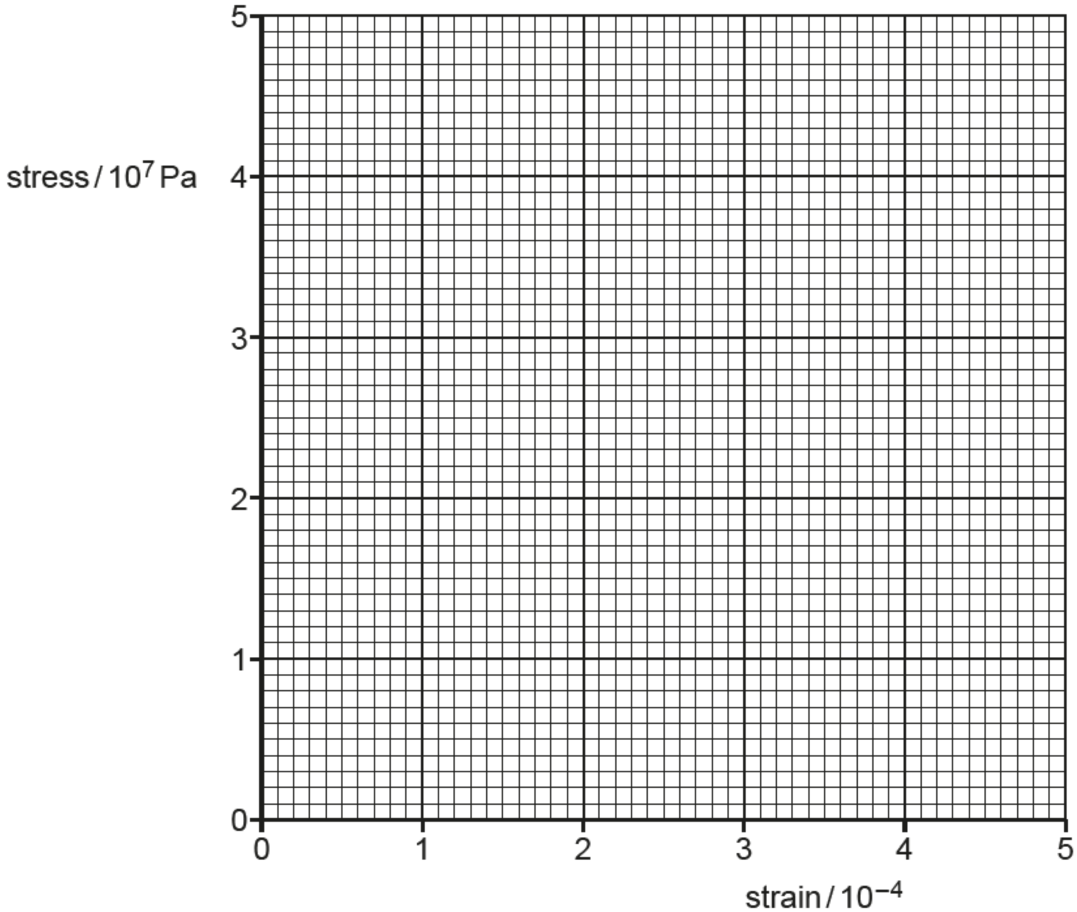


Fig. 4.1

[2]

(c) A second copper wire has the same length as the wire in **(b)** but a larger diameter. Both wires are subjected to a tensile force of 18 N.

By placing a tick (✓) in each row, complete Table 4.1 to compare the stress and strain of the two wires.

Table 4.1

	greater in second wire	less in second wire	the same in both wires
stress			
strain			

[2]

[Total: 8]

Question 16

A pinball machine uses a spring to launch a small metal ball of mass 4.5×10^{-2} kg up a ramp. The spring is compressed by 8.0×10^{-2} m and held in equilibrium, as shown in Fig. 4.1.

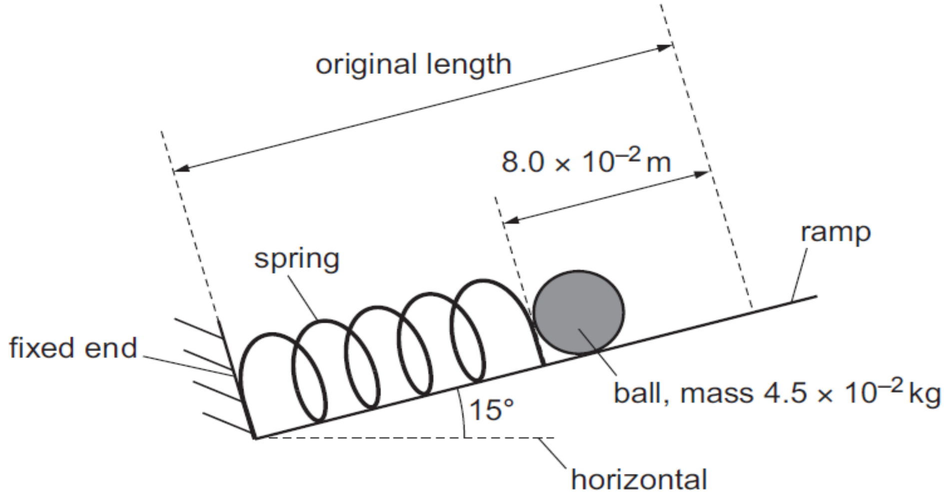


Fig. 4.1 (not to scale)

The ramp is at an angle of 15° to the horizontal.

(a) The spring obeys Hooke's law and has a spring constant of $29\,\mathrm{N\,m^{-1}}$.

(a) The spring obeys Hooke's law and has a spring constant of $29\,\mathrm{N\,m^{-1}}$.

Calculate the elastic potential energy in the compressed spring.

elastic potential energy = ... J [2]

(b) The spring is released and expands quickly back to its original length.

(i) Calculate the increase in gravitational potential energy of the ball when the spring returns to its original length.

increase in gravitational potential energy = ... J [3]

(ii) The ball leaves the spring when the spring reaches its original length. Assume that all the elastic potential energy of the spring is transferred to the ball.

Calculate the speed of the ball as it leaves the spring.

speed = ... $m\,s^{-1}$ [3]

Question 17

(a) State Hooke's law.

....

.... [1]

(b) The variation of the applied force with the extension for a sample of a material is shown in Fig. 3.1.

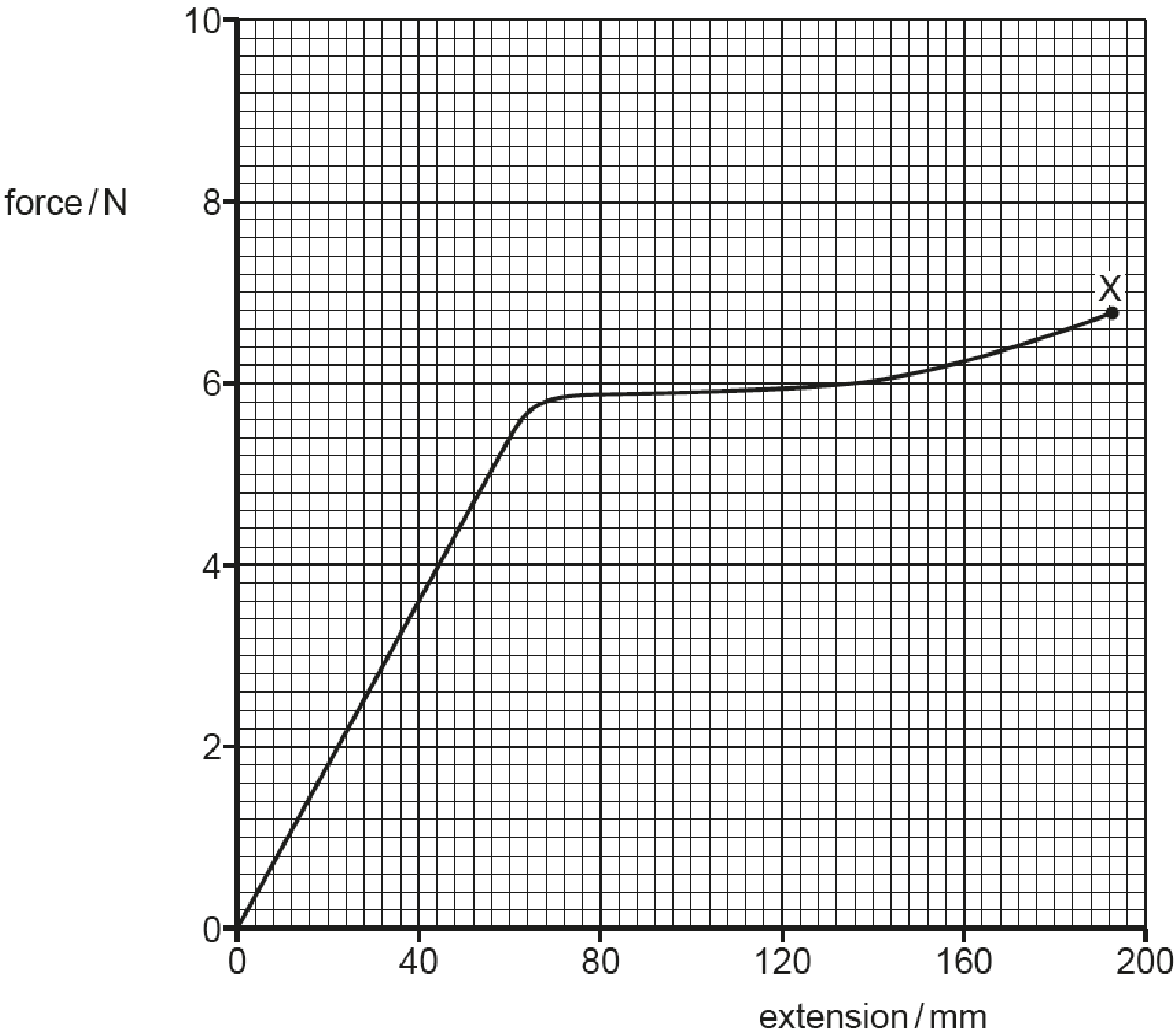


Fig. 3.1

The sample behaves elastically up to an extension of 80 mm and breaks at point X.

(i) On the line in Fig. 3.1, draw a cross (×) to show the limit of proportionality. Label this cross with the letter P. [1]

(ii) On the line in Fig. 3.1, draw a cross (×) to show the elastic limit. Label this cross with the letter E. [1]

(c) The sample in **(b)** has a cross-sectional area of 0.40 mm^2 and an initial length of 3.2 m.

For deformations within the limit of proportionality of the sample, determine:

(i) the spring constant of the sample

spring constant = ... $N\,m^{-1}$ [2]

(ii) the Young modulus of the material from which the sample is made.

Young modulus = ... Pa [3]

(d) Determine an estimate of the work done on the sample as it is extended from zero extension to its breaking point. Explain your reasoning.

work done = ... J [2]

(e) A second sample of the same material has a larger cross-sectional area than the original sample but the same initial length. The two samples are each deformed with the limit of proportionality.

State and explain qualitatively how the spring constant of the second sample compares with that of the original sample.

....

....

.... [2]

[Total: 12]

Question 18

(a) Define the Young modulus of a material.

....

.... [1]

(b) A metal wire P that obeys Hooke's law is stretched within its limit of proportionality.

(i) On Fig. 4.1, sketch the variation of tensile force F in the wire with its extension x.

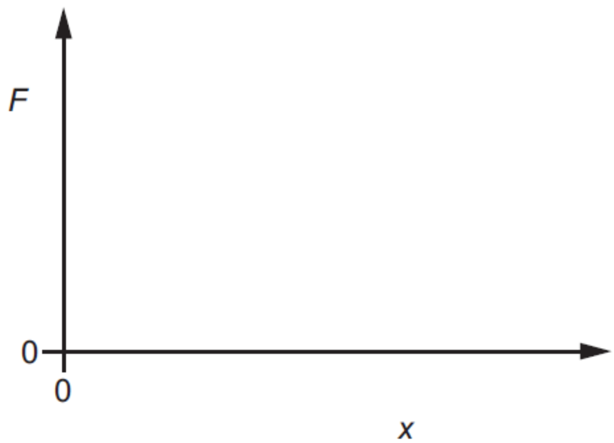


Fig. 4.1

[1]

(ii) State the name of the quantity represented by the gradient of the line in Fig. 4.1.

.... [1]

(iii) State the name of the quantity represented by the area under the line in Fig. 4.1.

.... [1]

(c) Another wire Q is made from a metal that has twice the Young modulus of the metal of wire P in **(b)**. Wire Q has the same volume as wire P but has double the cross-sectional area of wire P.

The two wires are extended by equal tensile forces within their limits of proportionality.

State and explain how the extension of wire Q compares with the extension of wire P.

....

....

....

....

.... [3]

[Total: 7]

Question 19

(a) The variation of stress with strain for a metal P is shown in Fig. 3.1.

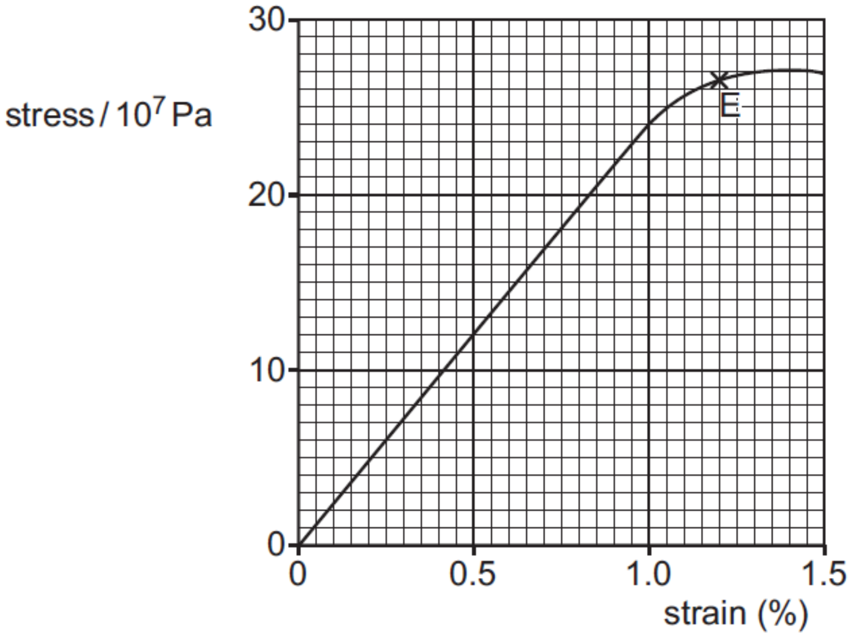


Fig. 3.1

Point E is the elastic limit of the metal.

(i) Use Fig. 3.1 to determine the Young modulus for P.

Young modulus = ... Pa [2]

(ii) On the line in Fig. 3.1, draw a cross (×) to show the limit of proportionality. Label this point Q. [1]

Question 20

(a) Define:

(i) stress

....

.... [1]

(ii) strain.

....

.... [1]

(b) Two wires X and Y, with equal unstretched lengths of 0.84 m, are suspended from fixed points that are at the same horizontal level. The lower ends of the wires are attached to a beam of negligible mass. The beam is horizontal and in equilibrium, as shown in Fig. 4.1.

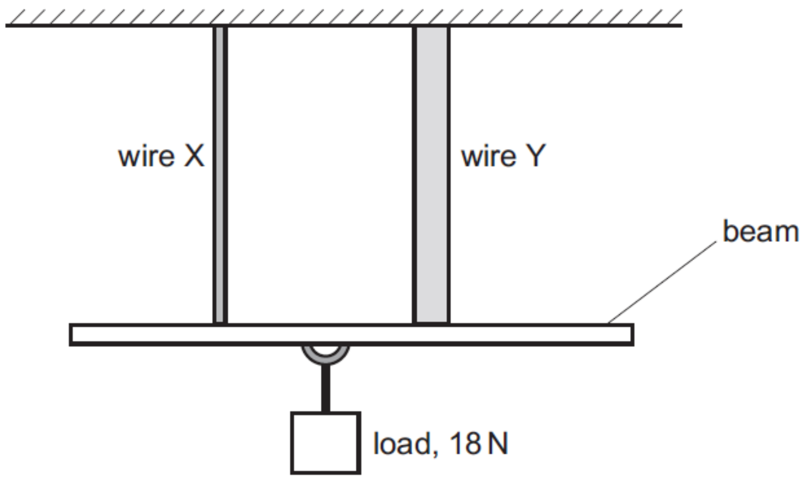


Fig. 4.1

Wire X is made from a metal that has a Young modulus of 1.9×10^{9} Pa.
Wire Y is made from a different metal.

A load of weight 18 N is suspended from the beam at a point that is equidistant from the two wires. This load causes both wires to extend by 0.47 mm.

(i) Determine the cross-sectional area of wire X.

cross-sectional area = ... m^2 [3]

(ii) Wire Y has a greater diameter than wire X.

Explain, without calculation, whether the Young modulus of the metal from which wire Y is made is less than, the same as or greater than 1.9×10^9 Pa.

....

....

....

.... [2]

[Total: 7]

(i) Determine the cross-sectional area of wire X.

cross-sectional area = ... m^2 [3]

(ii) Wire Y has a greater diameter than wire X.

Explain, without calculation, whether the Young modulus of the metal from which wire Y is made is less than, the same as or greater than 1.9×10^9 Pa.

....

....

....

.... [2]

[Total: 7]

Question 21

(a) Define the Young modulus.

....

.... [1]

(b) A wire of unstretched length 0.81 m is made of a metal with Young modulus 95 GPa. The wire obeys Hooke's law and has a constant cross-sectional area. Fig. 5.1 shows the force–extension graph for the wire.

(b) A wire of unstretched length 0.81 m is made of a metal with Young modulus 95 GPa. The wire obeys Hooke's law and has a constant cross-sectional area. Fig. 5.1 shows the force–extension graph for the wire.

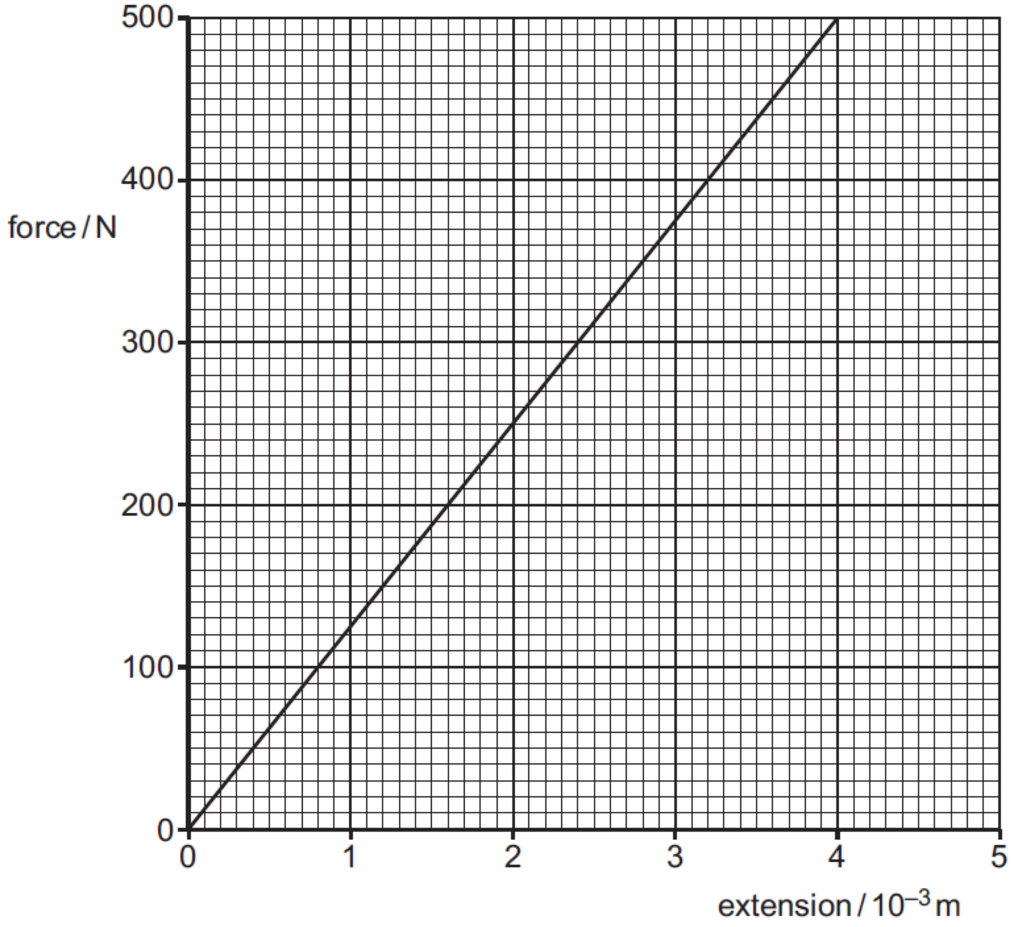


Fig. 5.1

(i) Determine the cross-sectional area of the wire.

area = ... m^2 [3]

(ii) The extension of the wire is initially 2.0×10^{-3} m.

Determine the work done to increase the extension of the wire to 3.0×10^{-3} m.

work done = ... J [3]

[Total: 7]

Question 22

A wire has length L and cross-sectional area A. The wire is made from a metal that has Young modulus E and resistivity ρ.

(a) Define the Young modulus of a material.

....

.... [1]

(b) **(i)** State an expression, in terms of some or all of L, A, E and ρ, for the resistance R_0 of the wire.

R_0 = ... [1]

(ii) Show that the spring constant k_0 of the wire is given by

$$k_0 = \frac{EA}{L}.$$

[2]

(c) The wire is stretched, within the limit of proportionality, by a tensile force *F*. Assume that any changes in the cross-sectional area of the wire are negligible.

(i) On Fig. 3.1, sketch the variation with *F* of the resistance *R* of the wire.

Fig. 3.1

[1]

(ii) On Fig. 3.2, sketch the variation with *F* of the spring constant *k* of the wire.

Fig. 3.2

[1]

(d) Copper has a resistivity of $1.8 \times 10^{-8}\,\Omega\,m$ and a Young modulus of 1.3×10^{11} Pa.

A copper wire of diameter 1.6 mm has a resistance of $0.034\,\Omega$.

(i) Show that the length of the wire is 3.8 m.

[1]

(ii) Use the equation in **(b)(ii)** to determine the spring constant of the wire.

spring constant = ... $N\,m^{-1}$ [2]

[Total: 9]

Question 23

A spring is fixed at one end and attached to the frame of a pulley at the other end. A cable is passed around the wheel of the pulley. The spring is stretched to a fixed length using the cable and pulley.

Fig. 3.1 shows the view from above of the spring, cable and pulley.

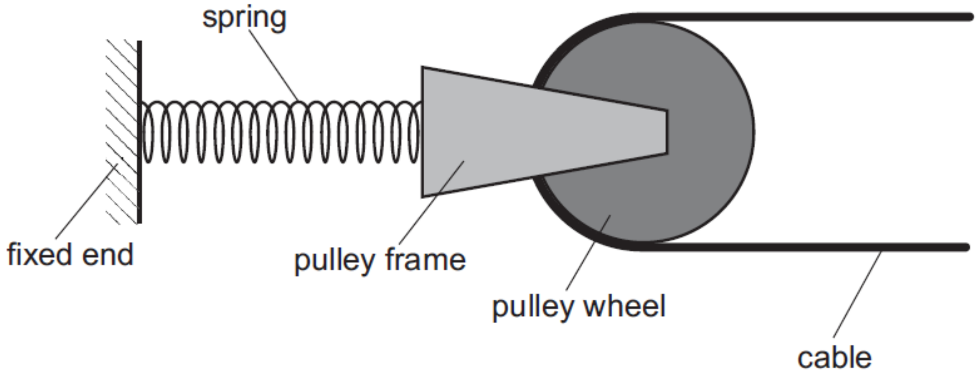


Fig. 3.1

The spring obeys Hooke's law and has a spring constant *k* of 250 N m^{-1}. A force *F* acts on the spring. The tension in the cable is *T*. The pulley is in equilibrium.

The spring obeys Hooke's law and has a spring constant *k* of 250 N m^{-1}. A force *F* acts on the spring. The tension in the cable is *T*. The pulley is in equilibrium.

(a) On Fig. 3.2, draw labelled arrows to show the directions of the forces acting on the pulley.

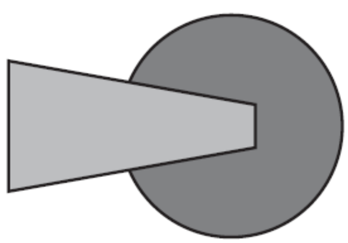


Fig. 3.2

[2]

(b) The force F is 110 N.

(i) Determine T.

T = ... N [1]

(ii) Calculate the extension of the spring.

extension = ... m [2]

(c) A second identical spring with the same spring constant of 250 N m^{-1} is now also connected to the pulley, as shown in Fig. 3.3.

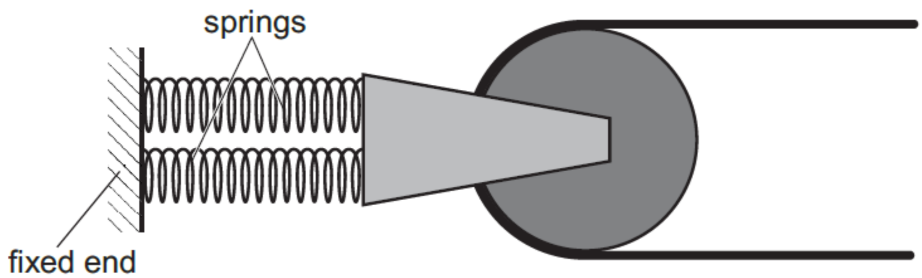


Fig. 3.3

The tension in the cable is kept the same. The pulley is again in equilibrium.

(i) Determine the extension of the springs.

extension = ... m [2]

(ii) The elastic potential energy stored in the spring in Fig. 3.1 is E_1. The **total** elastic potential energy stored in the two springs in Fig. 3.3 is E_2.

Calculate the ratio $\dfrac{E_1}{E_2}$.

ratio = ... [2]

[Total: 9]

Question 24

A bungee jumper of mass 64 kg secures one end of an elastic rope to a bridge. The other end is attached to the bungee jumper. The jumper falls from rest from the bridge and descends into the valley below, as shown in Fig. 3.1.

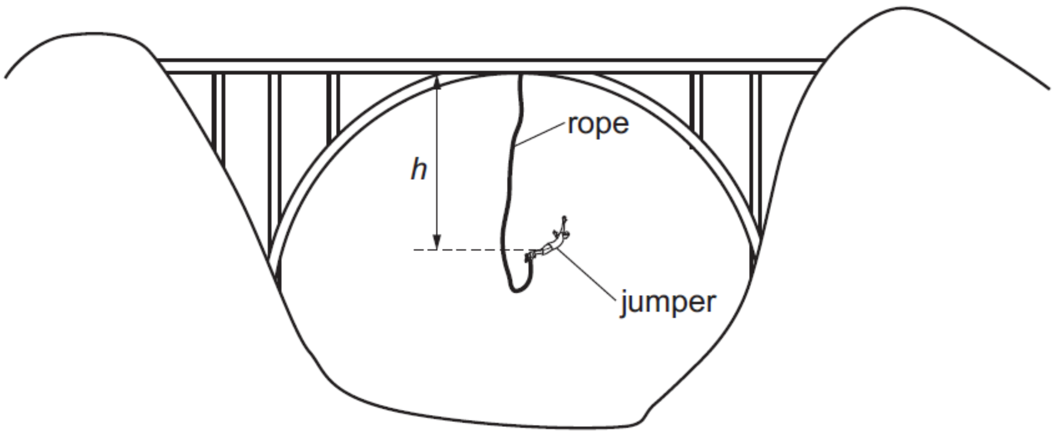


Fig. 3.1 (not to scale)

Fig. 3.2 shows the variation of the tension T in the rope with the vertical distance h of the jumper below the level of the bridge.

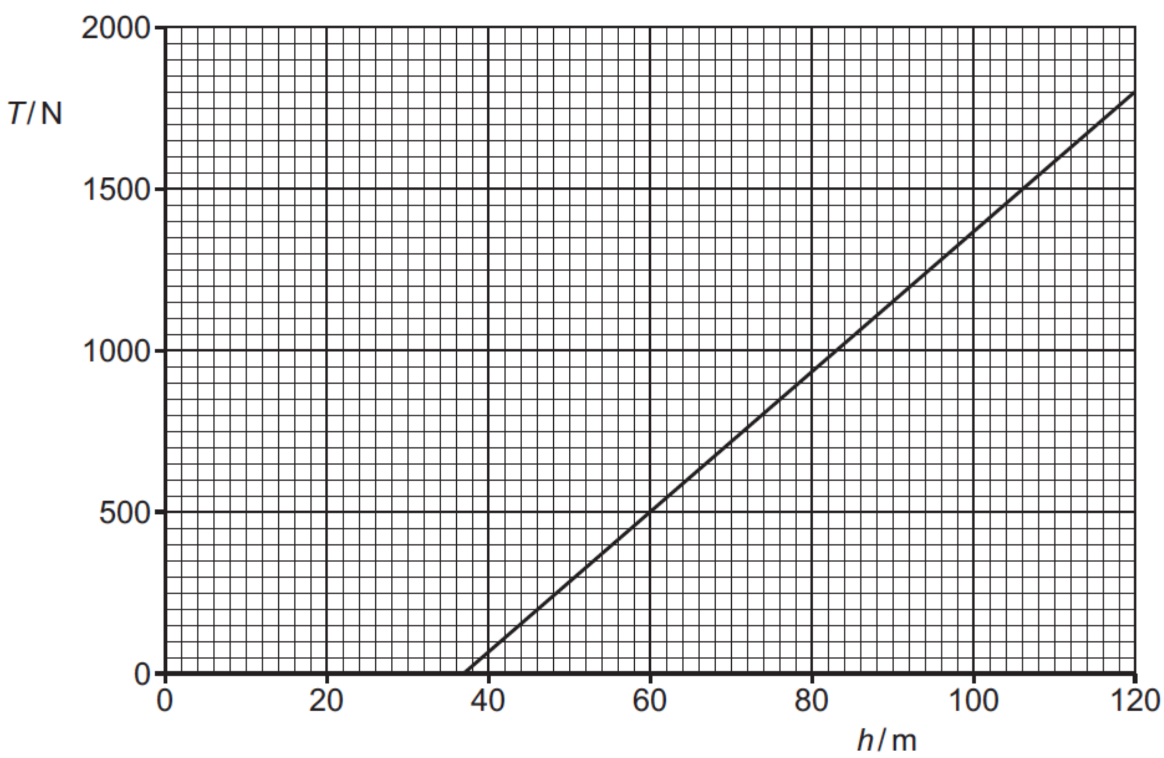


Fig. 3.2

(a) The rope obeys Hooke's law.

State Hooke's law.

....

.... [1]

(b) **(i)** Determine the unstretched length of the rope.

length = ... m [1]

(ii) Determine the spring constant k of the rope.

k = ... $N\,m^{-1}$ [2]

(c) For the position of the bungee jumper at a distance of 120 m below the bridge:

(i) show that the loss of gravitational potential energy since leaving the bridge is 75 kJ

[2]

(ii) show that the elastic potential energy in the rope is 75 kJ.

[2]

(d) Explain what can be deduced from the information in **(c)** about the speed of the bungee jumper when at a distance of 120 m below the bridge.

....

....

.... [2]

[Total: 10]

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