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International Examinations Papers

Mob: +974 55249797 / 55258711
E-mail:rashed.saba@gmail.com

Matter and materials: 7

TOPIC- Density, pressure, compressive and tensile forces, **HOOKE'S LAW,** modulus of elasticity (Young), Experiment, elastic potential energy

For Examiner's Use

Q.1 **(a)** Distinguish between the structure of a metal and of a polymer.

metal: ....

....

....

polymer: ....

....

.... [4]

(b) Latex is a natural form of rubber. It is a polymeric material.

(i) Describe the properties of a sample of latex.

....

....

.... [2]

(ii) The process of heating latex with a small amount of sulphur creates cross-links between molecules. Natural latex has very few cross-links between its molecules.

Suggest how this process changes the properties of latex.

....

....

.... [2]

For Examiner's Use

2 **(a)** State Hooke's law.

....

.... [1]

(b) A spring is attached to a support and hangs vertically, as shown in Fig. 6.1. An object M of mass 0.41 kg is attached to the lower end of the spring. The spring extends until M is at rest at R.

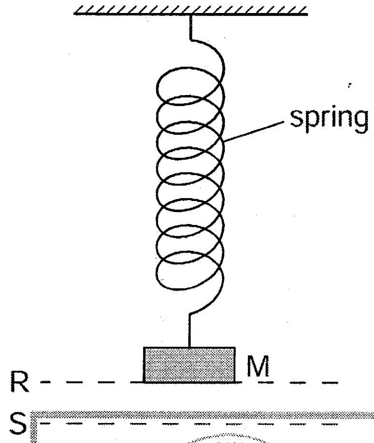


Fig. 6.1

The spring constant of the spring is 25 N m^{-1}. Show that the extension of the spring is about 0.16 m.

[2]

(c) The object M in Fig. 6.1 is pulled down a further 0.060 m to S and is then released. For M, just as it is released,

(i) state the forces acting on M,

.... [1]

(ii) calculate the acceleration of M.

acceleration = ... m s^{-2} [3]

(d) Describe and explain the energy changes from the time the object M in Fig. 6.1 is released to the time it first returns to R.

For Examiner's Use

....

....

....

.... [2]

Please turn over for Question 7.

For Examiner's Use

3 **(a)** Define

(i) *stress*,

....

.... [1]

(ii) *strain*.

....

.... [1]

(b) Explain the term *elastic limit*.

....

.... [1]

(c) Explain the term *ultimate tensile stress*.

....

....

.... [2]

(d) **(i)** A **ductile** material in the form of a wire is stretched up to its breaking point. On Fig. 3.1, sketch the variation with extension x of the stretching force F.

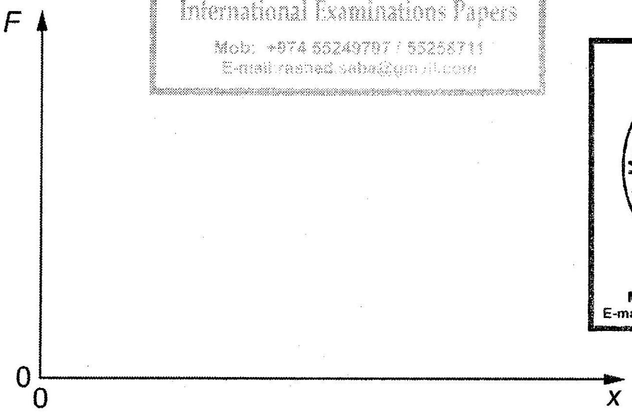


Fig. 3.1

[2]

For Examiner's Use

(ii) On Fig. 3.2, sketch the variation with x of F for a **brittle** material up to its breaking point.

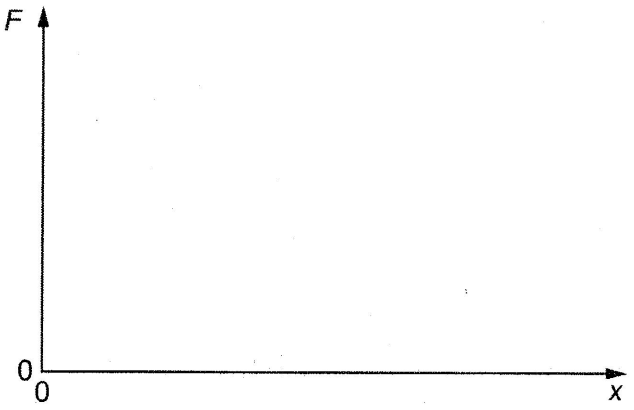


Fig. 3.2

[1]

(e) (i) Explain the features of the graphs in **(d)** that show the characteristics of ductile and brittle materials.

....

....

....

....

....[2]

(ii) The force F is removed from the materials in **(d)** just before the breaking point is reached. Describe the subsequent change in the extension for

1. the ductile material,

....

....[1]

2. the brittle material.

....

....[1]

4 (a) (i) Define the terms

1. tensile stress,

....

.... [1]

2. tensile strain,

....

.... [1]

3. the Young modulus.

....

.... [1]

(ii) Suggest why the Young modulus is not used to describe the deformation of a liquid or a gas.

....

.... [1]

(b) The change ΔV in the volume V of some water when the pressure on the water increases by Δp is given by the expression

$$\Delta p = 2.2 \times 10^9 \frac{\Delta V}{V}$$

where Δp is measured in pascal.
In many applications, water is assumed to be incompressible.
By reference to the expression, justify this assumption.

....

....

.... [2]

For Examiner's Use

(c) Normal atmospheric pressure is 1.01×10^5 Pa.

Divers in water of density $1.08 \times 10^3\,\mathrm{kg\,m^{-3}}$ frequently use an approximation that every 10 m increase in depth of water is equivalent to one atmosphere increase in pressure. Determine the percentage error in this approximation.

error = ... % [3]

5 **(a)** Define the *Young modulus*.

....

.... [1]

(b) Two wires P and Q of the same material and same original length l_0 are fixed so that they hang vertically, as shown in Fig. 5.1.

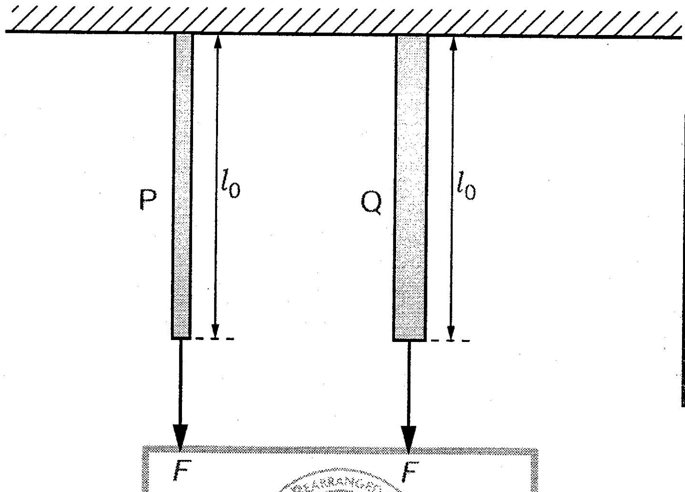


Fig. 5.1 (not to scale)

The diameter of P is *d* and the diameter of Q is 2*d*. The same force *F* is applied to the lower end of each wire.

Show your working and determine the ratio

(i) $\dfrac{\text{stress in P}}{\text{stress in Q}}$,

ratio = ... [2]

(ii) $\dfrac{\text{strain in P}}{\text{strain in Q}}$.

ratio = ... [2]

For Examiner's Use

6 **(a)** Explain what is meant by *plastic deformation*.

....

.... [1]

(b) A copper wire of uniform cross-sectional area $1.54 \times 10^{-6}\,m^2$ and length 1.75 m has a breaking stress of 2.20×10^{8} Pa. The Young modulus of copper is 1.20×10^{11} Pa.

(i) Calculate the breaking force of the wire.

breaking force = ... N [2]

(ii) A stress of 9.0×10^{7} Pa is applied to the wire. Calculate the extension.

extension = ... m [2]

(c) Explain why it is not appropriate to use the Young modulus to determine the extension when the breaking force is applied.

....

.... [1]

07 A student measures the Young modulus of a metal in the form of a wire.

(a) Describe, with the aid of a diagram, the apparatus that could be used.

[2]

(b) Describe the method used to obtain the required measurements.

[4]

For Examiner's Use

(c) Describe how the measurements taken can be used to determine the Young modulus.

....

....

....

....

....

....

....

....

....

.... [4]

08 **(a)** Define

For Examiner's Use

(i) stress,

.... [1]

(ii) strain.

.... [1]

(b) The Young modulus of the metal of a wire is 0.17 TPa. The cross-sectional area of the wire is $0.18\,mm^2$.

The wire is extended by a force F. This causes the length of the wire to be increased by 0.095 %.

Calculate

(i) the stress,

stress = ... Pa [4]

(ii) the force F.

F = ... N [2]

For Examiner's Use

0 9 (a) A uniform wire has length L and constant area of cross-section A. The material of the wire has Young modulus E and resistivity ρ. A tension F in the wire causes its length to increase by ΔL.

For this wire, state expressions, in terms of L, A, F, ΔL and ρ for

(i) the stress σ,

.... [1]

(ii) the strain ε,

.... [1]

(iii) the Young modulus E,

.... [1]

(iv) the resistance R.

.... [1]

(b) One end of a metal wire of length 2.6 m and constant area of cross-section $3.8 \times 10^{-7}\,\text{m}^2$ is attached to a fixed point, as shown in Fig. 4.1.

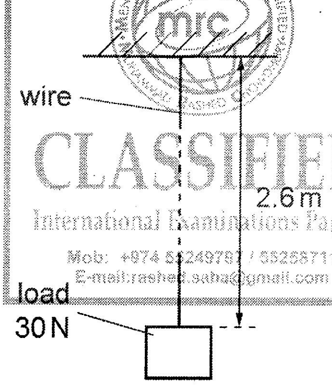


Fig. 4.1

The Young modulus of the material of the wire is 7.0×10^{10} Pa and its resistivity is $2.6 \times 10^{-8}\,\Omega$ m.
A load of 30 N is attached to the lower end of the wire. Assume that the area of cross-section of the wire does not change.
For this load of 30 N,

For Examiner's Use

(i) show that the extension of the wire is 2.9 mm,

[1]

(ii) calculate the change in resistance of the wire.

change = ... Ω [2]

(c) The resistance of the wire changes with the applied load.
Comment on the suggestion that this change of resistance could be used to measure the magnitude of the load on the wire.

....

....

.... [2]

10 A spring is kept horizontal by attaching it to points A and B, as shown in Fig. 4.1.

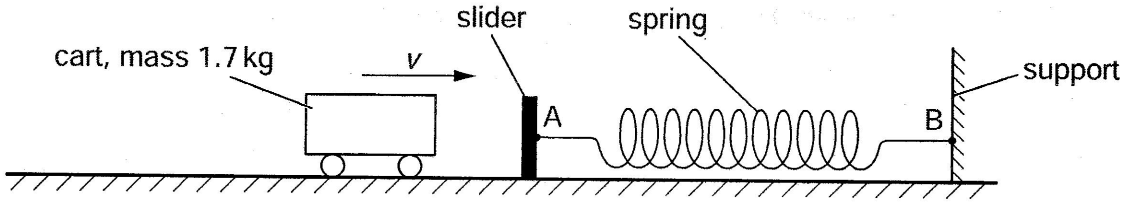


Fig. 4.1

Point A is on a movable slider and point B is on a fixed support. A cart of mass 1.7 kg has horizontal velocity *v* towards the slider. The cart collides with the slider. The spring is compressed as the cart comes to rest. The variation of compression *x* of the spring with force *F* exerted on the spring is shown in Fig. 4.2.

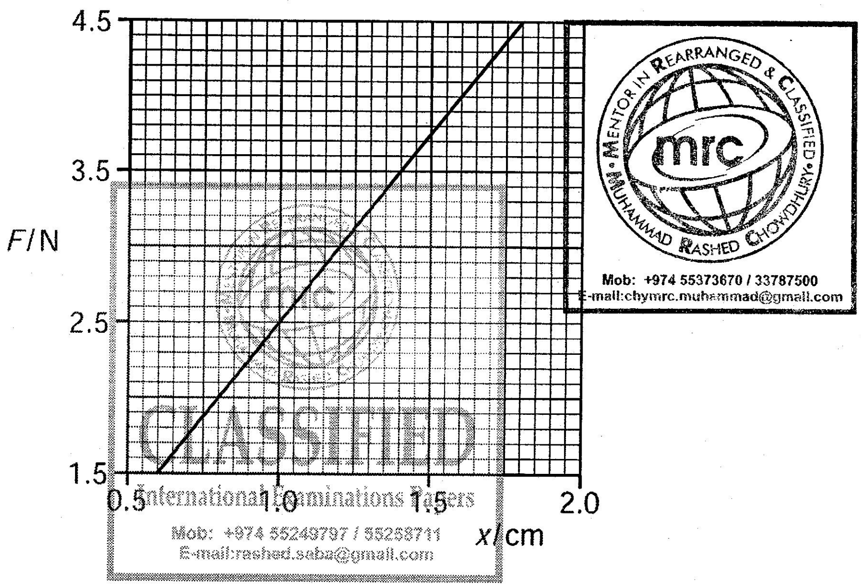


Fig. 4.2

Fig. 4.2 shows the compression of the spring for *F* = 1.5 N to *F* = 4.5 N. The cart comes to rest when *F* is 4.5 N.

(a) Use Fig. 4.2 to

(i) show that the compression of the spring obeys Hooke's law,

....

....

.... [2]

(ii) determine the spring constant of the spring,

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

(iii) determine the elastic potential energy E_P stored in the spring due to the cart being brought to rest.

E_P = ... J [3]

(b) Calculate the speed v of the cart as it makes contact with the slider. Assume that all the kinetic energy of the cart is converted to the elastic potential energy of the spring.

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

1 A trolley T moves at speed $1.2\,\text{m}\,\text{s}^{-1}$ along a horizontal frictionless surface. The trolley collides with a stationary block on the end of a fixed spring, as shown in Fig. 3.1.

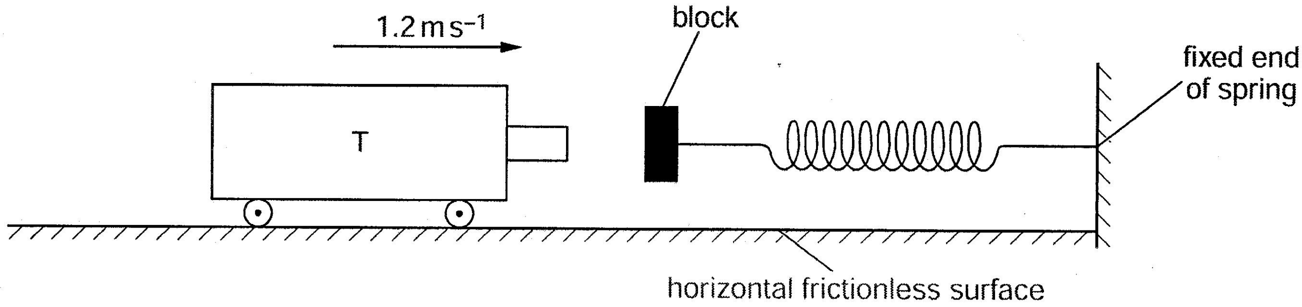


Fig. 3.1

The mass of T is 250 g. T compresses the spring by 5.4 cm as it comes to rest.
The relationship between the force F applied to the block and the compression x of the spring is shown in Fig. 3.2.

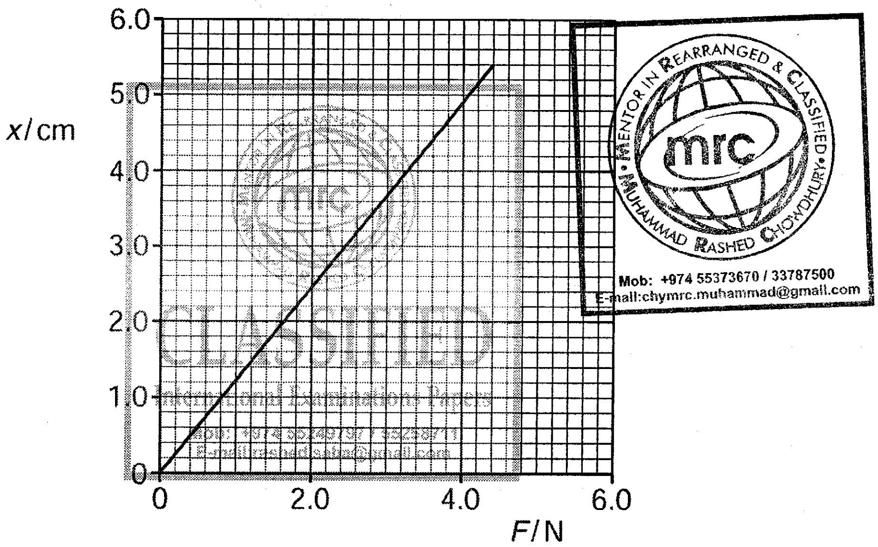


Fig. 3.2

(a) Use Fig. 3.2 to determine

(i) the spring constant of the spring,

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

(ii) the work done by T compressing the spring by 5.4 cm.

work done = ... J [2]

(b) The spring then expands and causes T to move in a direction opposite to its initial direction. At the time that T loses contact with the block, it is moving at a speed of $0.75\,m\,s^{-1}$.

From the time that T is in contact with the block,

(i) describe the energy changes,

....

....

....

....[2]

(ii) determine the change in momentum of T.

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

12 **(a)** State Hooke's law.

....

.... [1]

(b) The variation with extension x of the force F for a spring A is shown in Fig. 6.1.

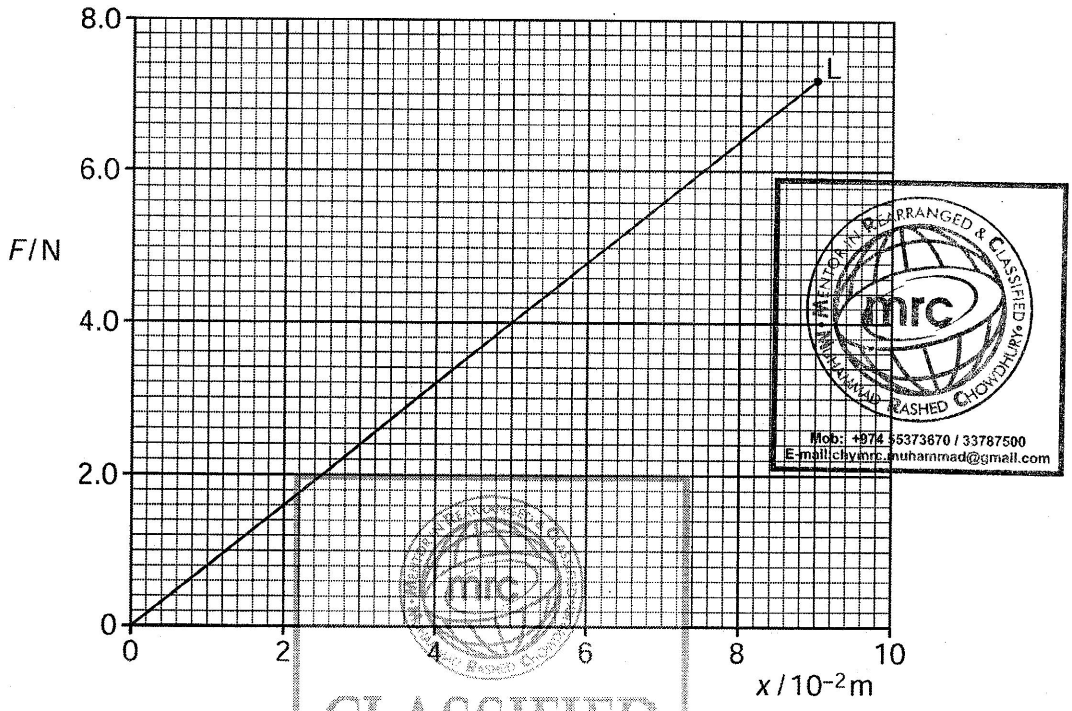


Fig. 6.1

The point L on the graph is the elastic limit of the spring.

(i) Describe the meaning of *elastic limit*.

....

....

.... [1]

(ii) Calculate the spring constant k_A for spring A.

k_A = ... N m^{-1} [1]

For Examiner's Use

(iii) Calculate the work done in extending the spring with a force of 6.4 N.

For Examiner's Use

work done = ... J [2]

(c) A second spring B of spring constant $2k_A$ is now joined to spring A, as shown in Fig. 6.2.

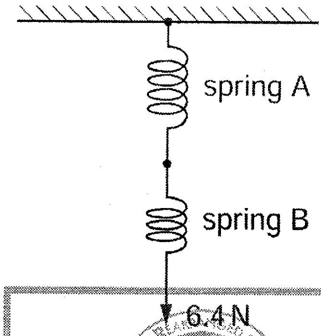


Fig. 6.2

A force of 6.4 N extends the combination of springs.

For the combination of springs, calculate

(i) the total extension,

extension = ... m [1]

(ii) the spring constant.

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

13 (a) A metal wire has spring constant *k*. Forces are applied to the ends of the wire to extend it within the limit of Hooke's law.
Show that, for an extension *x*, the strain energy *E* stored in the wire is given by

$$E = \tfrac{1}{2}kx^2.$$

[4]

(b) The wire in **(a)** is now extended beyond its elastic limit. The forces causing the extension are then removed.
The variation with extension *x* of the tension *F* in the wire is shown in Fig. 4.1.

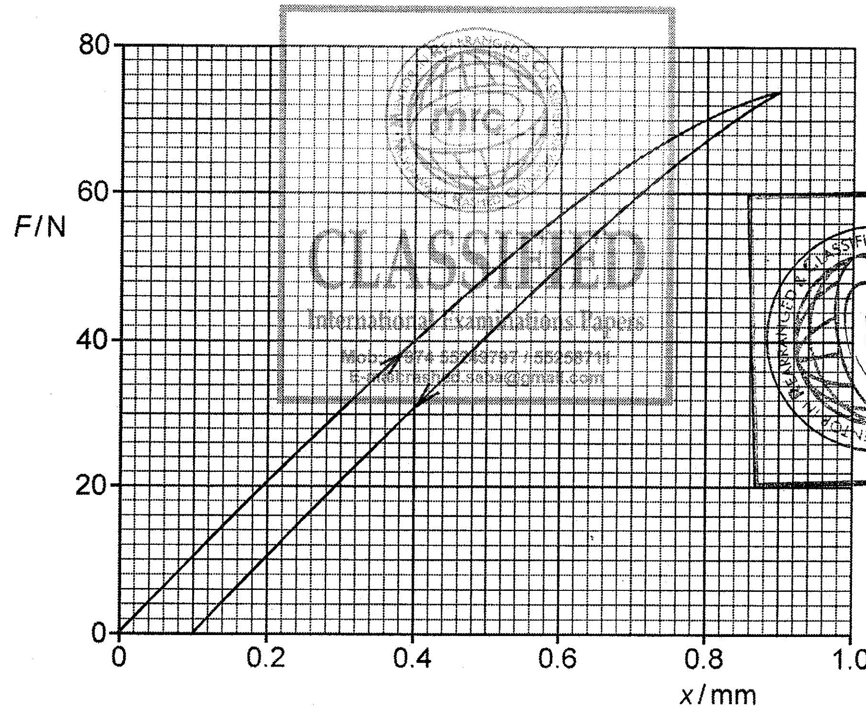


Fig. 4.1

Energy E_S is expended to cause a permanent extension of the wire.

(i) On Fig. 4.1, shade the area that represents the energy E_S. [1]

(ii) Use Fig. 4.1 to calculate the energy E_S.

For Examiner's Use

E_S = ... mJ [3]

(iii) Suggest the change in the structure of the wire that is caused by the energy E_S.

....

....[1]

4 A spring is placed on a flat surface and different weights are placed on it, as shown in Fig. 2.1.

For Examiner's Use

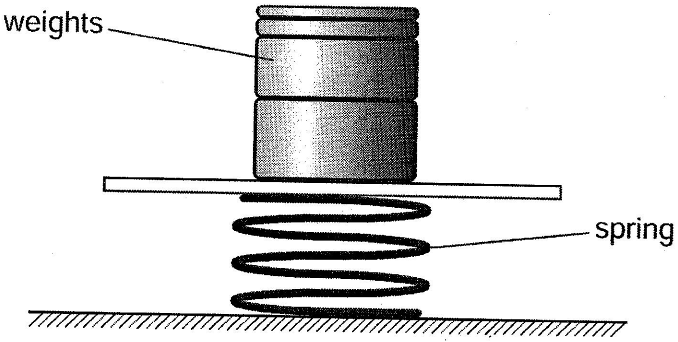


Fig. 2.1

The variation with weight of the compression of the spring is shown in Fig. 2.2.

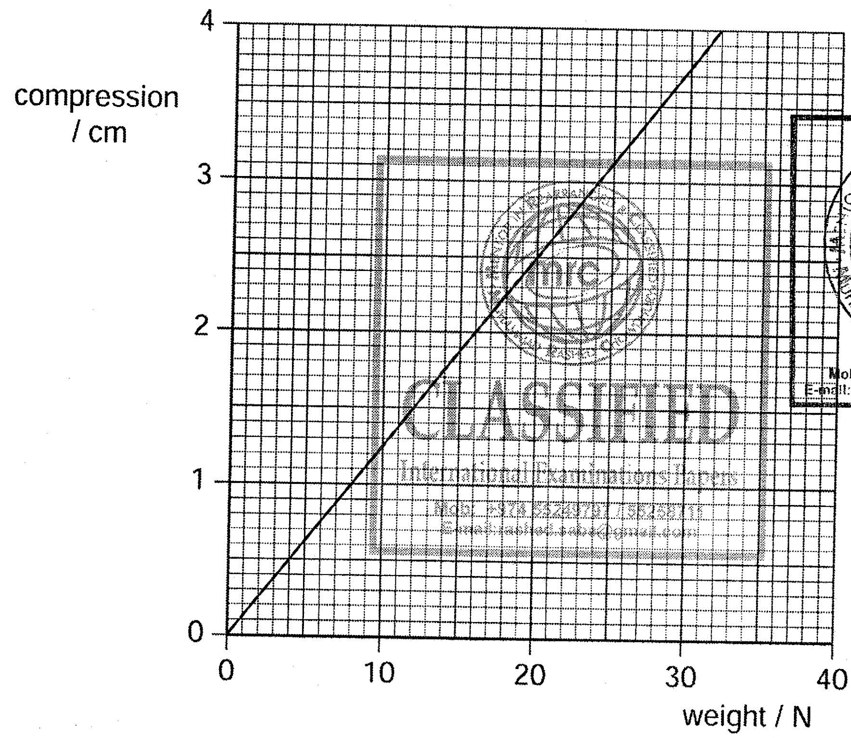


Fig. 2.2

The elastic limit of the spring has not been exceeded.

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

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

For Examiner's Use

(ii) Deduce that the strain energy stored in the spring is 0.49 J for a compression of 3.5 cm.

[2]

(b) Two trolleys, of masses 800 g and 2400 g, are free to move on a horizontal table. The spring in **(a)** is placed between the trolleys and the trolleys are tied together using thread so that the compression of the spring is 3.5 cm, as shown in Fig. 2.3.

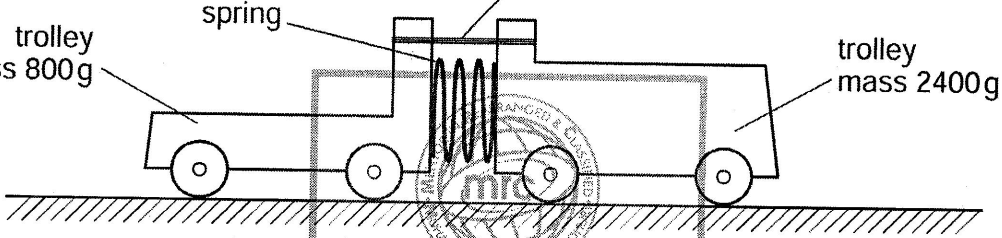


Fig. 2.3

Initially, the trolleys are not moving.
The thread is then cut and the trolleys move apart.

(i) Deduce that the ratio

$$\frac{\text{speed of trolley of mass 800 g}}{\text{speed of trolley of mass 2400 g}}$$

is equal to 3.0.

[2]

(ii) Use the answers in **(a)(ii)** and **(b)(i)** to calculate the speed of the trolley of mass 800 g.

For Examiner's Use

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

5 **(a)** The variation with extension x of the tension F in a spring is shown in Fig. 3.1.

For Examiner's Use

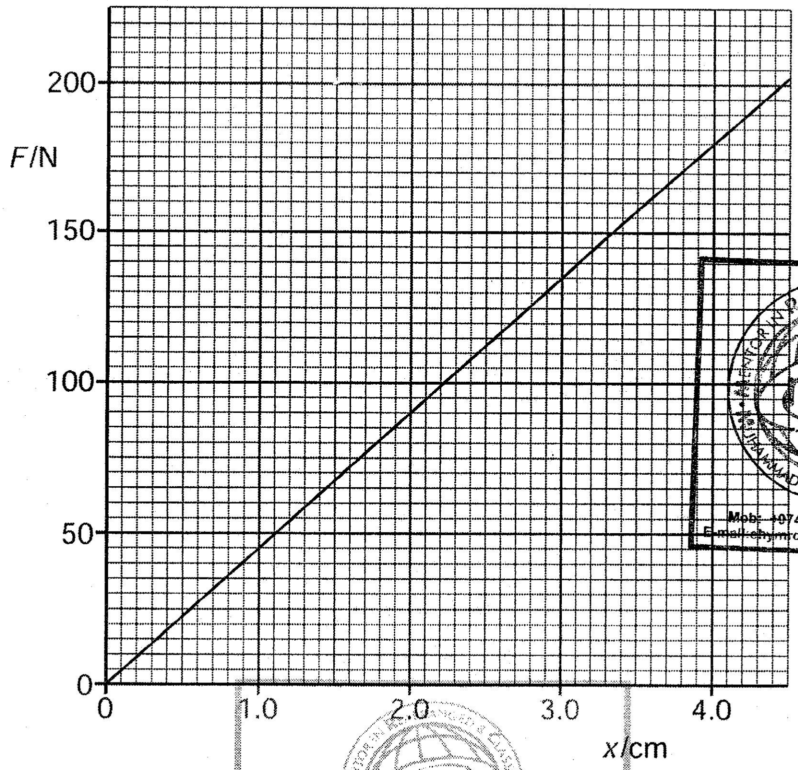


Fig. 3.1

Use Fig. 3.1 to calculate the energy stored in the spring for an extension of 4.0 cm.
Explain your working.

energy = ... J [3]

(b) The spring in **(a)** is used to join together two frictionless trolleys A and B of mass M_1 and M_2 respectively, as shown in Fig. 3.2.

For Examiner's Use

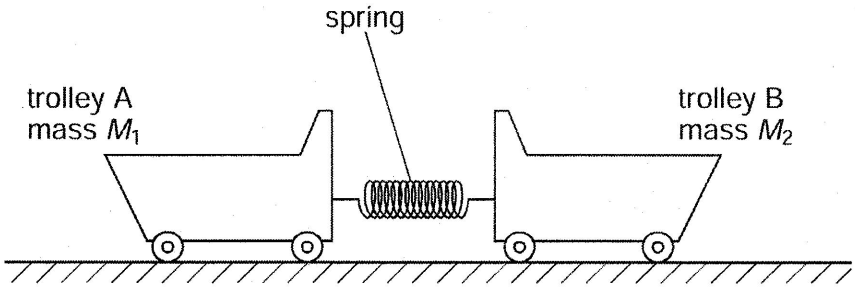


Fig. 3.2

The trolleys rest on a horizontal surface and are held apart so that the spring is extended.

The trolleys are then released.

(i) Explain why, as the extension of the spring is reduced, the momentum of trolley A is equal in magnitude but opposite in direction to the momentum of trolley B.

....

....

....

.... [2]

(ii) At the instant when the extension of the spring is zero, trolley A has speed V_1 and trolley B has speed V_2.
Write down

1. an equation, based on momentum, to relate V_1 and V_2,

....

.... [1]

2. an equation to relate the initial energy E stored in the spring to the final energies of the trolleys.

....

.... [1]

For Examiner's Use

(iii) **1.** Show that the kinetic energy E_K of an object of mass m is related to its momentum p by the expression

$$E_K = \frac{p^2}{2m}.$$

[1]

2. Trolley A has a larger mass than trolley B.
Use your answer in **(ii) part 1** to deduce which trolley, A or B, has the larger kinetic energy at the instant when the extension of the spring is zero.

....

....[1]

For Examiner's Use

16 (a) State Hooke's Law.

....

.... [1]

(b) A spring is compressed by applying a force. The variation with compression x of the force F is shown in Fig. 4.1.

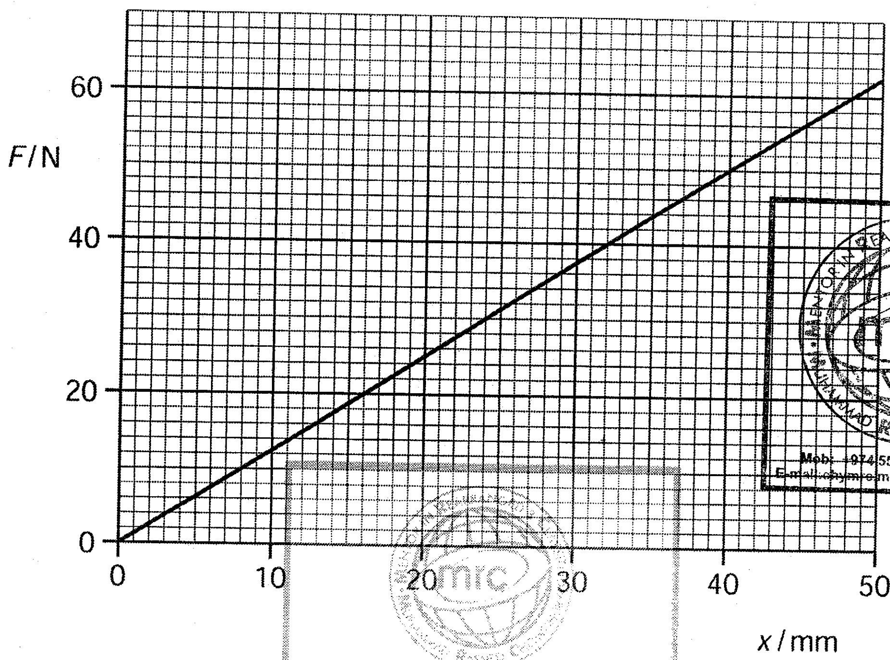


Fig. 4.1

(i) Calculate the spring constant.

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

(ii) Show that the work done in compressing the spring by 36 mm is 0.81 J.

[2]

(c) A child's toy uses the spring in **(b)** to shoot a small ball vertically upwards. The ball has a mass of 25 g. The toy is shown in Fig. 4.2.

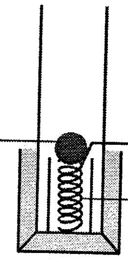


Fig. 4.2

(i) The spring in the toy is compressed by 36 mm. The spring is released.
Assume all the strain energy in the spring is converted to kinetic energy of the ball.
Using the result in **(b)(ii)**, calculate the speed with which the ball leaves the spring.

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

(ii) Determine the compression of the spring required for the ball to leave the spring with twice the speed determined in **(i)**.

compression = ... mm [2]

(iii) Determine the ratio

$$\frac{\text{maximum possible height for compression in (i)}}{\text{maximum possible height for compression in (ii)}}.$$

ratio = ... [2]

For Examiner's Use

17 **(a)** Fig. 3.1 shows the variation with tensile force of the extension of a copper wire.

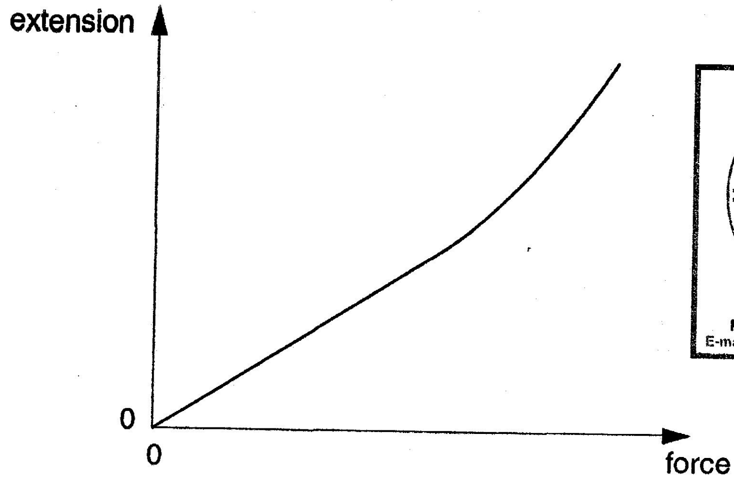


Fig. 3.1

(i) State whether copper is a ductile, brittle or polymeric material.

....

(ii) **1.** On Fig. 3.1, mark with the letter L the point on the line beyond which Hooke's law does not apply.

2. State how the spring constant for the wire may be obtained from Fig. 3.1.

....

.... [3]

(b) A copper wire is fixed at one end and passes over a pulley. A mass hangs from the free end of the wire, as shown in Fig. 3.2.

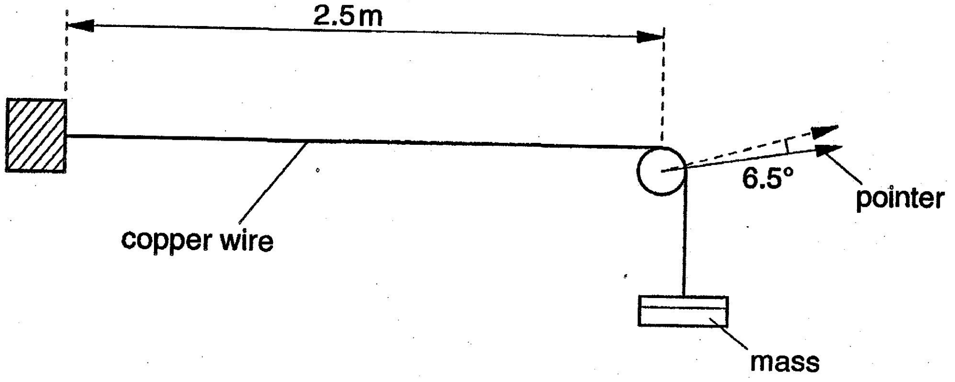


Fig. 3.2

The length of wire between the fixed end and the pulley is 2.5 m. When the mass on the wire is increased by 6.0 kg, a pointer attached to the pulley rotates through an angle of 6.5°. The pulley, of diameter 3.0 cm, is rough so that the wire does not slide over it.

(i) For this increase in mass,

1. show that the wire extends by 0.17 cm,

2. calculate the increase in strain of the wire.

increase in strain = ...
[4]

18 The Young modulus of the material of a wire can be determined using the apparatus shown in Fig. 3.1.

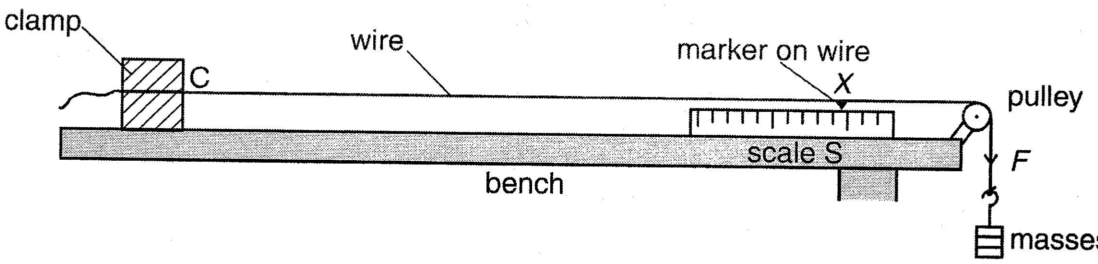


Fig. 3.1

One end of the wire is clamped at C and a marker is attached to the wire above a scale S. A force to extend the wire is applied by attaching masses to the other end of the wire.

The reading X of the marker on the scale S is determined for different forces F applied to the end of the wire. The variation with X of F is shown in Fig. 3.2.

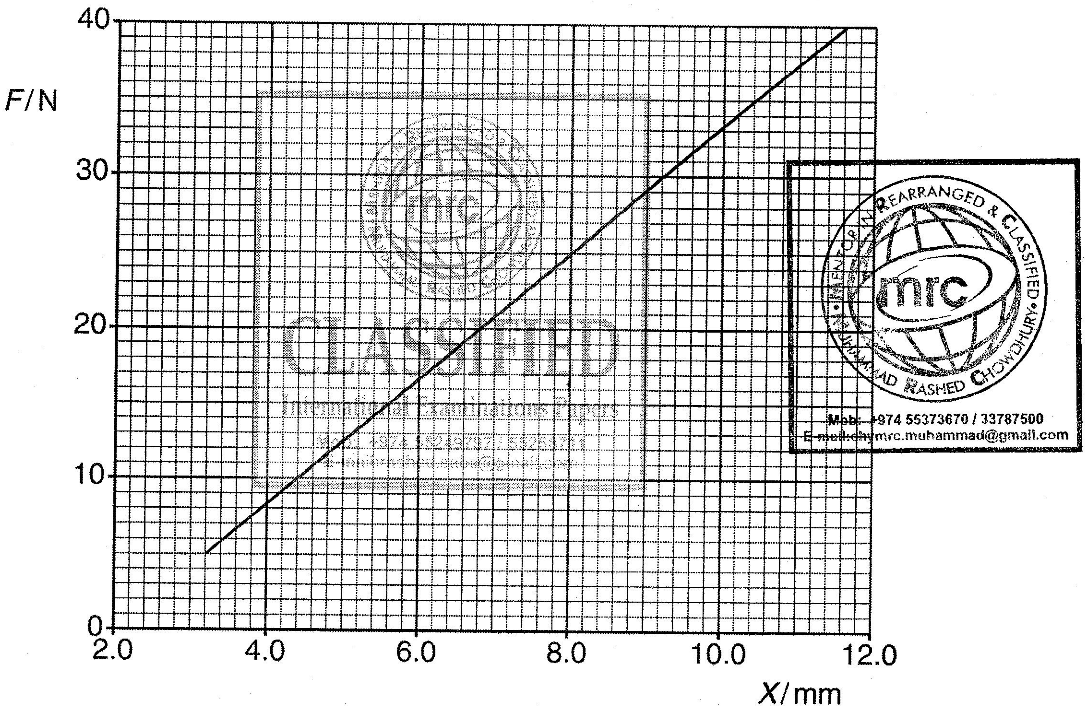


Fig. 3.2

(a) The length of the wire from C to the marker for $F = 0$ is 3.50 m. The diameter of the wire is 0.38 mm.

Use the gradient of the line in Fig. 3.2 to determine the Young modulus E of the material of the wire in TPa.

E = ... TPa [3]

(b) The experiment is repeated with a thicker wire of the same material and length.

State how the range of the force F must be changed to obtain the same range of scale readings as in Fig. 3.2.

....

....

.... [1]

[Total: 4]

1 9 Fig. 4.1 shows the values obtained in an experiment to determine the Young modulus E of a metal in the form of a wire.

quantity	value	instrument
diameter d	0.48 mm	
length l	1.768 m	
load F	5.0 N to 30.0 N in 5.0 N steps	
extension e	0.25 mm to 1.50 mm	

Fig. 4.1

(a) **(i)** Complete Fig. 4.1 with the name of an instrument that could be used to measure each of the quantities. [3]

(ii) Explain why a series of values of F, each with corresponding extension e, are measured.

....

.... [1]

(b) Explain how a series of readings of the quantities given in Fig. 4.1 is used to determine the Young modulus of the metal. A numerical answer for E is not required.

....

....

....

.... [2]

20 **(a)** Define, for a wire,

(i) *stress,*

....

.... [1]

(ii) *strain.*

....

.... [1]

(b) A wire of length 1.70 m hangs vertically from a fixed point, as shown in Fig. 4.1.

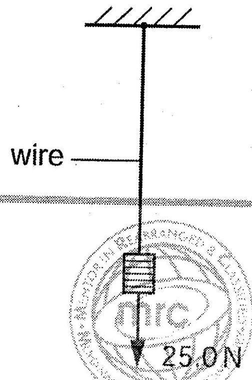


Fig. 4.1

The wire has cross-sectional area $5.74 \times 10^{-8}\,m^2$ and is made of a material that has a Young modulus of 1.60×10^{11} Pa. A load of 25.0 N is hung from the wire.

(i) Calculate the extension of the wire.

extension = ... m [3]

(ii) The same load is hung from a second wire of the same material. This wire is twice the length but the **same volume** as the first wire. State and explain how the extension of the second wire compares with that of the first wire.

....

....

.... [3]

2 1 (a) A metal wire has an unstretched length L and area of cross-section A. When the wire supports a load F, the wire extends by an amount ΔL. The wire obeys Hooke's law.

For Examiner's Use

Write down expressions, in terms of L, A, F and ΔL, for

(i) the applied stress,

....

(ii) the tensile strain in the wire,

....

(iii) the Young modulus of the material of the wire.

....

[3]

(b) A steel wire of uniform cross-sectional area $7.9 \times 10^{-7}\,m^2$ is heated to a temperature of 650 K. It is then clamped between two rigid supports, as shown in Fig. 5.1.

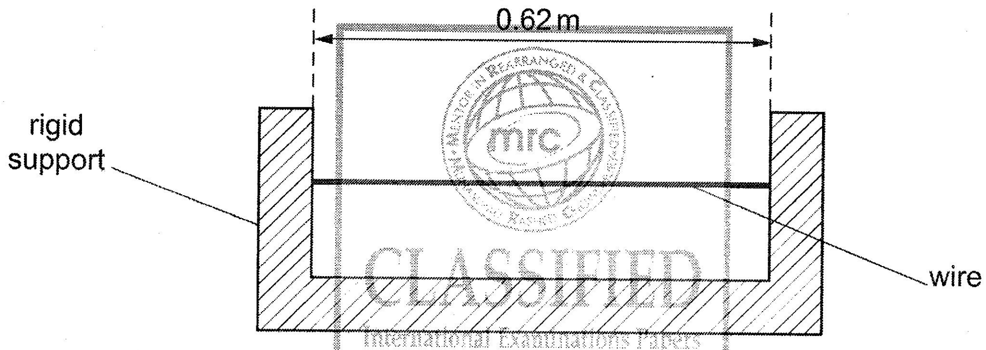


Fig. 5.1

The wire is straight but not under tension and the length between the supports is 0.62 m. The wire is then allowed to cool to 300 K.

When the wire is allowed to contract freely, a 1.00 m length of the wire decreases in length by 0.012 mm for every 1 K decrease in temperature.

(i) Show that the change in length of the wire, if it were allowed to contract as it cools from 650 K to 300 K, would be 2.6 mm.

[2]

For Examiner's Use

(ii) The Young modulus of steel is 2.0×10^{11} Pa. Calculate the tension in the wire at 300 K, assuming that the wire obeys Hooke's law.

tension = ... N [2]

(iii) The ultimate tensile stress of steel is 250 MPa. Use this information and your answer in **(ii)** to suggest whether the wire will, in practice, break as it cools.

....

.... [3]

For Examiner's Use

22 An aluminium wire of length 1.8 m and area of cross-section $1.7 \times 10^{-6}\,m^2$ has one end fixed to a rigid support. A small weight hangs from the free end, as illustrated in Fig. 9.1.

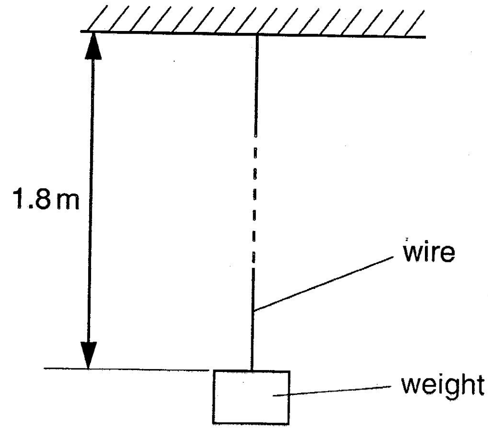


Fig. 9.1

The resistance of the wire is $0.030\,\Omega$ and the Young modulus of aluminium is 7.1×10^{10} Pa.

The load on the wire is increased by 25 N.

(a) Calculate

(i) the increase in stress,

increase = ... Pa

(ii) the change in length of the wire.

change = ... m
[4]

For Examiner's Use

(b) Assuming that the area of cross-section of the wire does not change when the load is increased, determine the change in resistance of the wire.

change = ... Ω [3]

3 (a) Force is a vector quantity. State three other vector quantities.

1. ....

2. ....

3. ....

[2]

(b) Three coplanar forces *X*, *Y* and *Z* act on an object, as shown in Fig. 3.1.

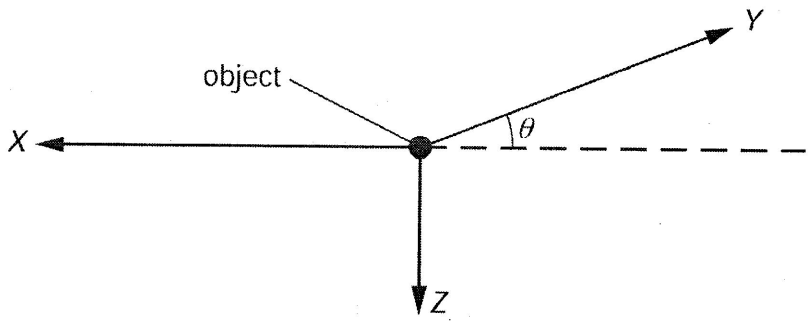


Fig. 3.1

The force *Z* is vertical and *X* is horizontal. The force *Y* is at an angle θ to the horizontal. The force *Z* is kept constant at 70 N.

In an experiment, the magnitude of force *X* is varied. The magnitude and direction of force *Y* are adjusted so that the object remains in equilibrium.

Fig. 3.2 shows the variation of the magnitude of force *Y* with the magnitude of force *X*.

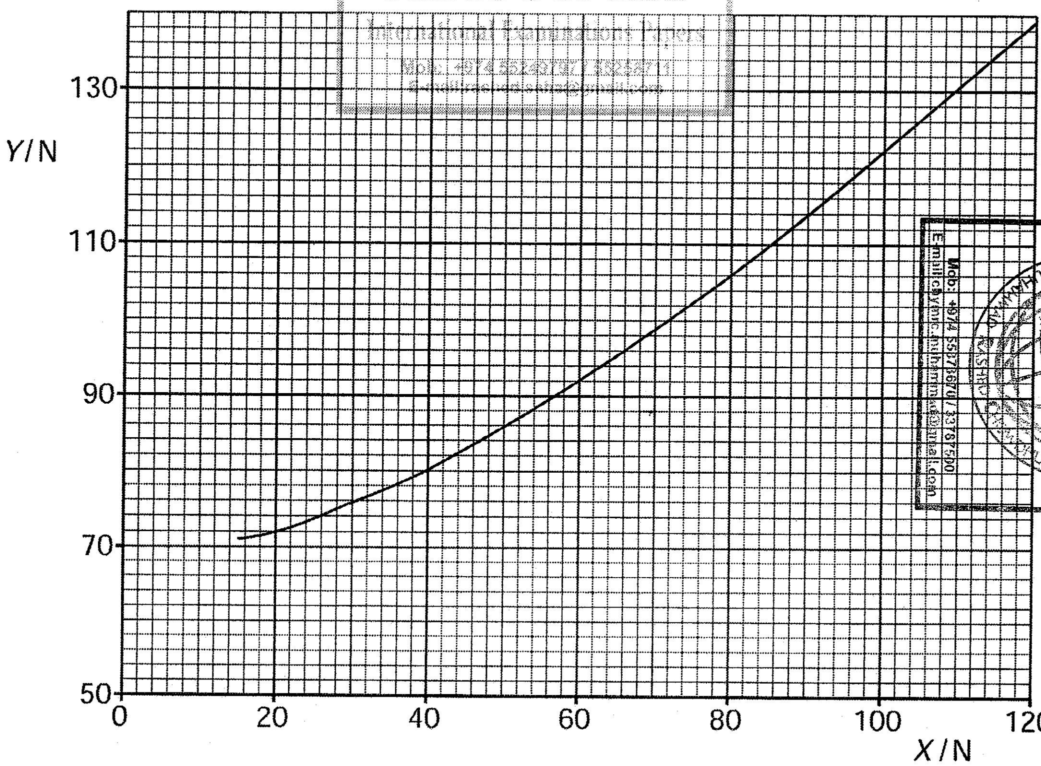


Fig. 3.2

(i) Use Fig. 3.2 to estimate the magnitude of Y for $X = 0$.

Y = ... N [1]

(ii) State and explain the value of θ for $X = 0$.

....

....

....[2]

(iii) The magnitude of X is increased to 160 N. Use resolution of forces to calculate the value of

1. angle θ,

θ = ... ° [2]

2. the magnitude of force Y.

Y = ... N [2]

(c) The angle θ decreases as X increases. Explain why the object cannot be in equilibrium for $\theta = 0$.

....

....

....[1]

2 4 (a) Tensile forces are applied to opposite ends of a copper rod so that the rod is stretched. The variation with stress of the strain of the rod is shown in Fig. 5.1.

For Examiner's Use

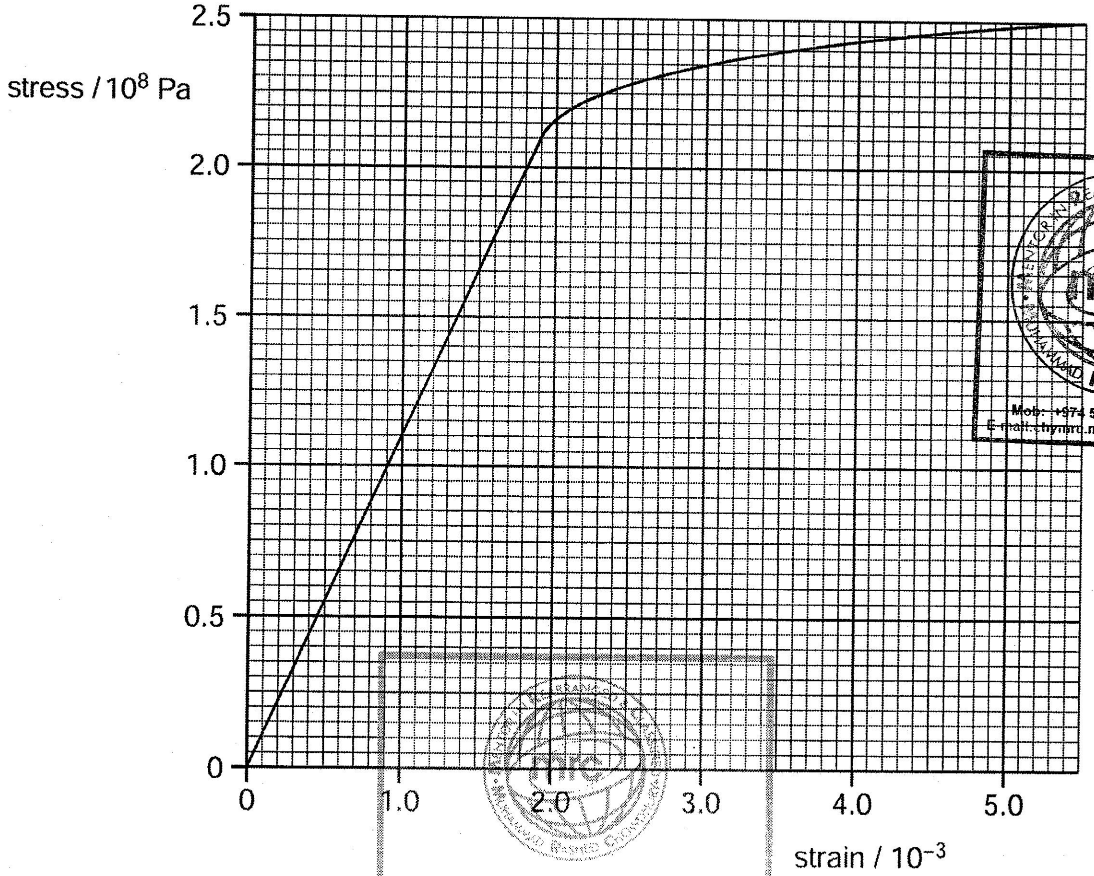


Fig. 5.1

(i) Use Fig. 5.1 to determine the Young modulus of copper.

Young modulus = ... Pa [3]

(ii) On Fig. 5.1, sketch a line to show the variation with stress of the strain of the rod as the stress is reduced from 2.5×10^6 Pa to zero. No further calculations are expected. [1]

(b) The walls of the tyres on a car are made of a rubber compound.
The variation with stress of the strain of a specimen of this rubber compound is shown in Fig. 5.2.

For Examiner's Use

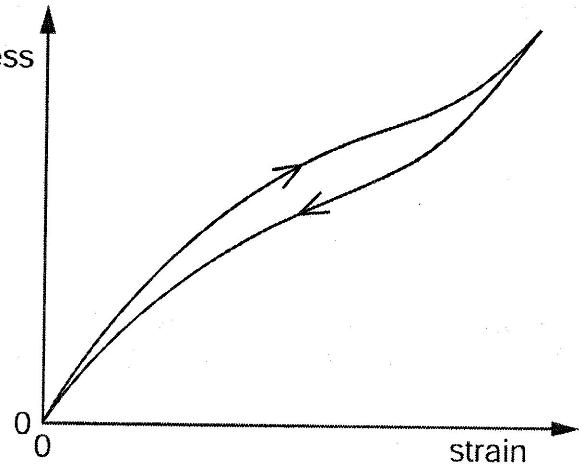


Fig. 5.2

As the car moves, the walls of the tyres bend and straighten continuously.

Use Fig. 5.2 to explain why the walls of the tyres become warm.

....

....

....

.... [3]

2 5 A metal ball of mass 40 g falls vertically onto a spring, as shown in Fig. 4.1.

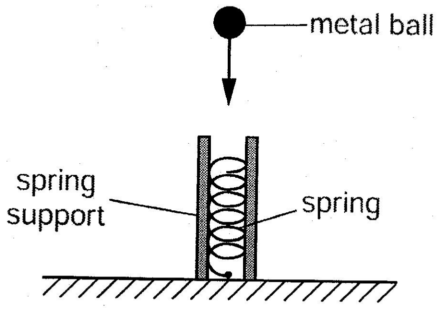


Fig. 4.1 (not to scale)

The spring is supported and stands vertically. The ball has a speed of $2.8\,\text{m}\,\text{s}^{-1}$ as it makes contact with the spring. The ball is brought to rest as the spring is compressed.

(a) Show that the kinetic energy of the ball as it makes contact with the spring is 0.16 J.

[2]

(b) The variation of the force F acting on the spring with the compression x of the spring is shown in Fig. 4.2.

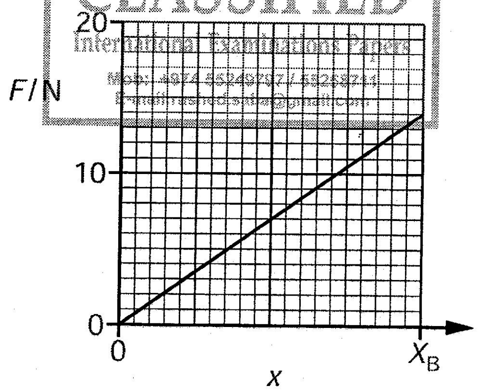


Fig. 4.2

The ball produces a maximum compression X_B when it comes to rest. The spring has a spring constant of $800\,\text{N}\,\text{m}^{-1}$.
Use Fig. 4.2 to

(i) calculate the compression X_B,

X_B = ... m [2]

(ii) show that not all the kinetic energy in **(a)** is converted into elastic potential energy in the spring.

[2]

26 A glass fibre of length 0.24 m and area of cross-section 7.9×10^{-7} m^2 is tested until it breaks. The variation with load F of the extension x of the fibre is shown in Fig. 4.1.

For Examiner's Use

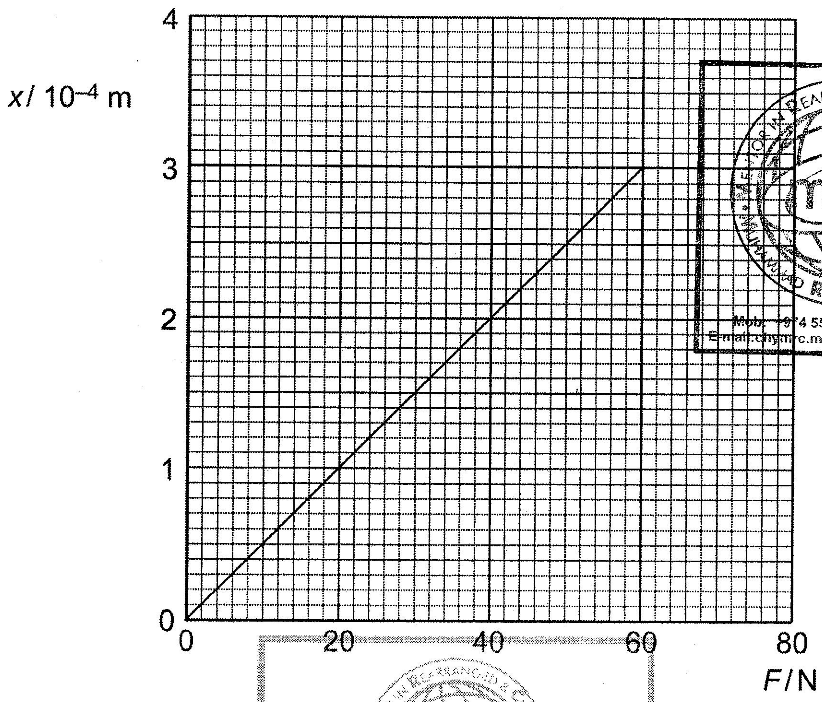


Fig. 4.1

(a) State whether glass is ductile, brittle or polymeric.

.... [1]

(b) Use Fig. 4.1 to determine, for this sample of glass,

(i) the ultimate tensile stress,

ultimate tensile stress = ... Pa [2]

For Examiner's Use

(ii) the Young modulus,

Young modulus = ... Pa [3]

(iii) the maximum strain energy stored in the fibre before it breaks.

maximum strain energy = ... J [2]

(c) A hard ball and a soft ball, with equal masses and volumes, are thrown at a glass window. The balls hit the window at the same speed. Suggest why the hard ball is more likely than the soft ball to break the glass window.

....

....

....

....[3]

27 A uniform wire has length L and area of cross-section A.
The wire is fixed at one end so that it hangs vertically with a load attached to its free end, as shown in Fig. 4.1.

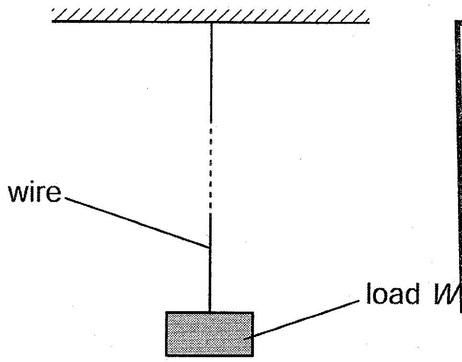


Fig. 4.1

When the load of magnitude W is attached to the wire, it extends by an amount e. The elastic limit of the wire is not exceeded.

The material of the wire has resistivity ρ.

(a) **(i)** Explain what is meant by extends *elastically*.

....

....

.... [2]

(ii) Write down expressions, in terms of L, A, W, ρ and e for

1. the resistance R of the unstretched wire,

R = ... [1]

2. the Young modulus E of the wire.

E = ... [1]

For Examiner's Use

(b) A steel wire has resistance 0.44 Ω. Steel has resistivity 9.2×10^{-8} Ω m.

A load of 34 N hung from the end of the wire causes an extension of 7.7×10^{-4} m.

Using your answers in **(a)(ii)**, calculate the Young modulus E of steel.

E = ... Pa [3]

For Examiner's Use

2 8 A sample of material in the form of a cylindrical rod has length L and uniform area of cross-section A. The rod undergoes an increasing tensile stress until it breaks.
Fig. 4.1 shows the variation with stress of the strain in the rod.

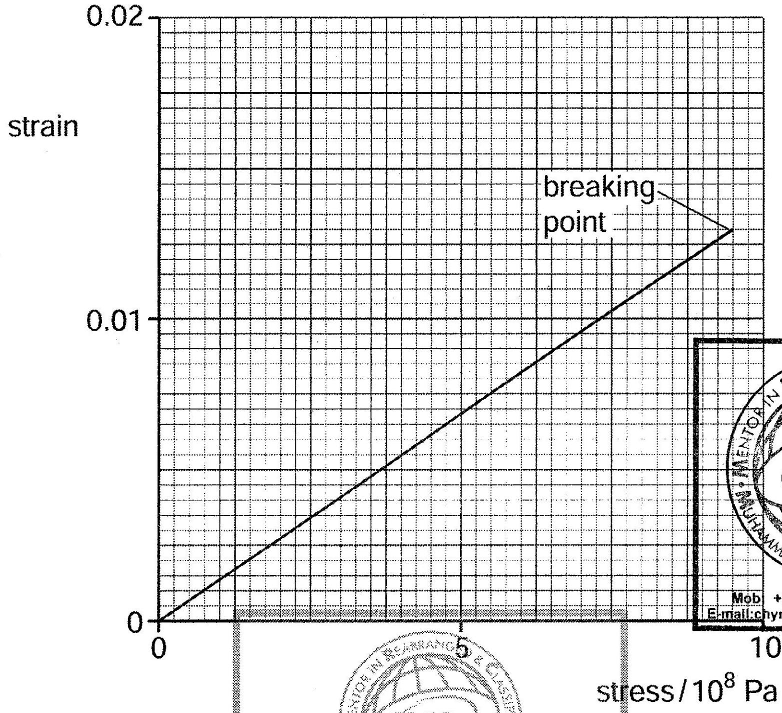


Fig. 4.1

(a) State whether the material of the rod is ductile, brittle or polymeric.

.... [1]

(b) Determine the Young modulus of the material of the rod.

Young modulus = ... Pa [2]

(c) A second cylindrical rod of the same material has a spherical bubble in it, as illustrated in Fig. 4.2.

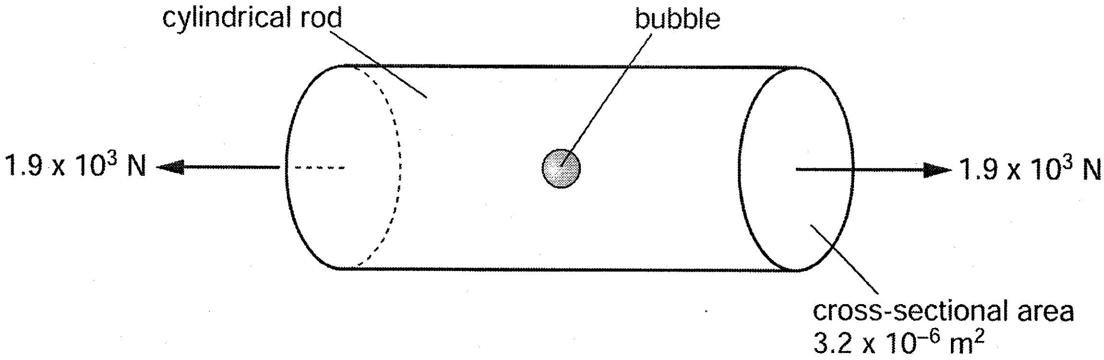


Fig. 4.2

The rod has an area of cross-section of $3.2\square10^{-6}$ m^2 and is stretched by forces of magnitude $1.9\square10^3$ N.
By reference to Fig. 4.1, calculate the maximum area of cross-section of the bubble such that the rod does not break.

area = ... m^2 [3]

(d) A straight rod of the same material is bent as shown in Fig. 4.3.

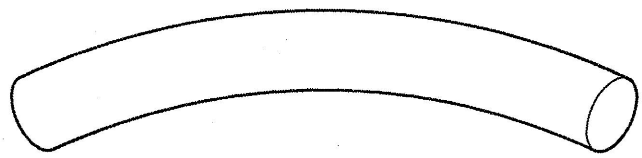


Fig. 4.3

Suggest why a thin rod can bend more than a thick rod without breaking.

....

....

.... [2]

29 A spring hangs vertically from a point P, as shown in Fig. 4.1.

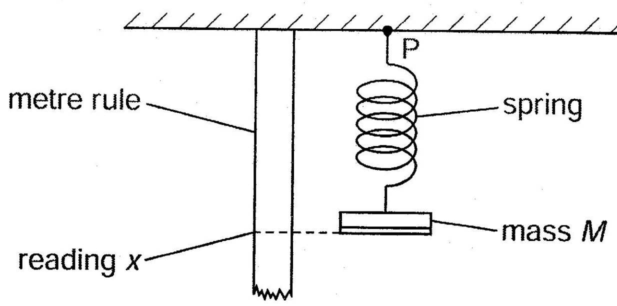


Fig. 4.1

A mass *M* is attached to the lower end of the spring. The reading *x* from the metre rule is taken, as shown in Fig. 4.1. Fig. 4.2 shows the relationship between *x* and *M*.

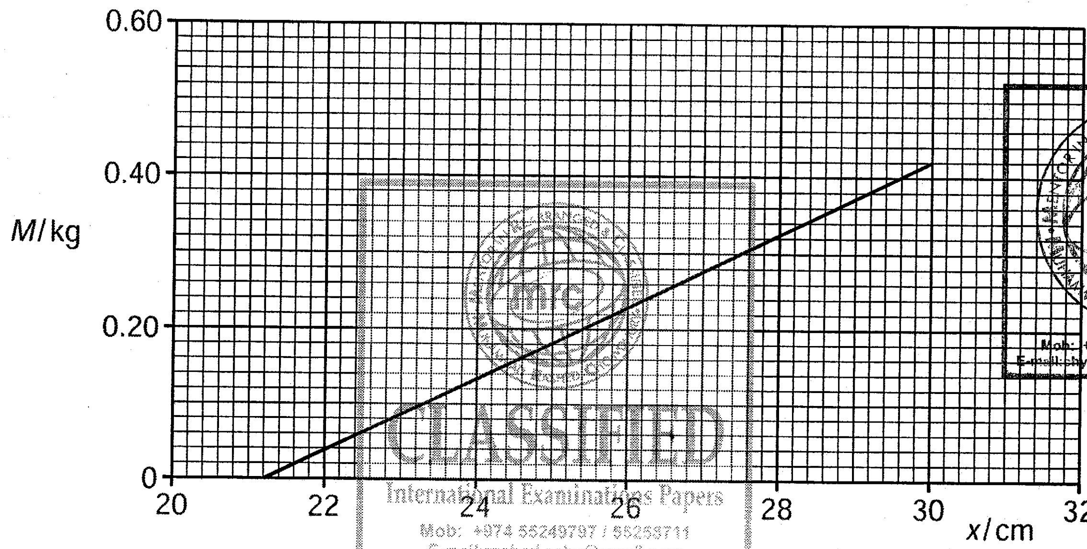


Fig. 4.2

(a) Explain how the apparatus in Fig. 4.1 may be used to determine the load on the spring at the elastic limit.

....

....

....

....[2]

(b) State and explain whether Fig. 4.2 suggests that the spring obeys Hooke's law.

....

....

....[2]

(c) Use Fig. 4.2 to determine the spring constant, in $N\,m^{-1}$, of the spring.

spring constant = ... $N\,m^{-1}$ [3]

For Examiner's Use

3 0 **(a)** Define the *Young modulus*.

....

.... [1]

(b) A load F is suspended from a fixed point by a steel wire. The variation with extension x of F for the wire is shown in Fig. 5.1.

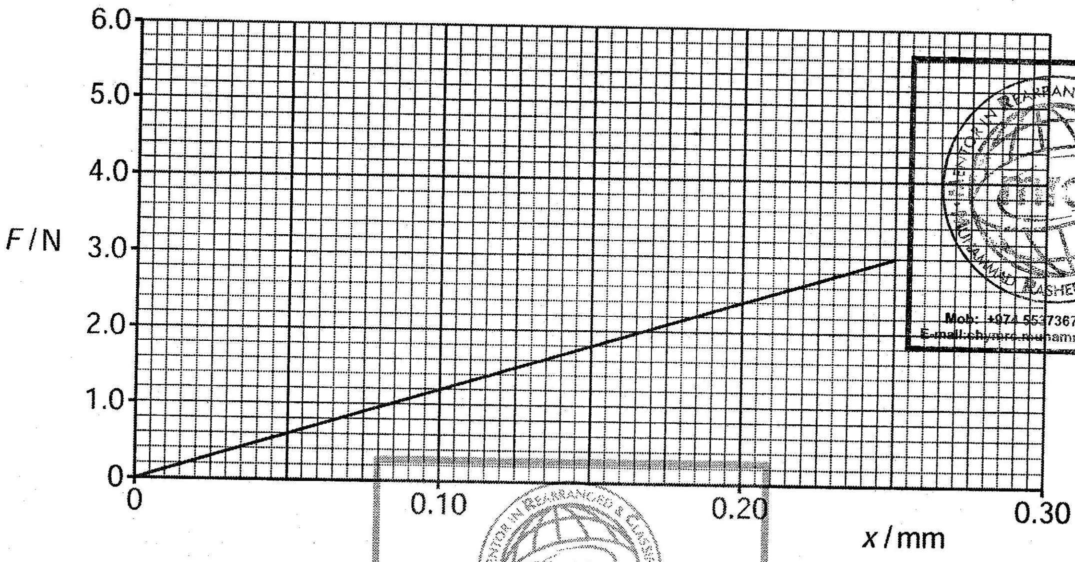


Fig. 5.1

(i) State two quantities, other than the gradient of the graph in Fig. 5.1, that are required in order to determine the Young modulus of steel.

1. ....

2. ....

[1]

(ii) Describe how the quantities you listed in **(i)** may be measured.

....

....

.... [2]

(iii) A load of 3.0 N is applied to the wire. Use Fig. 5.1 to calculate the energy stored in the wire.

For Examiner's Use

energy = ... J [2]

(c) A copper wire has the same original dimensions as the steel wire. The Young modulus for steel is $2.2 \times 10^{11}\,\mathrm{N\,m^{-2}}$ and for copper is $1.1 \times 10^{11}\,\mathrm{N\,m^{-2}}$.

On Fig. 5.1, sketch the variation with x of F for the copper wire for extensions up to 0.25 mm. The copper wire is not extended beyond its limit of proportionality. [2]

3 1 (a) State what is meant by *elastic potential energy*.

....

....[1]

(b) A spring is extended by applying a force. The variation with extension x of the force F is shown in Fig. 4.1 for the range of values of x from 20 cm to 40 cm.

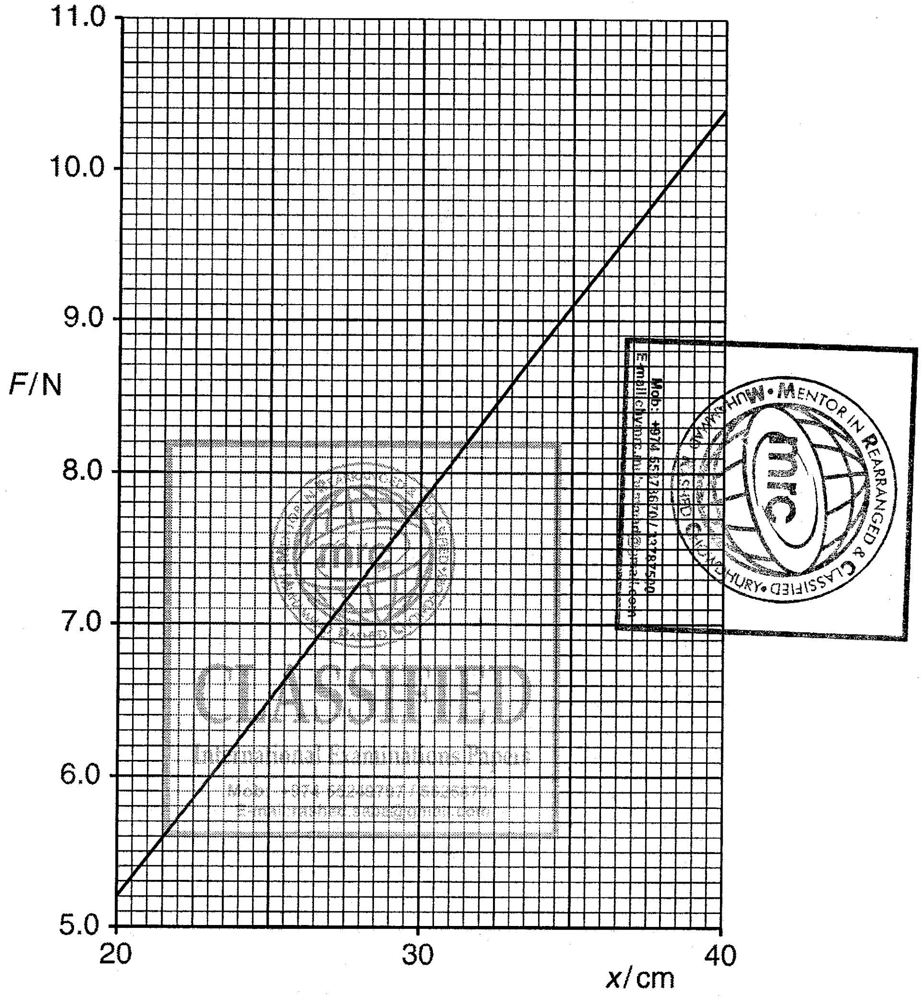


Fig. 4.1

(i) Use data from Fig. 4.1 to show that the spring obeys Hooke's law for this range of extensions.

....

....

....[2]

(ii) Use Fig. 4.1 to calculate

1. the spring constant,

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

2. the work done extending the spring from $x = 20\,cm$ to $x = 40\,cm$.

work done = ... J [3]

(c) A force is applied to the spring in **(b)** to give an extension of 50 cm.

State how you would check that the spring has not exceeded its elastic limit.

....

....[1]

[Total: 9]

3 (a) State Hooke's law.

....

....[1]

(b) The variation with compression x of the force F acting on a spring is shown in Fig. 3.1.

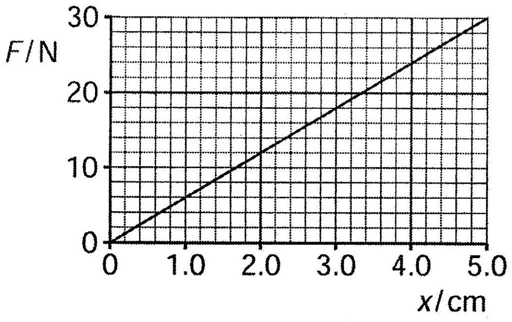


Fig. 3.1

The spring is fixed to the closed end of a horizontal tube. A block is pushed into the tube so that the spring is compressed, as shown in Fig. 3.2.

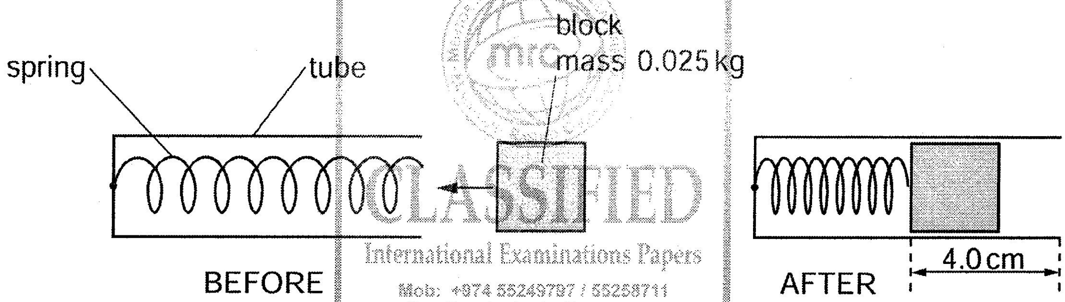


Fig. 3.2 (not to scale)

The compression of the spring is 4.0 cm. The mass of the block is 0.025 kg.

(i) Calculate the spring constant of the spring.

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

(ii) Show that the work done to compress the spring by 4.0 cm is 0.48 J.

[2]

(iii) The block is now released and accelerates along the tube as the spring returns to its original length. The block leaves the end of the tube with a speed of $6.0\,\text{m}\,\text{s}^{-1}$.

1. Calculate the kinetic energy of the block as it leaves the end of the tube.

kinetic energy = ... J [2]

2. Assume that the spring has negligible kinetic energy as the block leaves the tube. Determine the average resistive force acting against the block as it moves along the tube.

resistive force = ... N [3]

(iv) Determine the efficiency of the transfer of elastic potential energy from the spring to the kinetic energy of the block.

efficiency = ... [2]

[Total: 12]

3 **(a)** State the *principle of conservation of momentum.*

....

....

....[2]

(b) Two blocks, A and B, are on a horizontal frictionless surface. The blocks are joined together by a spring, as shown in Fig. 2.1.

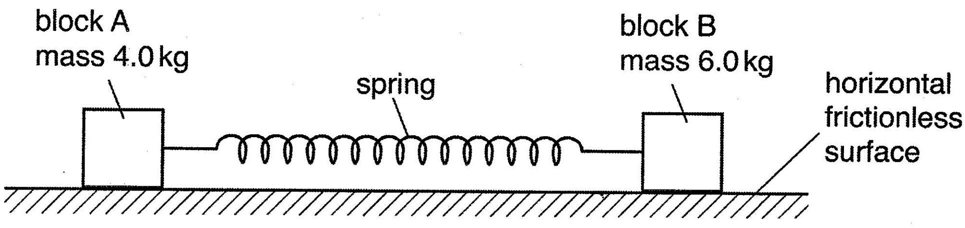


Fig. 2.1

Block A has mass 4.0 kg and block B has mass 6.0 kg.

The variation of the tension F with the extension x of the spring is shown in Fig. 2.2.

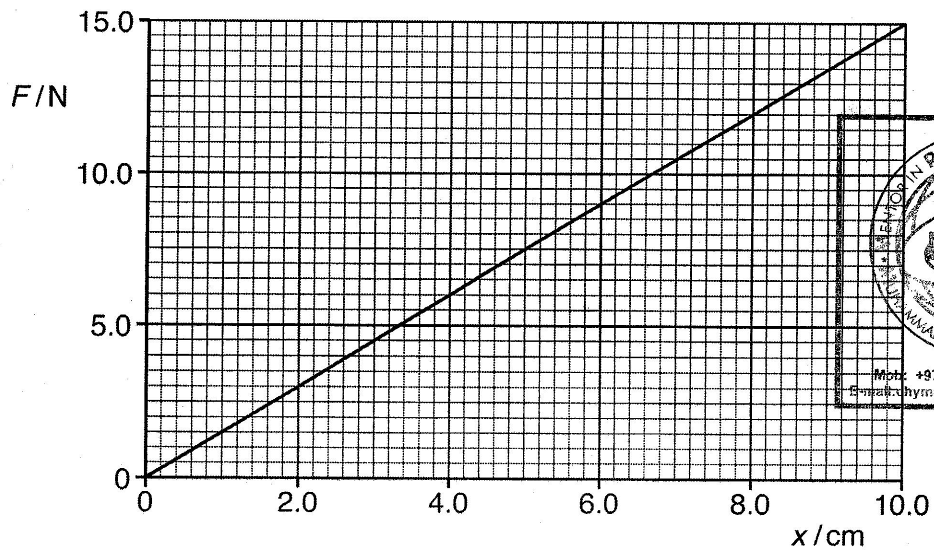


Fig. 2.2

The two blocks are held apart so that the spring has an extension of 8.0 cm.

(i) Show that the elastic potential energy of the spring at an extension of 8.0 cm is 0.48 J.

[2]

(ii) The blocks are released from rest at the same instant. When the extension of the spring becomes zero, block A has speed v_A and block B has speed v_B.

For the instant when the extension of the spring becomes zero,

1. use conservation of momentum to show that

$$\frac{\text{kinetic energy of block A}}{\text{kinetic energy of block B}} = 1.5$$

[3]

2. use the information in **(b)(i)** and **(b)(ii)1** to determine the kinetic energy of block A. It may be assumed that the spring has negligible kinetic energy and that air resistance is negligible.

kinetic energy of block A = ... J [2]

(iii) The blocks are released at time $t = 0$.

On Fig. 2.3, sketch a graph to show how the momentum of block A varies with time t until the extension of the spring becomes zero.
Numerical values of momentum and time are not required.

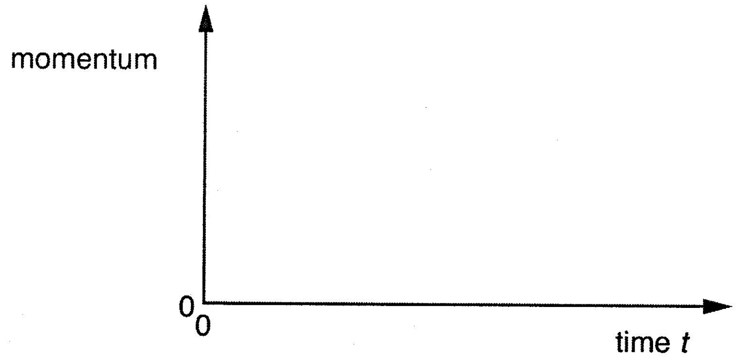


Fig. 2.3

[2]

[Total: 11]

4 A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension e. The elastic limit of the spring is not exceeded.

For Examiner's Use

(a) State

(i) what is meant by an *elastic deformation*,

....

....

.... [2]

(ii) the relation between k, L and e.

.... [1]

Question 4 continues on page 10

(b) Some identical springs, each with spring constant *k*, are arranged as shown in Fig. 4.1.

For Examiner's Use

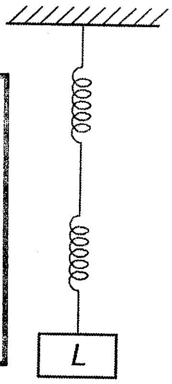
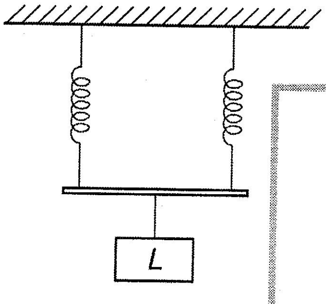
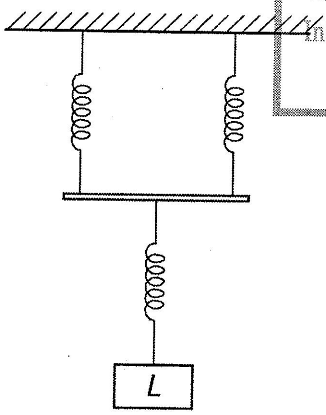
arrangement	total extension	spring constant of arrangement
	....	....
	....	....
	....	....

Fig. 4.1

The load on each of the arrangements is *L*.

For each arrangement in Fig. 4.1, complete the table by determining

(i) the total extension in terms of *e*,

(ii) the spring constant in terms of *k*.

[5]

5 A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension e. The elastic limit of the spring is not exceeded.

For Examiner's Use

(a) State

(i) what is meant by an *elastic deformation*,

....

....

.... [2]

(ii) the relation between k, L and e.

.... [1]

(b) Some identical springs, each with spring constant k, are arranged as shown in Fig. 4.1.

For Examiner's Use

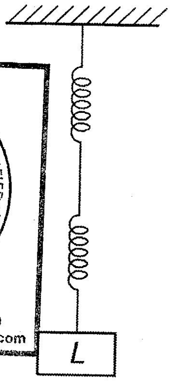
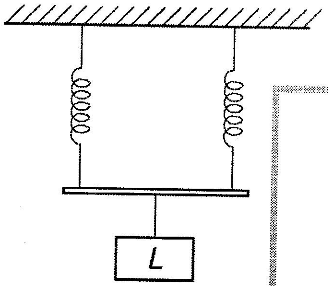
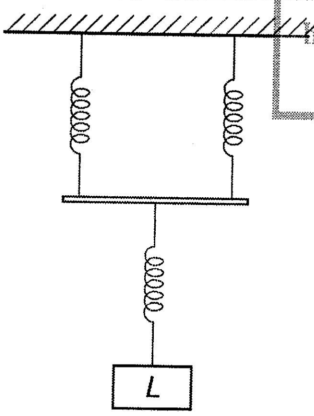
arrangement	total extension	spring constant of arrangement
	....	....
	....	....
	....	....

Fig. 4.1

The load on each of the arrangements is L.

For each arrangement in Fig. 4.1, complete the table by determining

(i) the total extension in terms of e,

(ii) the spring constant in terms of k.

[5]

6 (a) Explain what is meant by *strain energy* (*elastic potential energy*).

For Examiner's Use

....

....

.... [2]

(b) A spring that obeys Hooke's law has a spring constant k.

Show that the energy E stored in the spring when it has been extended elastically by an amount x is given by

$$E = \tfrac{1}{2}kx^2.$$

[3]

(c) A light spring of unextended length 14.2 cm is suspended vertically from a fixed point, as illustrated in Fig. 4.1.

For Examiner's Use

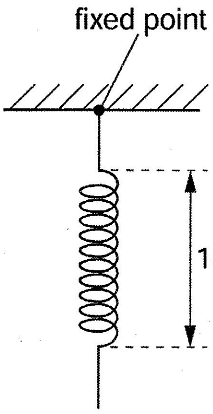


Fig. 4.1

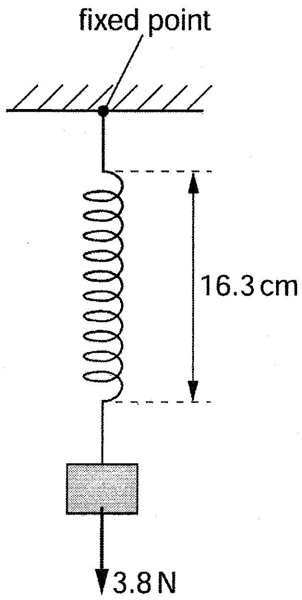


Fig. 4.2

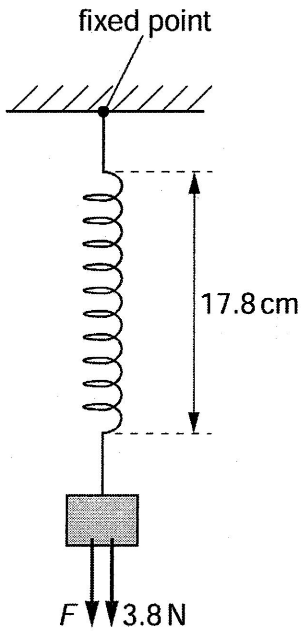


Fig. 4.3

A mass of weight 3.8 N is hung from the end of the spring, as shown in Fig. 4.2. The length of the spring is now 16.3 cm.

An additional force F then extends the spring so that its length becomes 17.8 cm, as shown in Fig. 4.3.

The spring obeys Hooke's law and the elastic limit of the spring is not exceeded.

(i) Show that the spring constant of the spring is $1.8\,\mathrm{N\,cm^{-1}}$.

[1]

For Examiner's Use

(ii) For the extension of the spring from a length of 16.3 cm to a length of 17.8 cm,

1. calculate the change in the gravitational potential energy of the mass on the spring,

change in energy = ... J [2]

2. show that the change in elastic potential energy of the spring is 0.077 J,

[1]

3. determine the work done by the force *F*.

work done = ... J [1]

For Examiner's Use

3 7 Fig. 5.1 shows the variation with force F of the extension x of a spring as the force is increased to F_3 and then decreased to zero.

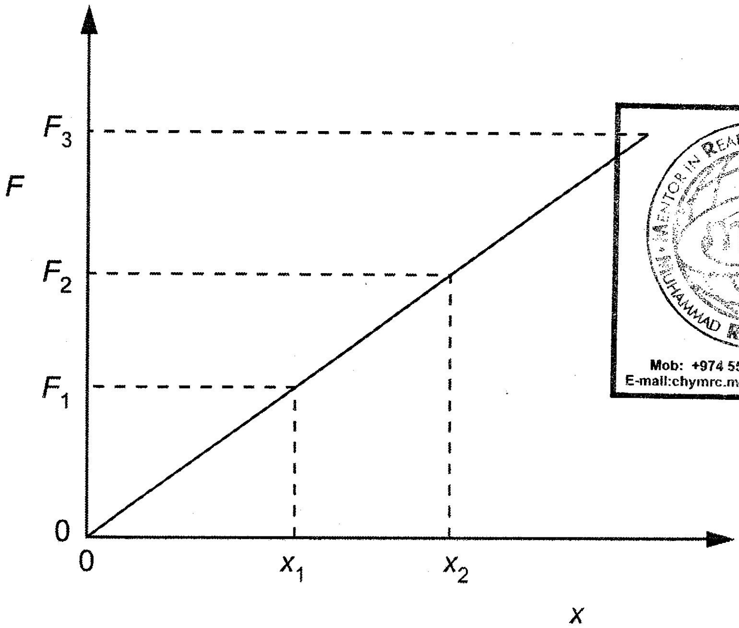


Fig. 5.1

(a) State, with a reason, whether the spring is undergoing an elastic change.

....

.... [1]

(b) The extension of the spring is increased from x_1 to x_2.

Show that the work W done in extending the spring is given by

$$W = \tfrac{1}{2}k(x_2^{\,2} - x_1^{\,2}),$$

where k is the spring constant.

[3]

(c) A trolley of mass 850 g is held between two fixed points by means of identical springs, as shown in Fig. 5.2.

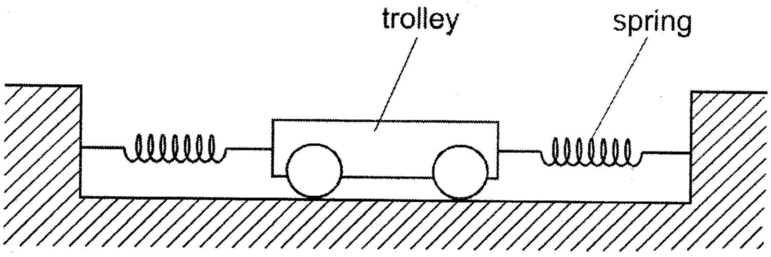


Fig. 5.2

When the trolley is in equilibrium, the springs are each extended by 4.5 cm. Each spring has a spring constant 16 N cm^{-1}.

The trolley is moved a distance of 1.5 cm along the direction of the springs. This causes the extension of one spring to be increased and the extension of the other spring to be decreased. The trolley is then released. The trolley accelerates and reaches its maximum speed at the equilibrium position.

Assuming that the springs obey Hooke's law, use the expression in **(b)** to determine the maximum speed of the trolley.

speed = ... m s^{-1} [4]

3 One end of a spring is fixed to a support. A mass is attached to the other end of the spring. The arrangement is shown in Fig. 3.1.

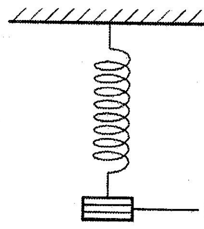


Fig. 3.1

(a) The mass is in equilibrium. Explain, by reference to the forces acting on the mass, what is meant by equilibrium.

....

....

.... [2]

(b) The mass is pulled down and then released at time $t = 0$. The mass oscillates up and down. The variation with t of the displacement of the mass d is shown in Fig. 3.2.

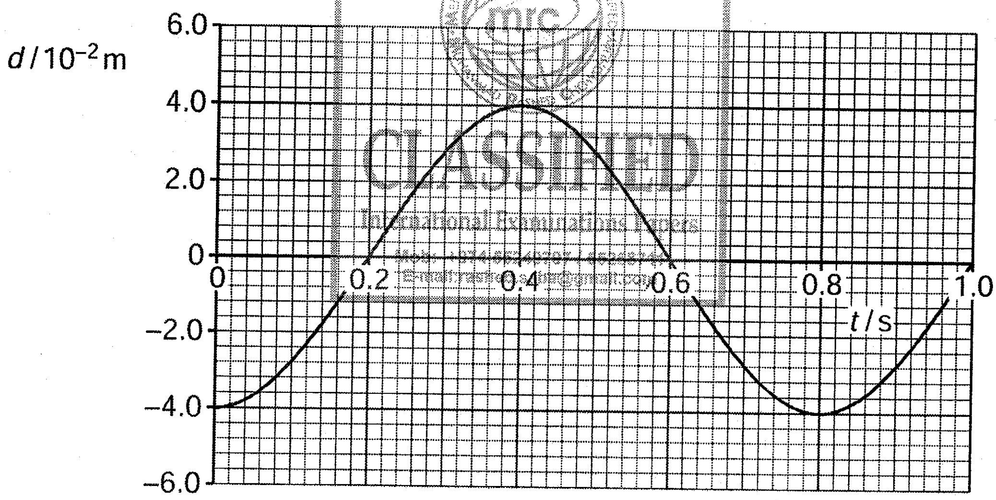


Fig. 3.2

Use Fig. 3.2 to state a time, one in each case, when

(i) the mass is at maximum speed,

time = ... s [1]

(ii) the elastic potential energy stored in the spring is a maximum,

time = ... s [1]

(iii) the mass is in equilibrium.

time = ... s [1]

(c) The arrangement shown in Fig. 3.3 is used to determine the length l of a spring when different masses M are attached to the spring.

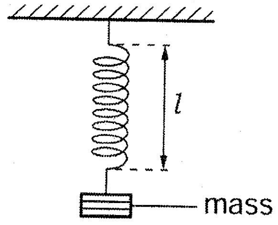


Fig. 3.3

The variation with mass M of l is shown in Fig. 3.4.

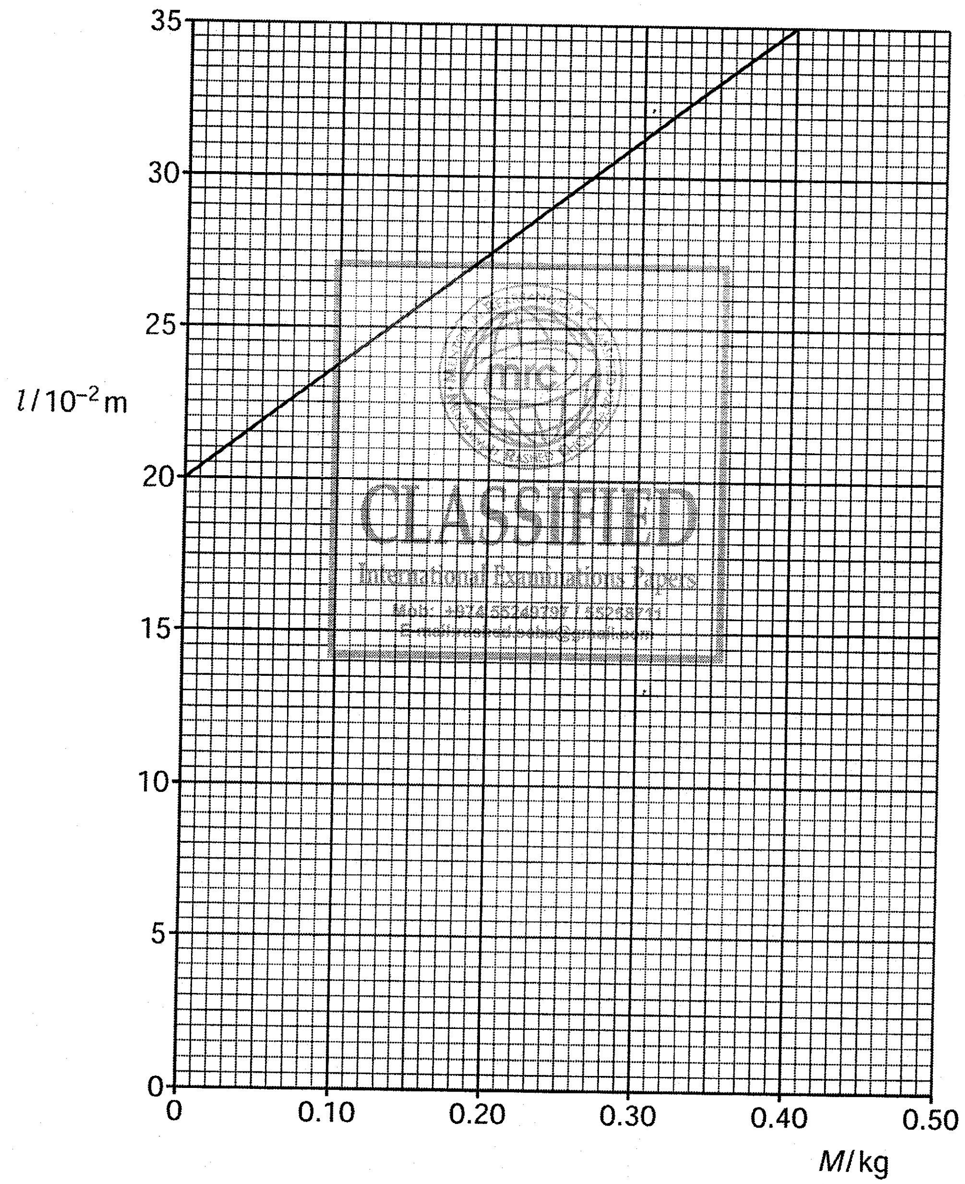


Fig. 3.4

(i) State and explain whether the spring obeys Hooke's law.

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....

....

.... [2]

(ii) Show that the force constant of the spring is 26 N m^{-1}.

[2]

(iii) A mass of 0.40 kg is attached to the spring. Calculate the energy stored in the spring.

energy = ... J [3]

[Turn over

A spring is supported so that it hangs vertically, as shown in Fig. 4.1.

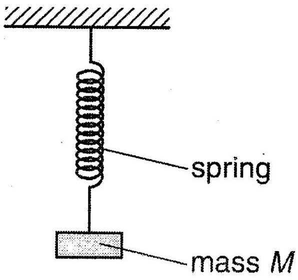

Fig. 4.1

Different masses are attached to the lower end of the spring. The extension x of the spring is measured for each mass M. The variation with x of M is shown in Fig. 4.2.

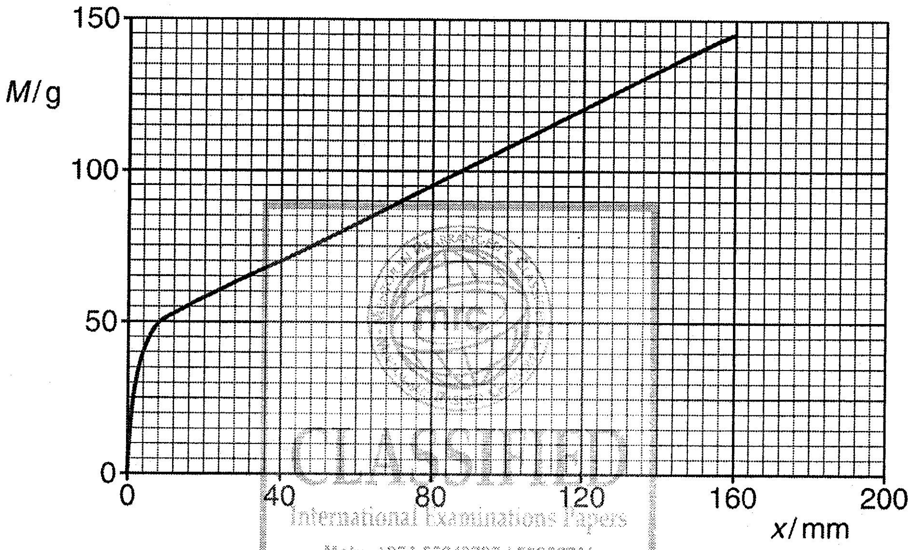

Fig. 4.2

(a) State and explain whether the spring obeys Hooke's law.

....

....[1]

(b) State the form of energy stored in the spring due to the addition of the masses.

....[1]

(c) Describe how to determine whether the extension of the spring is elastic.

....

....[1]

(d) Calculate the work done on the spring as it is extended from $x = 40.0$ mm to $x = 160$ mm.

work done = ... J [3]

[Total: 6]

(a) State what is meant by

(i) *work done,*

....

.... [1]

(ii) *elastic potential energy.*

....

.... [1]

(b) A block of mass 0.40 kg slides in a straight line with a constant speed of $0.30\,m\,s^{-1}$ along a horizontal surface, as shown in Fig. 3.1.

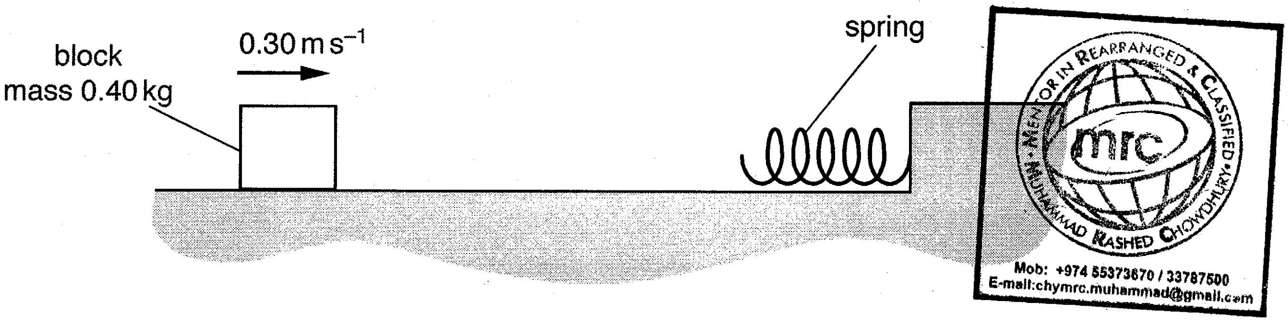

Fig. 3.1

The block hits a spring and decelerates. The speed of the block becomes zero when the spring is compressed by 8.0 cm.

(i) Calculate the initial kinetic energy of the block.

kinetic energy = ... J [2]

(ii) The variation of the compression x of the spring with the force F applied to the spring is shown in Fig. 3.2.

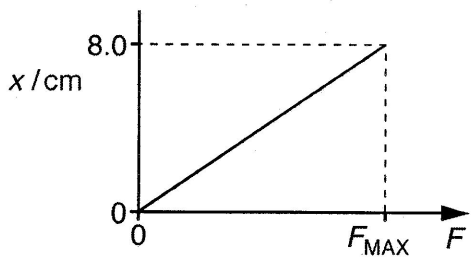

Fig. 3.2

Use your answer in **(b)(i)** to determine the maximum force F_{MAX} exerted on the spring by the block.
Explain your working.

F_{MAX} = ... N [3]

(iii) Calculate the maximum deceleration of the block.

deceleration = ... m s^{-2} [1]

(iv) State and explain whether the block is in equilibrium

1. before it hits the spring,

....

....

2. when its speed becomes zero.

....

....

[2]

(c) The energy E stored in a spring is given by

$$E = \frac{1}{2}kx^2$$

where k is the spring constant of the spring and x is its compression.

The mass m of the block in **(b)** is now varied. The initial speed of the block remains constant and the spring continues to obey Hooke's law.

On Fig. 3.3, sketch the variation of the maximum compression x_0 of the spring with mass m.

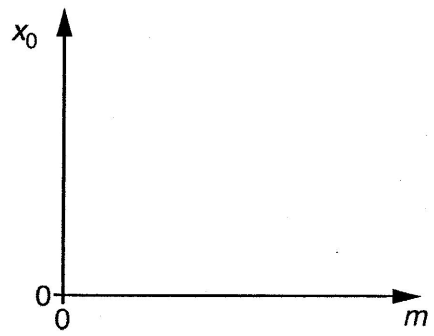

Fig. 3.3

[2]

[Total: 12]

A spring hangs vertically from a fixed point and a mass of 94 g is suspended from the spring, stretching the spring as shown in Fig. 5.1.

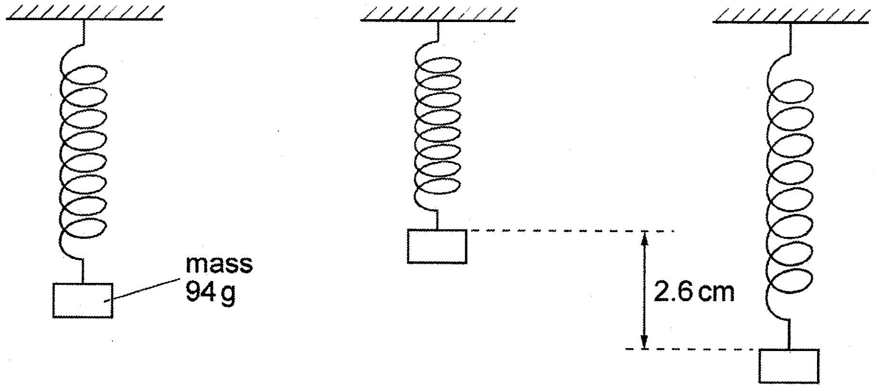

Fig. 5.1 Fig. 5.2 Fig. 5.3

The mass is raised vertically so that the length of the spring is its unextended length. This is illustrated in Fig. 5.2.

The mass is then released. The mass moves through a vertical distance of 2.6 cm before temporarily coming to rest. This position is illustrated in Fig. 5.3.

(a) State which diagram, Fig. 5.1, Fig. 5.2 or Fig. 5.3, illustrates the position of the mass such that

(i) the mass has maximum gravitational potential energy,

.... [1]

(ii) the spring has maximum strain energy.

.... [1]

(b) Briefly describe the variation of the kinetic energy of the mass as the mass falls from its highest position (Fig. 5.2) to its lowest position (Fig. 5.3).

....

.... [1]

(c) The strain energy E stored in the spring is given by the expression

For Examiner's Use

$$E = \frac{1}{2}kx^2$$

where k is the spring constant and x is the extension of the spring.

For the mass moving between the positions shown in Fig. 5.2 and Fig. 5.3,

(i) calculate the change in the gravitational potential energy of the mass,

change = ... J [2]

(ii) determine the extension of the spring at which the strain energy is half its maximum value.

extension = ... cm [3]

For Examiner's Use

(a) With reference to the arrangement of atoms, distinguish between metals, polymers and amorphous solids.

metals: ....

....

polymers: ....

....

amorphous solids: ....

.... [3]

(b) On Fig. 3.1, sketch the variation with extension x of force F to distinguish between a metal and a polymer.

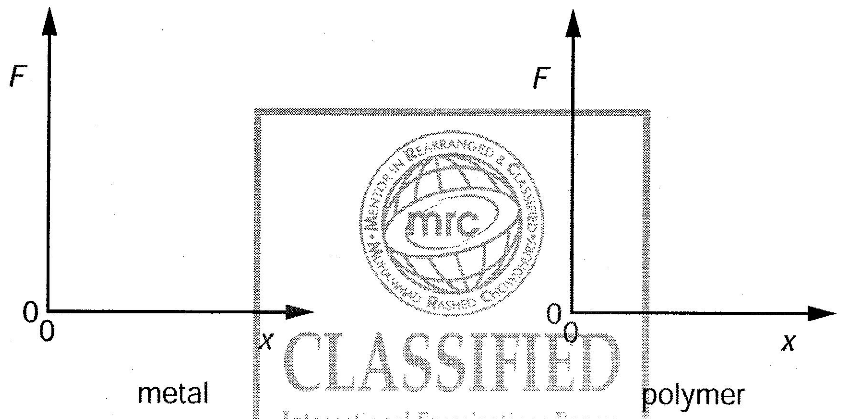

Fig. 3.1

[2]