1(a). The length of an unloaded spring is approximately 4 cm.

The force constant k of the spring is 0.62 N cm^{-1}.

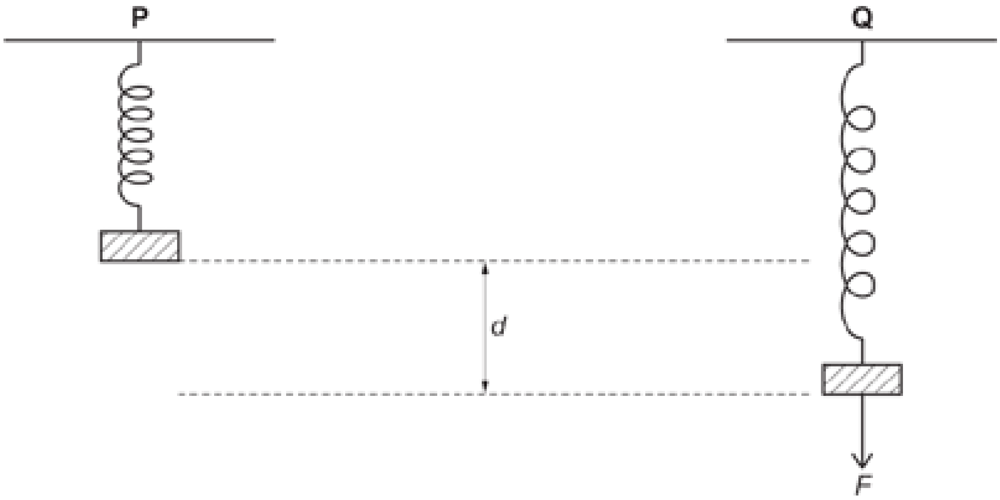
Describe how you could determine k using an appropriate experiment.

____**[3]**

(b). The figure below shows a block of mass 0.20 kg attached to one end of the spring. The other end of the spring is attached to a fixed support vertically above the block.

In position **P** the block rests in equilibrium. The extension of the spring is 3.2 cm.

In position **Q** a downwards force F has been applied to the block, so that it now rests a distance d below its position at **P**. The extension of the spring is now 8.5 cm.



The force F is removed.

i. Calculate the magnitude of the block's initial acceleration at the instant that the force F is removed.

Assume that the spring is not extended beyond its limit of proportionality.

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

ii. The block now moves with simple harmonic motion.

Calculate the frequency of this motion.

frequency = ... Hz **[3]**

(c). The block is replaced by a strong magnet **L** of slightly greater mass.

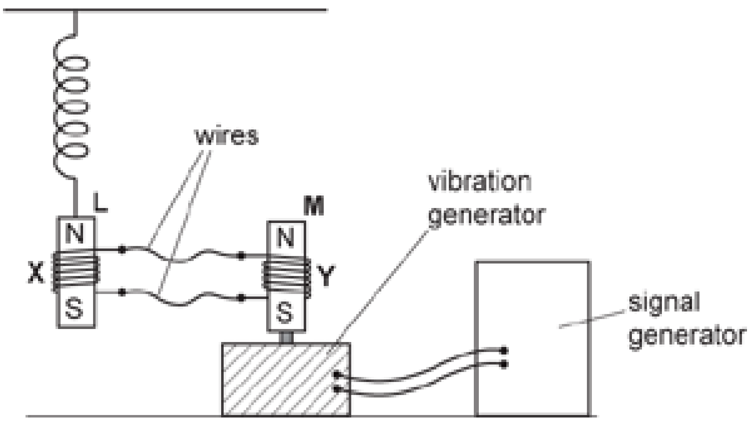
The oscillation frequency of this new arrangement is 2.5 Hz.

The magnet **L** is placed inside a coil **X** of insulated copper wire.

The coil **X** is connected with long wires to a second, identical coil **Y**.

A second strong magnet **M** is placed inside **Y** and attached to a vibration generator.

The vibration generator is then forced to oscillate with a frequency of approximately 2.5 Hz by adjusting the signal generator.



i. As magnet **M** oscillates, it moves in and out of coil **Y**.

The magnet **L** also begins to oscillate.

Explain why **L** oscillates.

[3]

ii. The frequency of the vibration generator is now varied between 0.5 Hz and 5.0 Hz.

Suggest how the amplitude and frequency of the oscillations of **L** will change as the frequency of the generator is varied.

You may draw a diagram to support your answer.

[3]

2(a). Mats made from rubber are often used in laboratories where heavy objects might be dropped.

A rubber cord is tested to determine the material's mechanical characteristics.

The cord is suspended from a ceiling and masses can be attached to the free end.

The apparatus is set up as shown in **Fig. 18.1**.

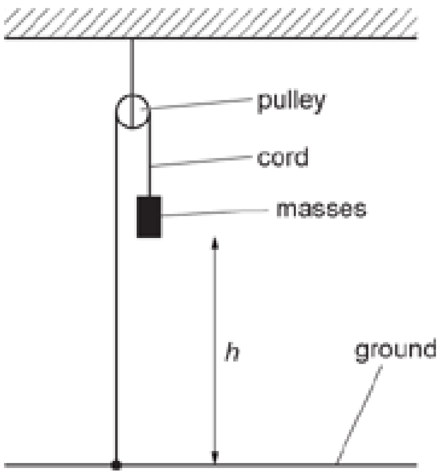


Fig. 18.1

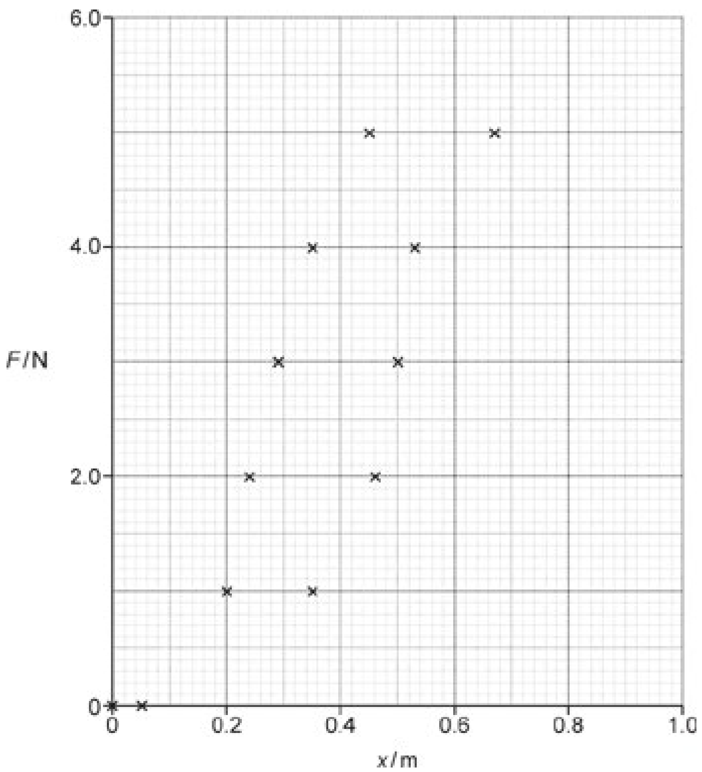
Masses are added and the height, h, of the base of the bottom mass from the floor is measured. The extension of the cord is x when the tension in the cord is F. After six masses have been added, they are removed one at a time and h measured each time.

The table shows the data collected.

***F* / N**	***h* / m**	***x* / m**
0.0	1.80	0.00
1.0	1.60	0.20
2.0	1.56	0.24
3.0	1.51	0.29
4.0	1.45	0.35
5.0	1.35	0.45
6.0	0.81	
5.0	1.13	0.67
4.0	1.27	0.53
3.0	1.30	0.50
2.0	1.34	0.46
1.0	1.45	0.35
0.0	1.75	0.05

i. Complete the final column of the table.

[1]



i. Plot the data point for F = 6.0 N on the graph above. The other points have been plotted.

Draw and label **two** curves to show the loading and unloading of the cord.

[3]

ii. Discuss whether Hooke's law can be applied to the cord.

____

____ **[2]**

iii. There is an area between the two curves that you have drawn on the graph.

1. State the **name** of the derived SI unit of this area.

____ **[1]**

2. Explain the significance of this area to the planned use of the rubber.

____

____

____ **[2]**

(b). An alternative arrangement for the experiment is to use a pulley as shown in **Fig. 18.2**.

The arrangement makes it possible to cover a larger range of extensions.

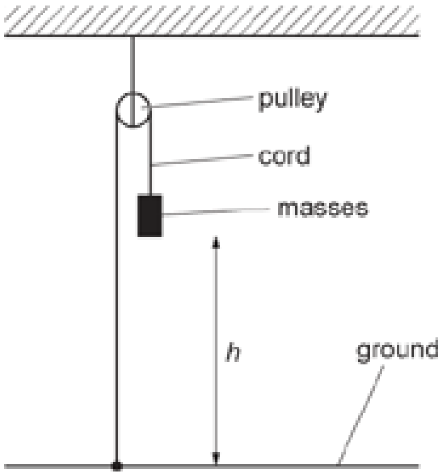


Fig. 18.2

The cord is fixed to the ground.

Describe **two** factors that would affect the accuracy of the results obtained using this alternative arrangement.

1 ____

____

2 ____

-- [2]

3. A spring has a force constant of 4900 N m^{-1}.

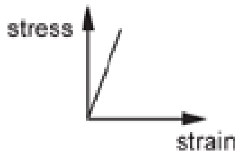
A force is applied to the spring, causing it to compress by 0.50 m.

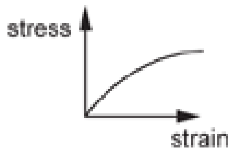
What is the change in the elastic potential energy stored in the spring?

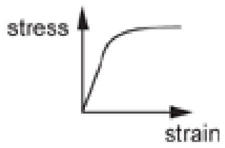
A decreases by 610 J
B decreases by 1200 J
C increases by 610 J
D increases by 1200 J

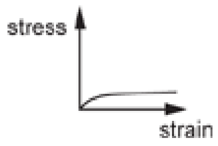
Your answer ☐ **[1]**

4. Which graph shows the stress-strain characteristics of a brittle material?

A


B


C


D


Your answer ☐ **[1]**

5(a). Two identical springs each have a force constant of 36 N m^{-1}. In an experiment, the two springs are suspended from a fixed support as shown in **Fig. 4.1**.

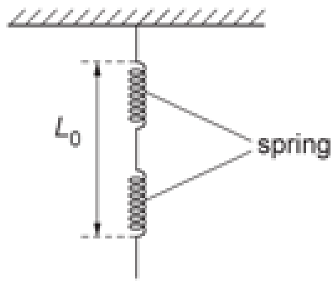


Fig. 4.1

The initial length of the spring arrangement is L_0.

An object of mass M is added to the spring arrangement as shown in **Fig. 4.2**.

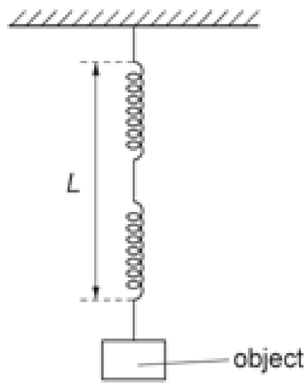


Fig. 4.2

The new length of the spring arrangement is L.

A student measures L_0 and L and records the results in a table.

Quantity	**Measurement / mm**
L_0	(22.2 ± 0.1)
L	(54.9 ± 0.1)

i. State the name of the instrument the student used to measure L_0 and L.

____ **[1]**

ii. Determine the extension x of the spring arrangement. Include the absolute uncertainty in your answer.

x = ... ± .... mm **[1]**

iii. Calculate the mass M of the object. Write your answer to **2** significant figures.

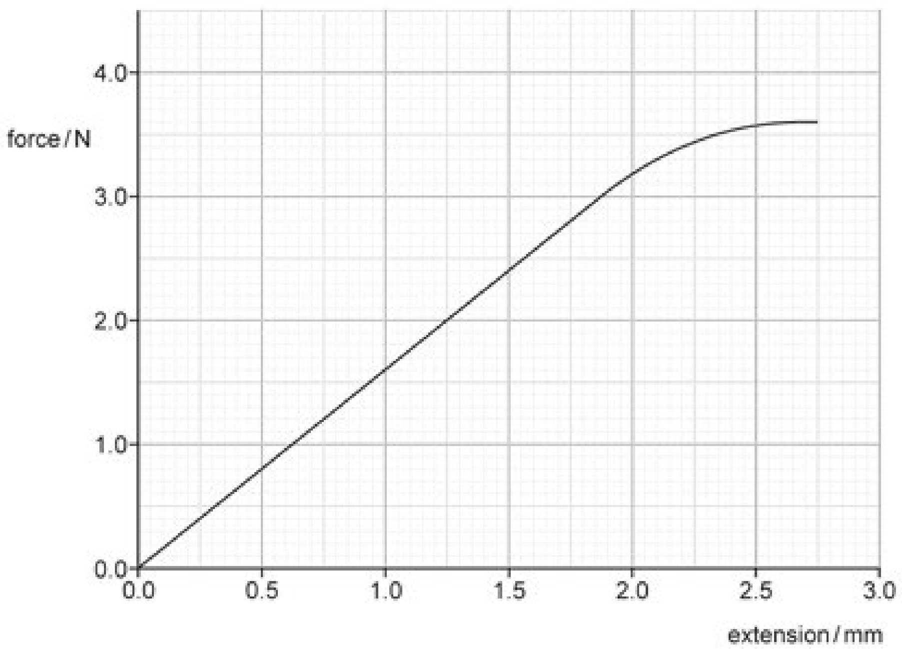
M = ... kg **[2]**

iv. Calculate the total energy W stored by the springs when the object is suspended.

W = ... J **[2]**

(b). A metal wire has a length of 4.4 m. The Young modulus of the metal is 120 GPa.

In an experiment force is applied to the wire and the extension is measured.
The graph shows the variation of the extension of the wire with the force applied.



i. The gradient of the linear section of the graph is 1.6 N mm $^{-1}$.

Determine the cross-sectional area A of the wire.

A = ... m^2 **[3]**

ii. Use the graph to determine an estimate of the work done E_w in stretching the wire when a 3.5 N force is applied.

E_w = ...J **[3]**

6(a). The figure below shows a stationary glider of mass *m* on an air track.

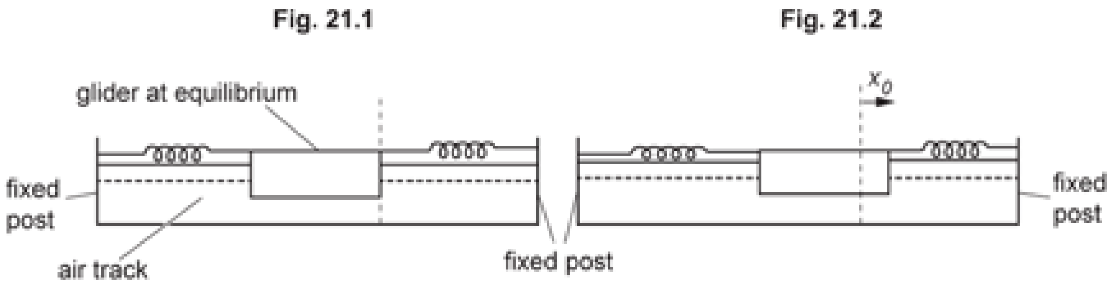
The glider has identical springs with force constant *k* attached to each end which are secured to fixed posts.

The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in the figure. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period *T* calculated.



The relationship between the period *T*, the mass of the glider *m* and the force constant *k* is described by the equation $T^2 = \frac{2\pi^2 m}{k}$.

i. Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

ii. Explain why the magnitude of the resultant force *F* on the glider is given by *F* = 2*kx* where *x* is the displacement at any time.

[2]

iii. State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

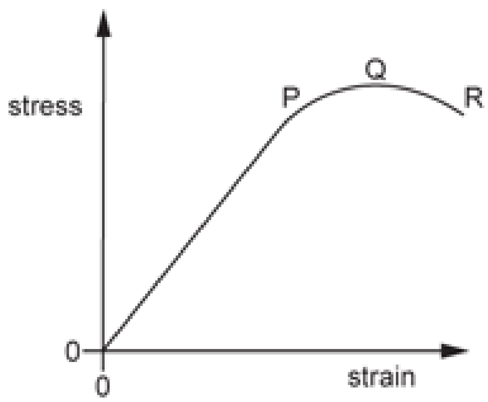
[2]

(b). When the initial displacement is increased, one spring increases its extension while the extension of the other spring decreases.

Explain why the **maximum** kinetic energy of the motion increases.

[4]

7. Which row in the table correctly identifies the elastic limit, fracture and ultimate tensile strength in the graph below?



	Elastic limit	Fracture	Ultimate tensile strength
A	P	Q	R
B	P	R	Q
C	P	R	R
D	Q	R	P

Your answer

[1]

8. A wire of cross-sectional area 3.9×10^{-6} m^2 carries a load of 240 N. The strain in the wire is 0.30%.

Which value of the Young modulus, in Pa, is correct and expressed to an appropriate number of significant figures?

A 2.05×10^8
B 2.1×10^8
C 2.05×10^{10}
D 2.1×10^{10}

Your answer ☐ **[1]**

9(a).

i. Show that an expression for the Young modulus E of a wire is $E = \frac{kL}{A}$

L = length of wire
A = cross-sectional area of wire
k = force constant of wire

[2]

ii. The student records the following results for a copper wire.

L = 2.0 m ± 0.05 %
A = 2.9×10^{-8} m^2 ± 2 %
k = 1670 N m^{-1} ± 1.25 %

Calculate the value of the Young modulus of the wire and its percentage uncertainty.

Young modulus = ...N m^{-2} ± ....% **[3]**

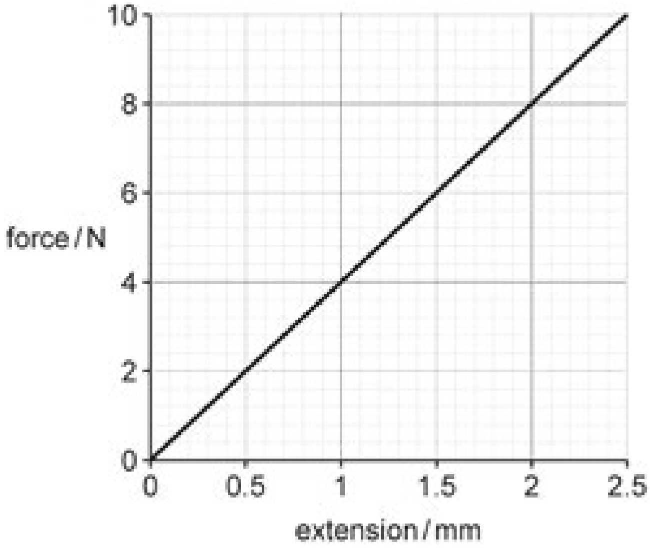
iii. The student researches the Young modulus of copper.

They find a value of 1.17×10^{11} N m^{-2}.

Determine whether this value is consistent with your answer to **(c)(ii)**.

[2]

(b). A student investigates the properties of a spring. They hang masses from the spring and measure the extension of the spring for every 100 g mass added. They plot their results on a graph of force against extension.



Calculate the force constant of the spring.

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

(c). A student carries out an investigation to determine the Young modulus of copper. They make measurements to determine the length and the cross-sectional area of a copper wire.

Describe how they should determine the cross-sectional area of the wire.

____

____

____

____

____

____ **[3]**

10(a). A tent is secured by 3 ropes along each of its long sides, as shown in **Fig. 18. 1**.

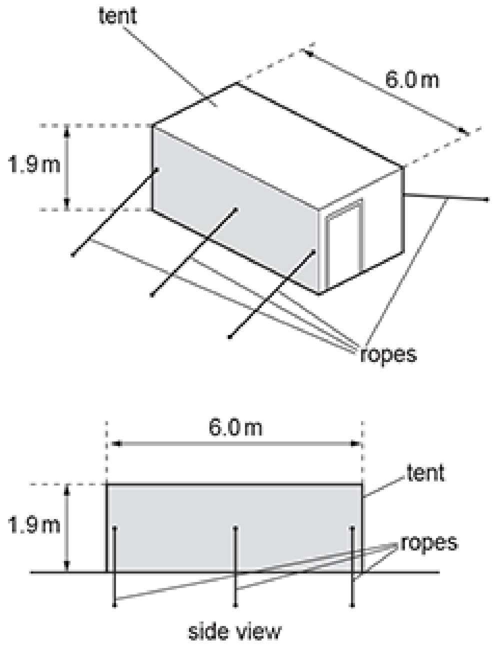


Fig. 18.1

Wind of speed 12 ms^{-1} blows at right angles to the **shaded** side of the tent for 3.0 s. The density of air is 1.2 kg m^{-3}.

i. Show that the mass of air which hits the tent in this time is about 490 kg.

[3]

ii. All of the air incident on the shaded side of the tent is deflected at 90° to the original direction as shown in **Fig. 18. 2**.

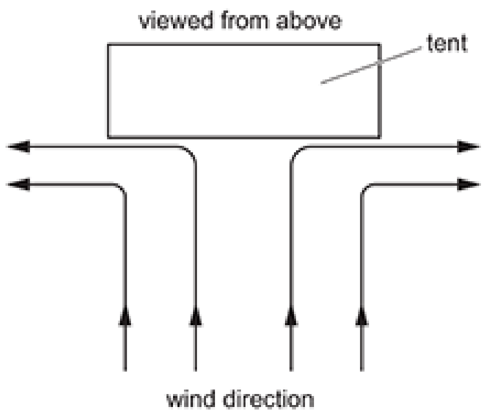


Fig. 18.2

Use the information given in **(a)(i)** to calculate the magnitude of the force *F* exerted by the wind on the shaded side of the tent.

F = ... N **[2]**

(b). *When the wind speed exceeds 20 ms^{-1} the ropes securing the tent break.

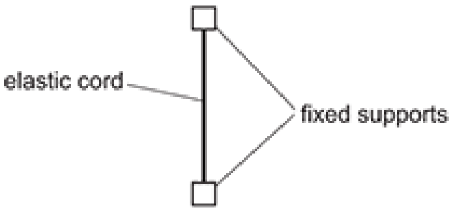
Describe, and explain in terms of forces, how the ropes and the shape of the tent could be modified to withstand wind speed exceeding 40 ms^{-1}.

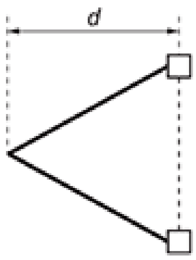
[6]

11(a). Describe how an experiment can be carried out to determine the force constant of an elastic cord in the laboratory by plotting a suitable graph. You may assume that the cord obeys Hooke's law.

[4]

(b). A simple catapult is made by an elastic cord fixed to two supports, as shown below.

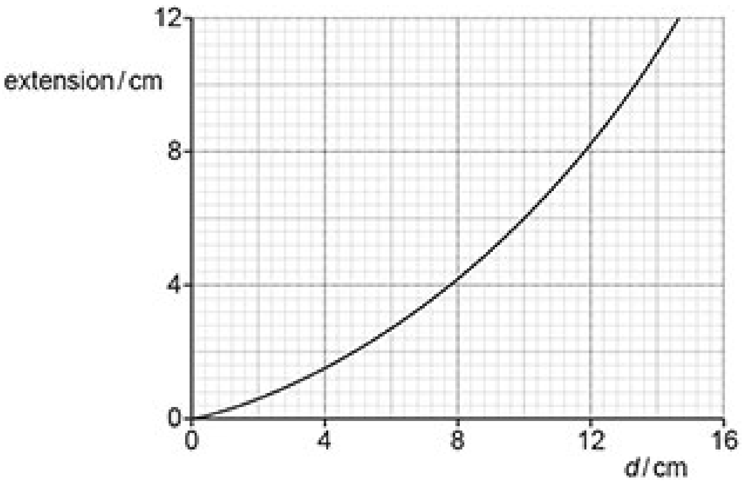




The unstretched length of the cord is the same as the distance between the supports.
The distance that the centre of the cord has been pulled back is *d*.

The cord has a force constant of 500 Nm^{-1}.

The variation of the extension of the cord with distance *d* is shown below.



A small ball of mass 30 g is placed at the centre of the cord and drawn back with *d* = 10 cm.

The ball is released and launched horizontally from a height of 1.5 m above the horizontal ground.

i. Use the graph to show that the elastic potential energy *E* in the cord is about 1 J.

[3]

ii. Show that the maximum speed at which the ball leaves the catapult is about 8 ms^{-1}.

[2]

iii. Calculate the horizontal distance *R* travelled by the ball before it strikes the horizontal ground. Ignore the effects of air resistance in your calculation.

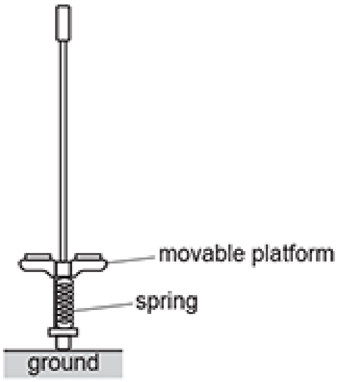
R = ... m **[3]**

iv. Explain how the value of *R* calculated in **(iii)** compares with the actual value.

[2]

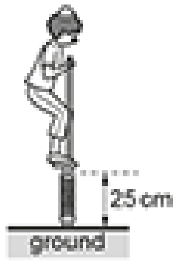
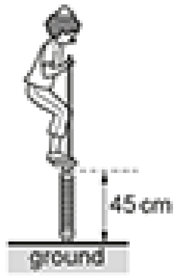
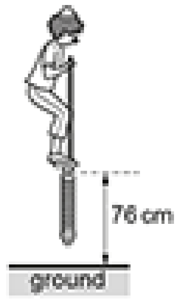
12(a). A pogo stick is a spring-based toy used by a circus clown for jumping vertically up and down.

A **compression** spring is fixed to the bottom of the pogo stick. The upper end of the spring is attached to a movable platform.



The force constant of the spring is 1.7×10^4 N m^{-1}.
The mass of the clown is 68 kg.
The mass of the pogo stick is negligible compared with the mass of the clown.

The table below shows the state of the spring and the clown in three different positions.

	Position A	**Position B**	**Position C**
			
State of spring	fully compressed	original length	original length
State of clown	stationary	Moving vertically upwards at maximum speed	stationary
Height of platform above the ground / cm	25	45	76

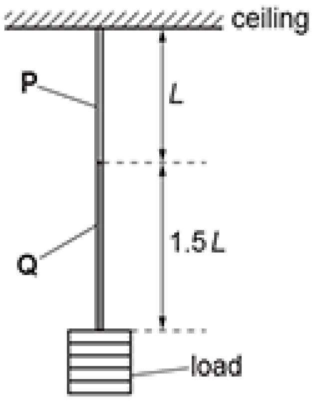
Calculate the maximum energy E stored in the compressed spring.

E = ... J **[2]**

(b). Describe how the force constant of the compression spring in the pogo stick can be verified in the laboratory.

[2]

13. A load is suspended from two wires **P** and **Q** as shown below.



Both wires have the same diameter.

The table below shows some data for these two wires.

	Original length of wire	Young modulus of wire's material	Extension of wire / mm
P	*L*	*E*	4.0
Q	1.5 *L*	3.0 *E*	

What is the extension of the wire **Q**?

A 2.0 mm
B 4.0 mm
C 6.0 mm
D 8.0 mm

Your answer **[1]**

END OF QUESTION PAPER