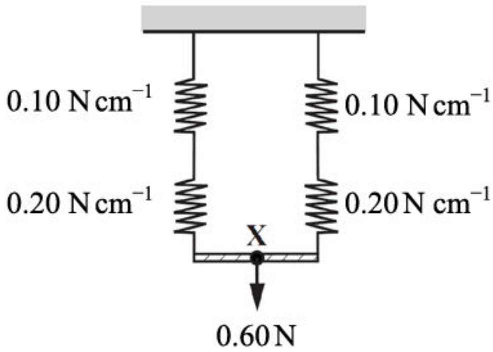
1 A spring with force constant 0.10 N cm^{-1} is placed in series with one of 0.20 N cm^{-1}. These are then placed in parallel with an identical set of springs as shown. A force of 0.60 N is applied.



What distance does the point **X** move down when the 0.60 N force is applied?

A 2.0 cm
B 3.0 cm
C 4.5 cm
D 9.0 cm

Your answer

[1]

2(a) * A group of scientists have designed an alloy which is less dense than copper but may have similar mechanical properties. A researcher is given the task to determine the Young modulus of this alloy in the form of a wire.

Write a plan of how the researcher could do this in a laboratory to obtain accurate results. Include the equipment used and any safety precautions necessary.

[6]

(b)

(i) State the meaning of *elastic* and *plastic* behaviour.

[1]

(ii) Repeatedly stretching and releasing rubber warms it up.
Fig. 18.1 shows a force-extension graph for rubber.

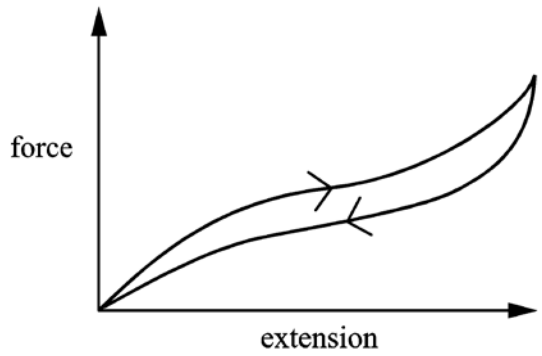


Fig. 18.1

Rubber is an ideal material for aeroplane tyres. Using the information provided, discuss the behaviour and properties of rubber and how its properties minimise the risks when aeroplanes land.

[3]

3 A wire of diameter 0.80 mm is stretched by a force of 40 N.

What is the tensile stress in the wire?

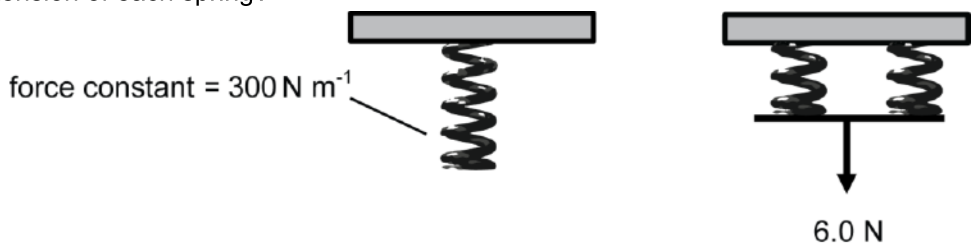
A 0.016 MPa
B 0.05 MPa
C 20 MPa
D 80 MPa

Your answer

[1]

4 A spring of force constant 300 N m^{-1} is cut in half. The two halves are then placed in **parallel** with each other. A force of 6.0 N is then applied to this parallel arrangement.

What is the extension of each spring?



A 0.5 cm
B 1.0 cm
C 2.0 cm
D 4.0 cm

Your answer

[1]

5 A 6.0 N force is applied to a spring which extends vertically downwards by a distance 5.0 cm. The force is suddenly removed so that the spring flies vertically upwards. The spring has mass 9.0 g.

What is the maximum height reached by the spring?

A 0.085 m
B 0.17 m
C 1.7 m
D 3.4 m

Your answer ☐ **[1]**

6(a) Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is held in tension *T* by the clamps at each end. The length of the wire in the magnetic field of flux density 0.032 tesla is 6.0 cm.

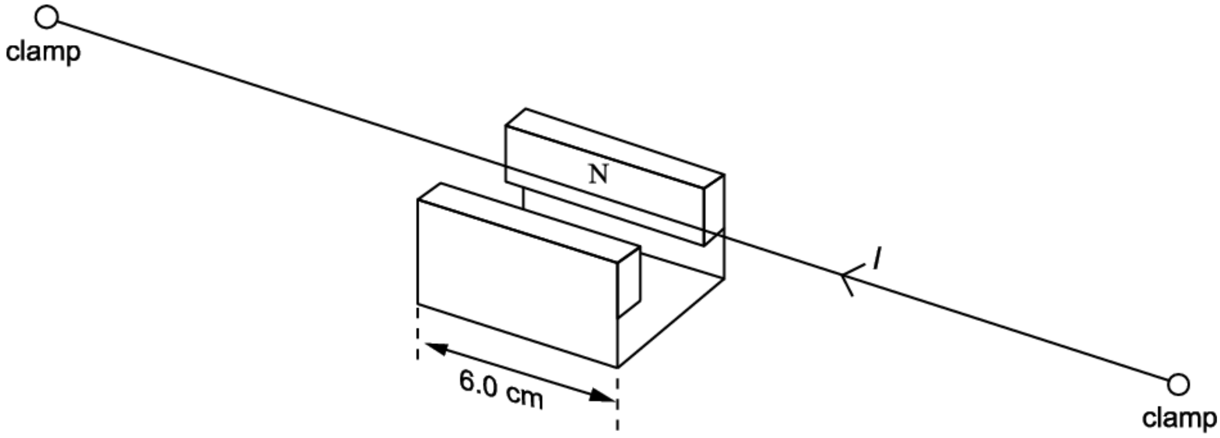


Fig. 5.1

The direct current is changed to an alternating current of constant amplitude and variable frequency, causing the wire to oscillate. The frequency of the current is increased until the fundamental natural frequency of the wire is found as shown in Fig. 5.2. This is 70 Hz.

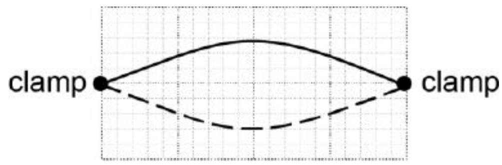


Fig. 5.2

(i) In the situation shown in Fig. 5.2 the amplitude of the oscillation of the centre point of the wire is 4.0 mm. Calculate the maximum acceleration of the wire at this point.

maximum acceleration = _____________________ m s^{-2} **[2]**

(ii) The frequency is increased until another stationary wave pattern occurs. The amplitude of this stationary wave is much smaller.

1 Sketch this pattern on Fig. 5.3 and state the frequency

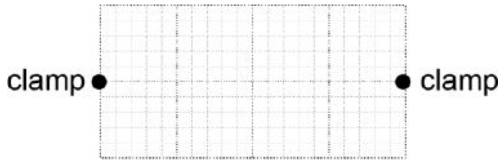


Fig. 5.3

frequency = ____________________ Hz **[1]**

2 Explain why the amplitude is so small. Suggest how the experiment can be modified to increase the amplitude.

____

____

____

____

____ **[3]**

(b)

The speed v of a transverse wave along the wire is given by $v = \sqrt{\frac{T}{\mu}}$ where T is the tension and μ is the mass per unit length of the wire.

(i) Assume that both the length and mass per unit length remain constant when the tension in the wire is halved. Calculate the frequency of the new fundamental mode of vibration of the wire.

frequency = ____________________ Hz **[1]**

(ii) In practice the mass per unit length changes because the wire contracts when the tension is reduced. For the situation in which the tension is halved the strain reduction is found to be 0.4%.

1 Calculate the percentage change in μ. State both the size and sign of the change.

percentage change in μ = ____________________ % **[1]**

2 Write down the percentage error this causes in your answer to **(i)**. State, giving your reasoning, whether the actual frequency would be higher or lower than your value.

____

____

____ **[2]**

7 A student is investigating two wires of different diameters made from the **same** metal. She plots graphs of force against extension and graphs of stress against strain for both wires.

The wires behave elastically.

Which of the following statements is / are correct?

1 Young modulus is equal to the gradient of the stress against strain graph.
2 Force constant is equal to the gradient of the force against extension graph.
3 The graphs of stress against strain have different gradients.

A 1, 2 and 3
B Only 1 and 2
C Only 2
D Only 1

Your answer

[1]

8(a) The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

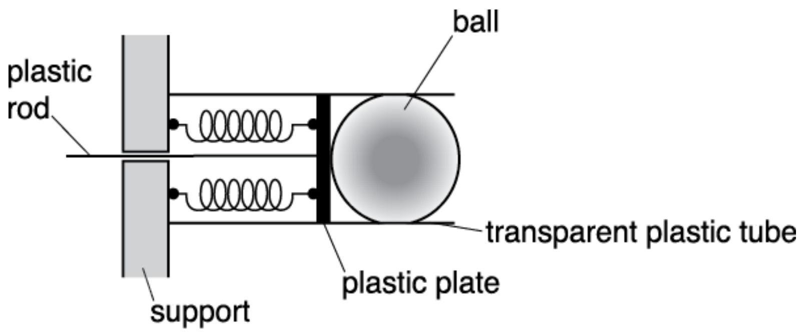


Fig. 17.1

A pair of identical compressible springs are fixed between a plastic plate and a support. The springs are in parallel. A plastic rod attached to the plate is pulled to the left to compress the springs. A ball, initially at rest, is fired when the plate is released.

The force constant of each spring is *k.*
Explain why the force constant of the two springs in parallel in Fig. 17.1 is equal to 2*k.*

--- **[1]**

(b) A group of students are conducting an experiment to investigate the ball-release mechanism shown in Fig. 17.1.
The students apply a force *F* and measure the compression *x* of the springs.
The table below shows the results.

F / N	*x* / cm
1.1 ± 0.2	2.0
2.0 ± 0.2	4.0
2.9 ± 0.2	6.0
4.0 ± 0.2	8.0
5.1 ± 0.2	10.0

Fig. 17.2 shows four data points from the table plotted on a *F* against *x* graph.

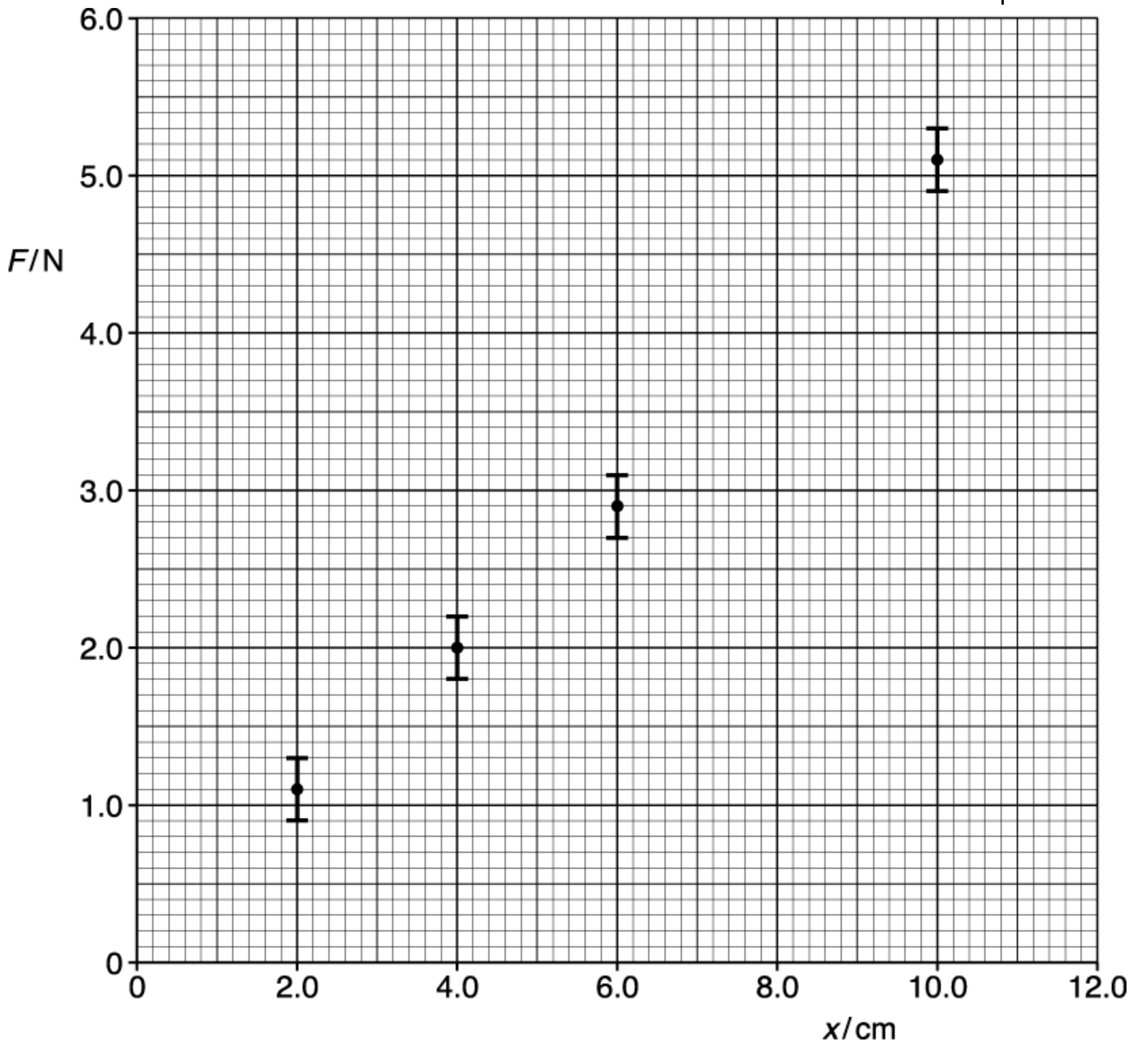


Fig. 17.2

(i) Plot the missing data point and the error bar on Fig. 17.2.

[1]

(ii) Describe how the data shown in the table may have been obtained in the laboratory.

____

____

____ **[2]**

(iii) Draw the best fit and the worst fit straight lines on Fig. 17.2.

Use the graph to determine the force constant *k* for a **single** spring and the absolute uncertainty in this value.

k = ______________ ± ______________ N m^{-1} **[4]**

(iv) State the feature of the graph that shows Hooke's law is obeyed by the springs.

____

____ **[1]**

(v) The mass of the ball is 0.39 kg.

Use your answer from **(iii)** to calculate the launch speed v of the ball when the plastic plate shown in Fig. 17.1 is pulled back 12.0 cm.

v = ____________________________ m s^{-1} **[3]**

(c) A new arrangement for the ball-release mechanism using three identical springs is shown in Fig. 17.3.

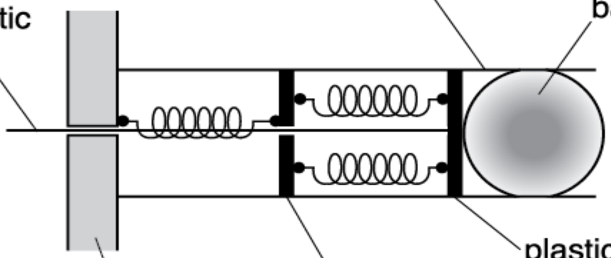


Fig. 17.3

The force constant of each spring is k.
The same ball of mass 0.39 kg is used. The plastic rod is pulled to the left by a distance of x.

Show that initial acceleration a of this ball is given by the equation

$$a = 1.7\ kx.$$

[2]

9 Fig. 18.2 shows an arrangement for lifting a car engine in a repair workshop.

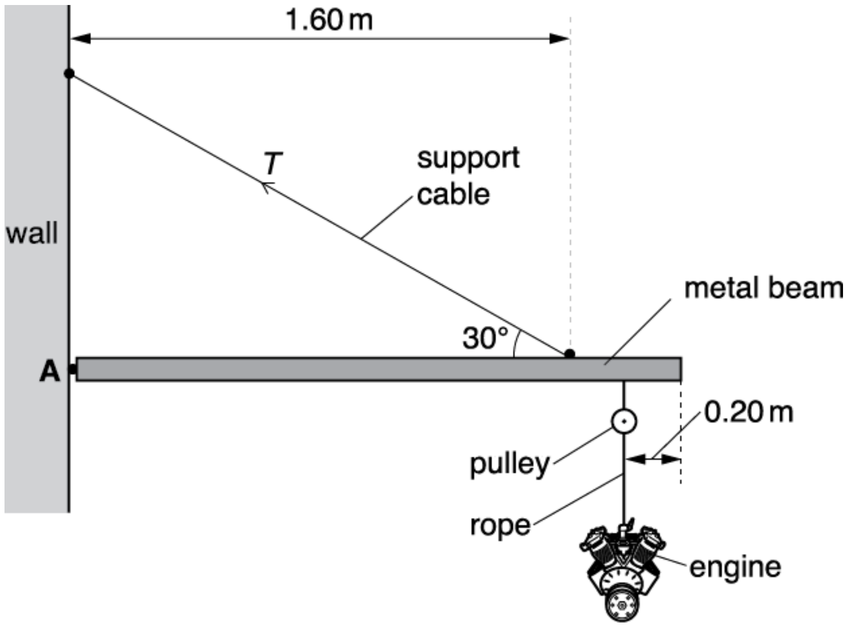


Fig. 18.2 (not to scale)

A **uniform** metal beam of length 2.00 m is hinged to a vertical wall at point **A**. The beam is held at rest in a horizontal position by a support cable of diameter of 3.0 cm. One end of this cable is fixed to the wall and the other end is fixed to the beam at a perpendicular distance of 1.60 m from the wall. The support cable makes an angle of 30° to the horizontal.

The car engine is lifted and lowered using a rope and a pulley. The pulley is fixed to the lower end of the beam at a distance of 0.20 m from the far end of the beam.

The metal beam has a mass of 120 kg and the car engine has a mass of 95 kg.

(i) Calculate the tension *T* in the support cable.

T = ______________________________ N **[3]**

(ii) Calculate the tensile stress σ in the support cable in kPa.

σ = ____________________________ kPa **[2]**

(iii) The engine is lowered using the pulley and the rope. The engine accelerates downwards.
Explain briefly the effect this would have on the tension *T* in the support cable.

____

____ **[1]**

Fig. 3.1 shows a simple representation of a hydrogen iodide molecule. It consists of two ions ${}^{1}_{1}H^{+}$ and ${}^{127}_{53}I^{-}$, held together by electric forces.

Fig. 3.1

Fig. 3.2 shows a simple mechanical model of the molecule consisting of two unequal masses connected by a spring of force constant *k* and negligible mass. The ions oscillate in simple harmonic motion when disturbed.

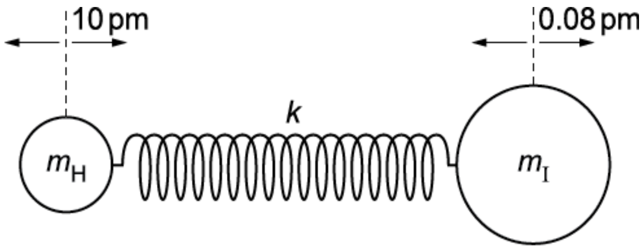


Fig. 3.2

(i) The approximate acceleration *a* of the hydrogen ion, mass m_H, is given by the equation

$$a = -\left(\frac{k}{m_H}\right)x$$

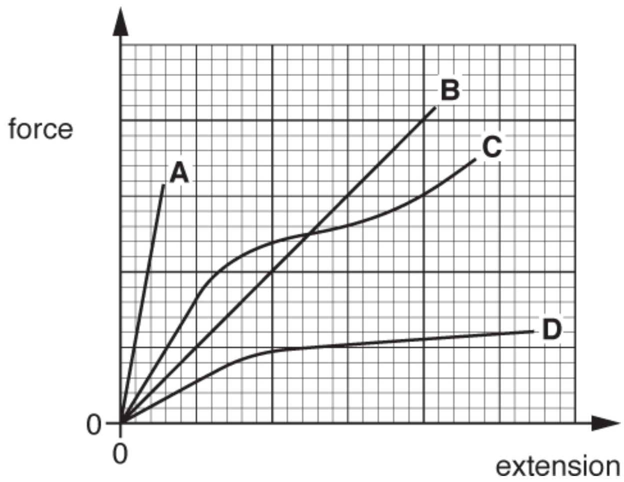
where *k* is the force constant of the spring and *x* is the displacement of the ion.
The ions oscillate with a frequency of 6.6×10^{13} Hz. The mass m_H is 1.7×10^{-27} kg.
Show that the value of *k* is about 300 N m^{-1}.

[3]

(ii) Use Newton's laws of motion and a requirement for simple harmonic motion to explain why the amplitude of oscillation of the iodine ion, mass m_I, is about 0.08 pm when the amplitude of oscillation of the hydrogen ion is about 10 pm.

[4]

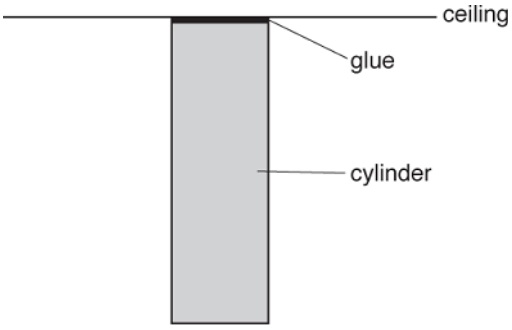
11 Four materials **A**, **B**, **C and D** have the same length and cross-sectional area. The force against extension graph for each material up to the breaking point is shown below.



Which material is brittle and has the greatest ultimate tensile strength?

Your answer [1]

12 The flat end of a uniform steel cylinder of weight 7.8 N is glued to a horizontal ceiling. The cylinder hangs vertically. The breaking stress for the glue is 130 kPa.



The glue only just holds the cylinder to the ceiling.

What is the cross-sectional area of the cylinder?

A 6.0×10^{-2} m^2

B 6.0×10^{-5} m^2

C 1.7×10^{-2} m^2

D 1.7×10^{1} m^2

Your answer [1]

13 A tensile force of 4.5 N is applied to a spring. The spring extends elastically by 3.2 cm.

What is the elastic potential energy of the spring?

A 0.072 J

B 0.14 J

C 2.4 J

D 14 J

Your answer [1]

14(a) This question is about the motion of a ball suspended by an elastic string above a bench. The mass of the string is negligible compared to that of the ball. Ignore air resistance.

Fig. 6.1

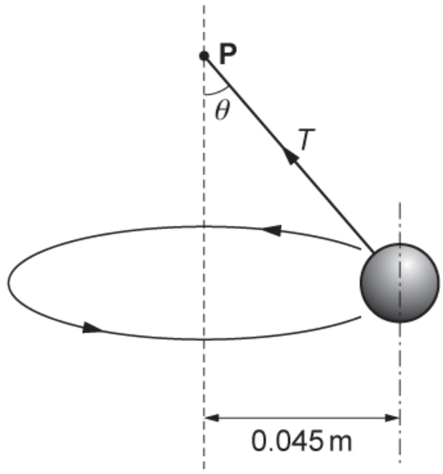


Fig. 6.2 (not to scale)

In Fig. 6.1 the ball of weight 1.2 N hangs vertically at rest from a point **P**. The extension of the string is 0.050 m. The string obeys Hooke's law.

In Fig. 6.2 the ball is moving in a horizontal circle of radius 0.045 m around a vertical axis through **P** with a period of 0.67 s. The string is at an angle θ to the vertical. The tension in the string is T.

On Fig. 6.2 draw and label one other force acting on the ball. **[1]**

(b)

(i) Resolve the tension *T* horizontally and vertically and show that the angle θ is 22°.

[2]

(ii) Calculate the extension *x* of the string shown in Fig. 6.2.

x = ____________________ m **[3]**

(c) Whilst rotating in the horizontal plane the ball suddenly becomes detached from the string. The bottom of the ball is 0.18 m above the bench at this instant. The ball falls as a projectile towards the bench beneath. Fig. 6.3 shows the view from above.

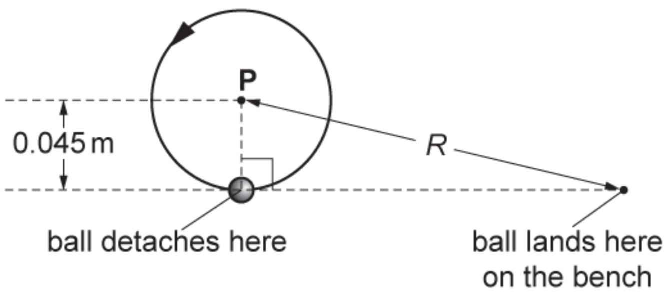


Fig. 6.3

Calculate the horizontal distance R from the point on the bench vertically below the point **P** to the point where the ball lands on the bench.

R = ____________________ m **[4]**

(d) Returning to the situation shown in Fig. 6.2, state and explain what happens when the rate of rotation of the ball is increased.

--- **[2]**

15 One end of a spring is fixed and a force F is applied to its other end. The elastic potential energy in the extended spring is *E*. The spring obeys Hooke's law.

What is the extension *x* of the spring?

A $x = \frac{E}{F}$

B $x = \frac{F}{E}$

C $x = \frac{2E}{F}$

D $x = \frac{F}{2E}$

Your answer [ ] **[1]**

16 The table below shows some data on two wires X and Y.

Wire	Young modulus of material / GPa	Cross–sectional area of wire / mm^2
X	120	1.0
Y	200	2.0

The wires **X** and **Y** have the same original length. The tension in each wire is the same.
Both wires obey Hooke's law.

What is the value of the ratio $\frac{\text{extension of } \mathbf{X}}{\text{extension of } \mathbf{Y}}$?

A 0.30
B 1.7
C 2.0
D 3.3

Your answer **[1]**

17(a) The 500 m tall Taipei 101 tower is shown in Fig. 2.1. The tower has a massive sphere suspended across five floors near the top of the building to dampen down movement of the tower in high winds and earthquakes. The sphere is connected to pistons (not shown) which drive oil through small holes providing damping. The vibration energy of the sphere is converted to thermal energy.

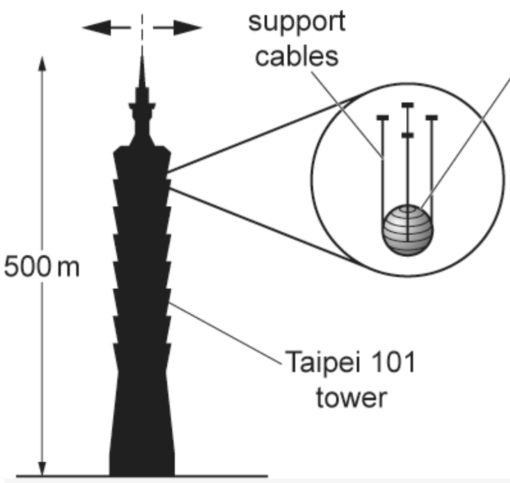


Fig. 2.1

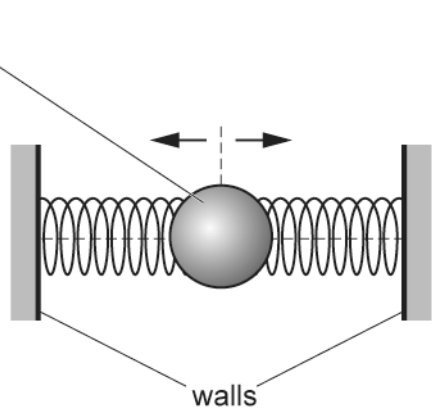


Fig. 2.2

Fig. 2.2 models the damper system as the sphere held between two springs. The movement of the walls of the tower forces the sphere to oscillate in **simple harmonic motion**.

In the strongest wind, the natural frequency of the oscillations of the tower is 0.15 Hz and the maximum acceleration of the sphere is 0.050 m s^{-2}.

Explain why the natural frequency of the damper system must be about 0.15 Hz.

--- [2]

(b) The acceleration *a* of the sphere is given by the equation

$$a = -\left(\frac{k}{m}\right)x$$

where *k* is the force constant of the spring combination, *x* is the displacement of the sphere and *m* is the mass of the sphere.

The mass of the sphere is 6.6×10^5 kg. The natural frequency of the oscillations of the sphere is 0.15 Hz.

(i) Show that the force constant *k* of the spring combination is about 6×10^5 N m^{-1}.

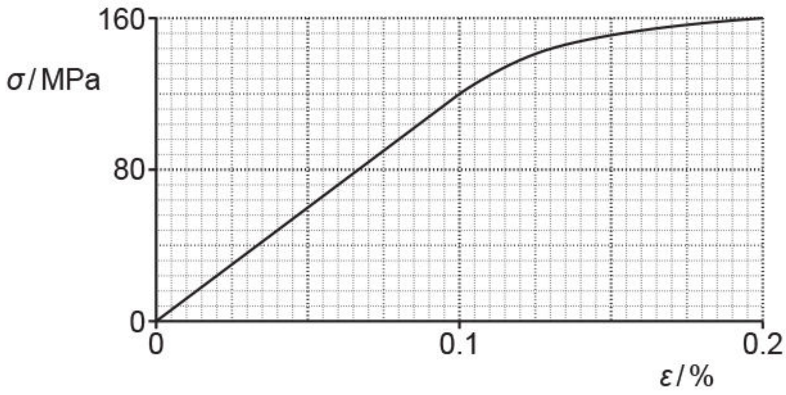
[3]

(ii) The S-wave of an earthquake causes a sudden movement of the building displacing the sphere 0.71 m from its equilibrium position relative to the building.

Use your answer in **(i)** to calculate the energy transferred to the springs of the damper system.

energy transferred = ------------------------------------ J **[2]**

18 A graph showing the variation of the stress σ with strain ε for a material is shown below.



What is the Young modulus of the material?

A 6.0×10^4 Pa

B 1.2×10^9 Pa

C 8.0×10^{10} Pa

D 1.2×10^{11} Pa

Your answer **[1]**

19(a) Explain what is meant by the **ultimate tensile strength** of a material.

[1]

(b) A footbridge is supported by a number of metal cables of the same length.
Each cable has uniform cross-section and diameter 4.20 mm as shown in Fig. 16.1.

Fig. 16.1 (not to scale)

A group of engineers investigate how the extension x varies with applied force F for one of the cables.

The results of the investigation are shown in Fig. 16.2.

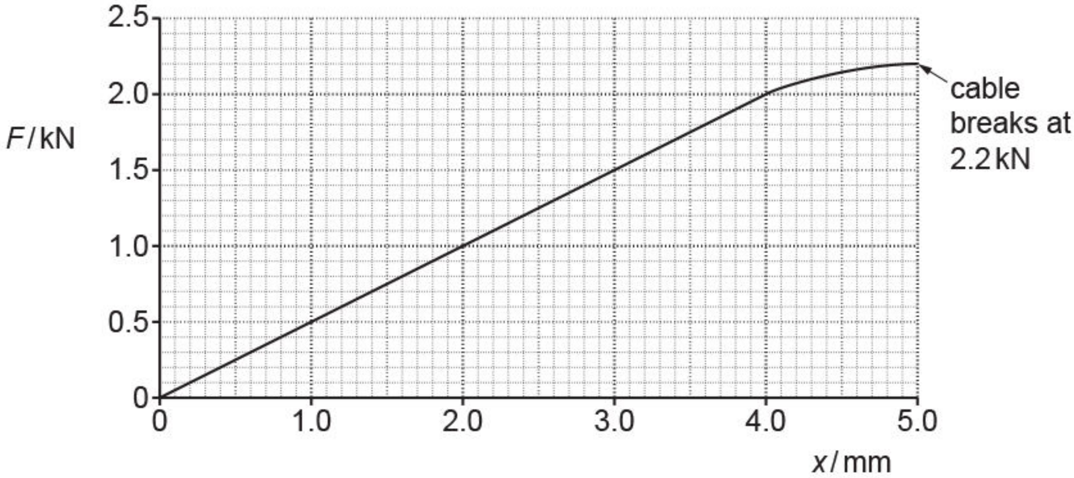


Fig. 16.2

The cable breaks when the force is 2.2 kN.

(i) Describe how a suitable measuring device may have been used by the engineers to demonstrate that the cable had uniform cross-section.

[2]

(ii) State any value of F when the cable behaves

1. elastically

F = ... kN

2. plastically.

F = ... kN

[2]

(iii) Use Fig. 16.2 to determine the force constant k in N m^{-1} of the cable.

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

(c)

Determine the breaking stress σ of the cable.
Assume that the cross-sectional area of the cable remains constant during the test.

σ = ... Pa **[2]**

(d)

Explain why the work done on the cable when its extension changes from 3.0 mm to 4.0 mm is greater than when its extension changes from 1.0 mm to 2.0 mm.

[2]

20(a) **Fig. 3.1** shows an experiment to investigate the extension of two identical springs connected side by side. A student uses a 30 cm ruler to measure the length L_0 of the two-spring combination without a load attached.

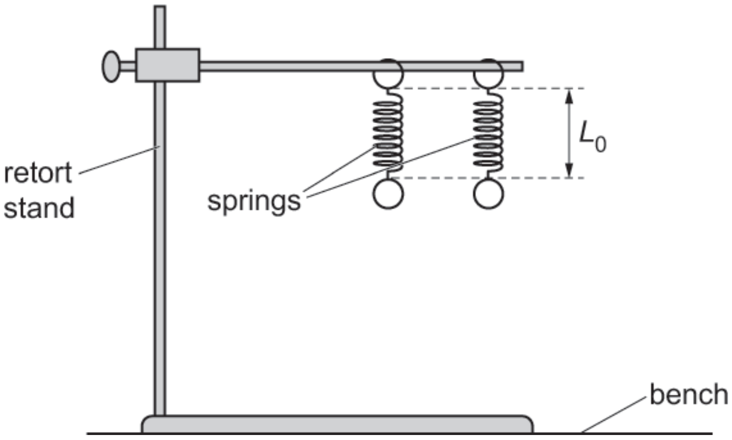


Fig. 3.1

The student then adds a rod and a mass *M* to the spring combination as shown in **Fig. 3.2**.

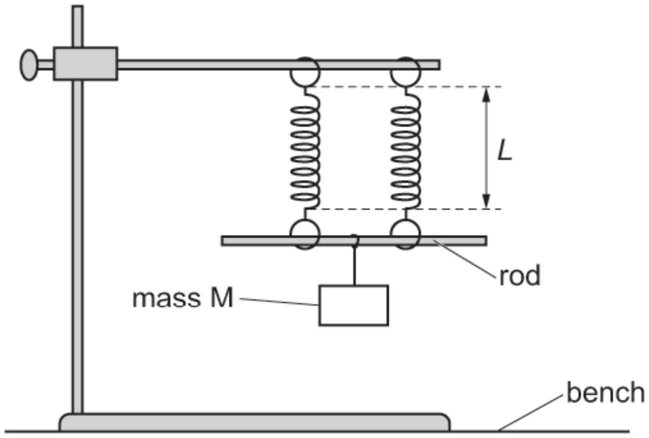
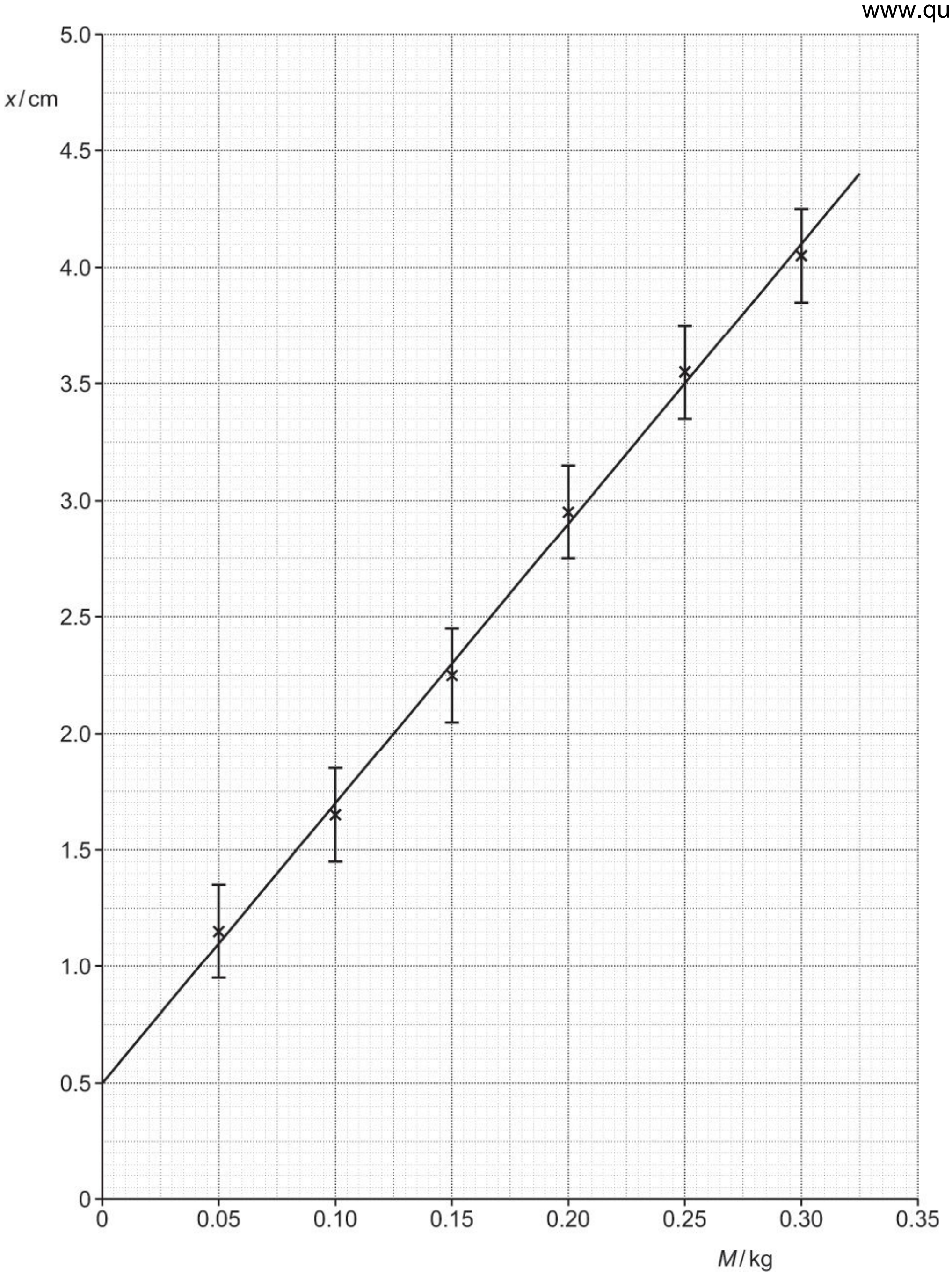


Fig. 3.2

The student then repeats the experiment for different values of *M*. For each value of *M*, the student determines the extension *x* of the spring combination and the absolute uncertainty in *x*.

The student plots a graph of extension *x* (*y*-axis) against mass *M* (*x*-axis) including error bars in *x*. The straight line of best fit is drawn.



It is suggested that the relationship between x and M is

$$x = \frac{Mg}{k} + R$$

where k is the force constant of the spring combination, g is the acceleration of free fall and R is a constant.

(i) Show that the gradient of the straight line of best fit is about 0.12 m kg^{-1}.

[2]

(ii) Using the gradient, determine a value for *k*.
Give your answer to an appropriate number of significant figures and include an appropriate unit.

k = ... unit .... **[2]**

(b)

(i) Draw a worst acceptable straight line.

[1]

(ii) Determine the gradient of your worst acceptable line.

gradient of worst acceptable line = ... m kg^{-1} **[1]**

(iii) Determine the percentage uncertainty in *k*.

percentage uncertainty = ... % **[2]**

21 Which pair of quantities have the same S.I. base units?

A force, strain
B force, stress
C pressure, stress
D strain, upthrust

Your answer [1]

22 A spring is stretched by hanging on it a variable mass *m*. The mass *m* is always at rest. The spring obeys Hooke's law.

What is the relationship between the elastic potential energy *E* in the spring and the mass *m*?

A $E \propto m^{-1}$
B $E \propto m^{-2}$
C $E \propto m$
D $E \propto m^{2}$

Your answer [1]

23
The Young modulus E of a metal can be determined using the expression $E = \frac{4F}{\varepsilon \pi d^2}$, where F is the tension in the wire, d is the diameter of the wire and ε is the strain of the wire.

Here is some data.

Quantity	Percentage uncertainty
F	5.3
ε	1.2
D	1.0

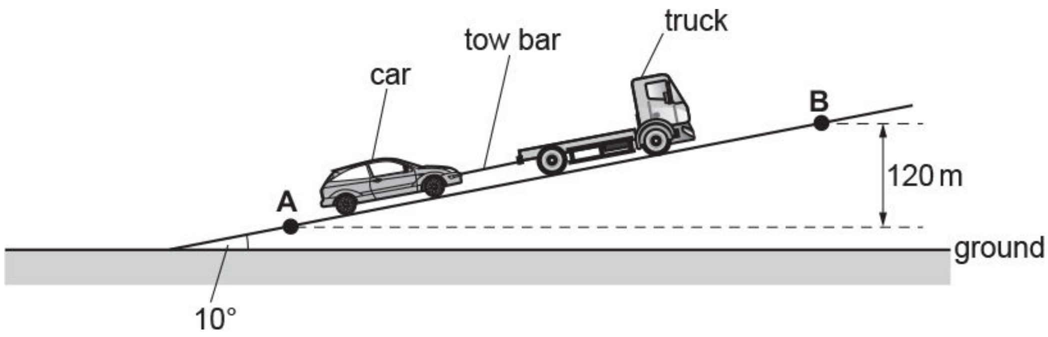
What is the percentage uncertainty in the calculated value of E?

A 2.1 %
B 6.4 %
C 7.5 %
D 8.5 %

Your answer **[1]**

24(a) A truck pulls a car up a slope at a **constant** speed.

The truck and the car are joined with a steel tow bar, as shown in the diagram.



The diagram is **not** drawn to scale.

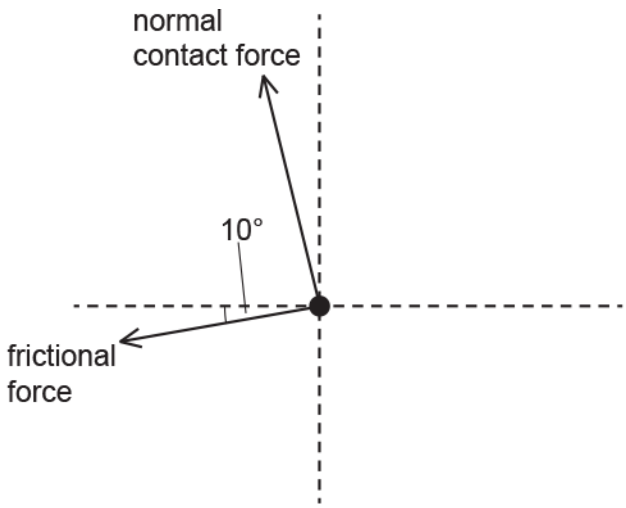
The slope is 10° to the horizontal ground.

The mass of the car is 1100 kg.

The car travels from **A** to **B** . The vertical distance between **A** and **B** is 120 m.

There are four forces acting on the **car** travelling up the slope.

Complete the free-body diagram below for the car and label the missing forces.



[2]

(b) Show that the component of the weight of the car *W*s acting down the slope is about 1900 N.

[1]

(c) The total frictional force acting on the car as it travels up the slope is 300 N.

Calculate the force provided by the tow bar on the car.

force = ... N **[1]**

(d) Calculate the work done by the force provided by the tow bar as the car travels from **A** to **B** .

work done = ... J **[3]**

(e) The steel tow bar used to pull the car has length 0.50 m and diameter 1.2×10^{-2} m.
The Young modulus of steel is 2.0×10^{11} Pa.
The force on the tow bar is 2200 N.

Calculate the extension *x* of the tow bar as the car travels up the slope.

x = ... m **[3]**

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			C	1	
			Total	1	
2	a		*** Level 3 (5–6 marks)** All points E1, 2, 3 and 4 for equipment All points M1, 2, 3 and 4 for measurements For calculations expect C1, C2, C3 and C4 Expect at least two points from reliability *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect E1 and E2; E3 or E4 for equipment Expect M2 and two from M1, M3, M4 for measurements For calculations expect at least C3 and C4 Expect at least one point from reliability *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect at least E1 and E2 for equipment Expect at least two from measurements Expect C5 for the calculation No real ideas for obtaining reliable results *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	B1 × 6	The complete plan consists of four parts: Equipment used safety (E) 1 Wire fixed at one end with load added to wire. 2 Suitable scale with suitable marker on wire. 3 Micrometer screw-gauge **or** digital / vernier callipers for measuring diameter of wire. 4 Reference to safety concerning wire snapping. Measurements (M) 1 Original length from fixed end to marker on wire. 2 Diameter of wire. 3 Measure load. 4 New length of wire when load increased. Calculation of Young modulus. (C) 1 Find extension (for each load) or strain (for each load). 2 Determine cross-sectional area or stress. 3 Plot graph of load-extension **or** graph of stress-strain. 4 Young modulus = gradient × original length / area **or** Young modulus = gradient. 5 Calculate Young modulus from single set of measurements of load, extension, area and length. Reliability of results (R) 1 Measure diameter in 3 or more places and take average. 2 Put on initial load to tension wire and take up ‘slack’ before measuring original length. 3 Take measurements of extension

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					while unloading to check elastic limit has not been exceeded. 4 Use long wire (to give measurable extension). Scale or ruler parallel to wire.
	b	i	Elastic: material returns to original dimensions when load is removed.	B1	
		i	Plastic: material has permanent change of shape when load is removed.		
		ii	The material is elastic because the removal of force returns the rubber to its original length.	B1	
		ii	The area under force-extension graph is work done.	B1	
		ii	Repeated stretching and releasing the rubber warms up the rubber because not all the strain energy is returned back. The area enclosed represents the amount of thermal energy. During landing, some of the aeroplane's kinetic energy is transferred to thermal energy and therefore the aeroplane does not "bounce" during landing; hence this minimises the risk to passengers.	B1	Mentioning 'hysteresis' is not enough to gain this mark.
			Total	10	
3			D	1	
			Total	1	
4			A	1	
			Total	1	
5			C	1	
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
6	a	i	a = (–) $4\pi^2f^2x$ = 4 × 9.87 × 4900 × 0.004	C1	**allow** 774 (m s^{-2})
		i	a = 770 (m s^{-2})	A1	
		ii	**1** sketch showing one wavelength and 140 (Hz)	B1	both sketch and value required for 1 mark
		ii	**2** driving force is around nodal point / AW;	B1	**max** 3 of the 4 marking points
		ii	points either side of nodal point try to move in opposite directions when force in one direction / AW;	B1	
		ii	move magnet to antinodal point; ¼ of distance between clamps	B1	**not** increase current
	b	i	*f α* √T so f = 70/√2 = 49 or 50 Hz	B1	
		ii	**1** μ increases / goes up by 0.4%	B1	**allow** +0.4% NOT 0.4%
		ii	**2** 0.2%,	B1	**or** half of answer to **(ii)1**
		ii	f is lower because μ is bigger and μ is on the bottom of the formula	B1	**or** greater inertia present with same restoring force / other physical argument
			Total	10	
7			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
8	a		The extension of each spring is halved because the force in each spring is halved. (Hence the force constant is *2k*.)	B1	**Allow** F = kx, x is halved for the same F, hence k doubles.
	b	i	Missing data point and error bar plotted correctly.	B1	**Allow** ½ square tolerance.
		ii	Force measured by pulling back plate with a newton–meter.	B1	
		ii	Extension measured with a ruler (placed close to the transparent plastic tube).	B1	
		iii	Best fit line drawn correctly and gradient determined correctly.	B1	**Ignore** POT for this mark; gradient = 50 ± 4 (N m^{-1})
		iii	Worst fit line drawn correctly and its gradient determined correctly.	B1	**Note**: The line must have a greater/smaller gradient than the best fit line and must pass through all the error bars. **Ignore** POT for this mark.
		iii	$2k$ = 50 (N m^{-1}), therefore k = 25 (N m^{-1})	B1	Possible ECF.
		iii	Absolute uncertainty determined correctly.	B1	Possible ECF within calculation.
		iv	$F \propto x$ / straight line passing through the origin.	B1	
		v	energy stored = ½ × 50 × 0.12^2	C1	Possible ECF from **(iii)**
		v	½ × 50 × 0.12^2 = ½ × 0.39 × v^2	C1	**Allow** 1 mark for v = 0.96 m s^{-1}; used k for single spring
		v	v = 1.4 (m s^{-1})	A1	
	c		force constant of spring arrangement) = $\frac{2k}{3}$ $\frac{2k}{3}x = ma$	M1	
			$a = \frac{2}{3 \times 0.39}kx$	M1	
			a = 1.7 kx	A0	
			Total	**14**	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9		i	(Sum of clockwise moments = sum of anticlockwise moments) 95 × 9.81 × 1.80 / 120 × 9.81 × 1.00 / 1.60 × *T* sin 30°	C1	
		i	(95 × 9.81 × 1.80) + (120 × 9.81 × 1.00) = 1.60 × *T* sin30°	C1	
		i	$T = 3.6 \times 10^3$ (N)	A1	**Note** answer to 3 s.f. is 3.57×10^3 (N)
		ii	$\sigma = \frac{3.6 \times 10^3}{\pi \times 0.015^2}$	C1	Possible ECF from part **(i)**
		ii	$\sigma = 5.1 \times 10^3$ (kPa)	A1	**Allow** 1 mark for 5.1×10^6; POT error **Note** using 3.57×10^3 N gives 5.05×10^3 (kPa)
		iii	The clockwise moment increases and therefore *T* increases.	B1	
			Total	6	
10		i	$a = 4\pi^2 f^2 \times$	C1	condition for SHM
		i	so $k = (m4\pi^2 f^2) = 1.7 \times 10^{-27} \times 4 \times 9.87 \times 43.7 \times 10^{26}$	B1	substitution
		i	$k = 292$ (N m^{-1})	A1	**ecf** if incorrect mass used
		ii	(N2 gives) $F_H = m_H a_H$ and $F_I = m_I a_I$	B1	**allow** total momentum = 0 at all times
		ii	(N3 gives) $F_H = F_I$ *can be implicit*	B1	SHM gives $v = 2\pi f x_{max}$
		ii	SHM gives $a \propto (-)x$	B1	so $m_H X_H = m_I x_I$
		ii	hence $x_H/x_I = a_H/a_I = m_I/m_H = 127$	B1	**accept** $127 = x_H/x_I \approx 10/0.08 = 125$
			Total	7	
11			B	1	**Examiner's Comments** This question was slightly more challenging.
			Total	1	
12			B	1	**Examiner's Comments** This question proved particularly straightforward and accessible to nearly all candidates.
			Total	1	

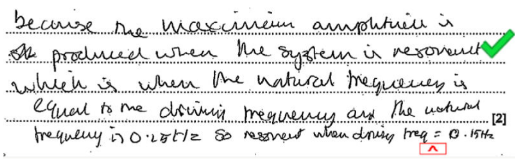
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13			A	1	Examiner's Comments This question proved particularly straightforward and accessible to nearly all candidates.
			Total	1	

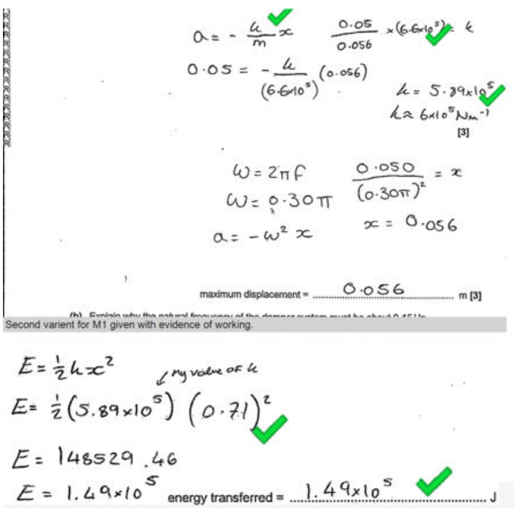
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14	a		arrow down through centre of ball labeled weight **or** W **or** mg **or** 1.2 N	B1	zero if any other arrows or forces present **Examiner's Comments** There were some carelessly drawn arrows on the diagram but otherwise this was done well. There were some arrows labelled *centripetal force.*
	b	i	(horizontally) mv^2/r (**or** $mr\omega^2$) = T sin θ **and** (vertically) W **or** mg = T cos θ (tan θ = v^2/rg **or** rw^2/g) tan θ = 0.045 × 4 × 9.87 × 2.2 / 9.81 **or** 0.48 / 1.2 (= 0.40) θ = 22°	M1 A1 A0	**accept** figures in place of algebra, r = 0.045 m v = 0.42 m s^{-1} ω = 3π rad s^{-1}; $r\omega^2$ = 4.0 m s^{-2} ; W = 1.2 N and m = 0.12 kg and $mr\omega^2$ = 0.48 N **accept** labelled triangle of forces diagram **N.B.** this is a *show that Q* ; sufficient calculation must be present to indicate that the candidate has not worked back from the answer
		ii	k = (mg / x_0 = 1.2 / 0.050) = 24 (N m^{-1}) (T = mg / cos θ = kx giving) x = 1.2 / 24 cos 22 x = 0.054 (m)	C1 C1 A1	**or** solution by ratios **Examiner's Comments** About half of the candidates completed the angle calculation successfully with a slightly smaller number finding the correct extension of the string.
	c		(y = ½gt^2 =) 0.18 = 0.5 × 9.81 × t^2 giving t = 0.19 (s) (x = vt =) 0.42 × 0.19 = 0.08 (m) distance = $\sqrt{(r^2 + x^2)}$ = √(0.0020 + 0.0064) = 0.092 (m)	C1 C1 C1 A1	**alt:** projectile motion: x = vt, y = ½gt^2 y = ½g$(x / v)^2$ **ecf (b)i** for v; $x^2 = 2yv^2/g$ = 2 × 0.18 × 0.42^2/9.81 **Examiner's Comments** About half of the candidates found the time for the ball to fall to the bench. Most then managed to find the horizontal distance from the point of release, but half forgot that the point of reference in the question was the centre of rotation so failing to complete the calculation.

Question			Answer/Indicative content	Marks	Guidance
	d		T increases **or** string stretches **or** angle θ increases to provide / create a larger centripetal force	M1 A1	**allow** mv^2/r **or** $mr\omega^2$ in place of *centripetal force* causality must be implied to gain the A mark **Examiner's Comments** About half of the candidates appreciated that the tension in the string increased or that the angle of the string to the vertical increased. Most answers gave the impression that the *centripetal force* was a *real* force rather than its provision being necessary for the ball to follow a circular path
			Total	12	
15			C	1	
			Total	1	
16			D	1	**Examiner's Comments** The tension for both wires is the same, yet wire X has half of the cross-sectional area. This means the stress for X will be twice that of Y. Strain = stress/Young modulus, so with half of the stress and (120/200) of the Young modulus, the strain for X will be 2 × (200/120) or times that of the strain for Y. The original lengths for X and Y are the same, so the extension of X will be 3.3 times that of Y.
			Total	1	

Question			Answer/Indicative content	Marks	Guidance
17	a		Maximum energy is transferred between tower (driver) and sphere when sphere (driven) is at/close to the natural frequency <u>of the tower</u> **or** in this forced oscillation/resonance situation	B1 B1	**allow** causes maximum damping <u>of the tower</u> **or** maximum amplitude <u>of the sphere/</u>AW **allow** AW e.g. sphere must be driven close to/at the natural/resonance frequency <u>of the tower</u> <u>Examiner's Comments</u> The answers gave a clear indication as to how well the candidates understood a resonance situation. Many omitted to explain which of the three oscillating elements were acting as drivers and which were driven. The candidate who wrote the answer (exemplar 3) shown here has some understanding of the situation but has failed to communicate it clearly to the reader. **Exemplar 3**  The ball was often quoted as just acting against the tower to reduce the amplitude rather than using the clue at the end of the initial paragraph about the energy drawn from the tower being absorbed by the dampers. Hence the requirement for the ball to be given a large amplitude or absorb the maximum amount of energy.
	b	i	$\omega^2 = k/m$ **or** $(2\pi f)^2 = k/m$ **or** $kA = ma_{max}$ $k =(m4\pi^2f^2)= 6.6 \times 10^5 \times (2\pi \times 0.15)^2$ **or** $(k= ma_{max}/A) = 6.6 \times 10^5 \times 0.05/0.056$ $k = 5.9 \times 10^5$ (N m^{-1})	C1 M1 A1	 **allow** ω or ω^2 = 0.88 or 0.89 quoted from **(a)** **ecf** value of A from **(a)** as this is a 'show that' question some definite evidence of working must be shown. **not** $k = 6 \times 10^5$ **allow** answer to 2 or more SF.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$E = ½kA^2 = = 0.5 × 5.9 × 10^5 × 0.71^2$ $E = 1.5 × 10^5$ (J)	C1 A1	**allow** value from (c)**(i)** or 6; **or** a = (k/m)A , F = ma, E = ½F*A* **accept** 1.48 to 1.51 or value from **ecf** **special case:** give 1/2 for $E = 3(.0) × 10^5$ (J) where **it is clear that** 2k has been used as the spring constant **Examiner's Comments** The exercise in this section completed successfully by most candidates was to perform standard calculations stating correct formulae and showing clear working to determine the required quantities. The example (exemplar 4) shown here is of a typical neat script. The most common error was to forget to square quantities in part (ii) or to use the amplitude calculated part (a) rather than the figure given in the stem of this part. **Exemplar 4** 
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18			D	1	Examiner's Comments The Young modulus is found by calculating the initial gradient of the material's stress-strain graph. The initial portion appears to be a straight line from the origin to the point (0.1, 120). The units on this graph are megapascals and %. This means the co-ordinates of the chosen point are in fact (0.1×10^{-2}, 120×10^{6}). Many candidates forgot to convert the strain into a decimal and left it as a percentage. Their answer was a factor of a 100 out, ie answer B. The correct answer is 120×10^{6} / 0.1×10^{2} = 1.2×10^{11} Pa. This is answer D.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a		The **maximum** (tensile) **stress** a material can withstand (before it breaks)	B1	<u>Examiner's Comments</u> Ultimate tensile strength is the maximum stress a material can withstand without breaking or failing. The most common incorrect answer included descriptions of force rather than stress.
	b	i	Use a micrometer / (Vernier) caliper Measure the diameter along its length in different directions (to ensure uniform cross-section) AW	B1 B1	 **Allow** either along length or in different directions
		ii	**1.** Any value between 0 and 2.0 (kN) **2.** Any value between 2.0 and 2.2 (kN)	B1 B1	
		iii	k = gradient $k = 5.0 \times 10^5$ (N m^{-1})	C1 A1	 **Allow** 1 mark for 5.0×10^n; $n \neq 5$ **Allow** 5 x 105 (N m^{-1})
	c		(A =) $\pi \times 0.0021^2$ or 1.39×10^{-5} (m^2) (σ) = $2200 / \pi \times 0.0021^2$ σ = 1.6 π 10^8 (Pa)	C1 A1	 **Allow** 1 marks for $4(.0) \times 10^7$; diameter used as radius Answer is 1.59×10^8 Pa to 3sf

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		Greater area under the graph (from 3 mm to 4 mm) / greater **average** force from (3 mm to 4 mm)	B1	ORA **Allow**: labelled/annotated diagram
			Mention of work done = **average** force x distance or work done = area under graph	B1	**Allow** energy (transferred) instead of work done **Allow** 2 marks for arguments including reference to W = ½ kx^2 **and** constant k **and** greater average x **<u>Examiner's Comments</u>** This question is best answered by referring to the graph in the question. Exemplars 1 and 2 indicate the difference between a low level and a high level response. **Exemplar 1** Work is the force aplied over a distance. If initial distance is larger then the work will be larger. [2] This exemplar shows a response that contains broadly true statements yet is only loosely linked to the context and so scored zero marks. **Exemplar 2** work done is equal to the area under the force extension graph and this area is larger for the area between 3 + 4 mm than 1 + 2 mm [2] This response is clearly and specifically about this context and uses the graph as supporting evidence. The link to the graph is that the area gives the work done and that a larger area for one region means a larger amount of work done for that region.
			Total	11	

Question			Answer/Indicative content	Marks	Guidance
20	a	i	points on the line read to the nearest half square size of triangle is greater than half the length of the drawn line and Δ*y* / Δ*x*	B1 B1	**Allow** Δ*y* for $y_2 - y_1$ and Δ*x* for $x_2 - x_1$ Δ*x* ≥ 0.1625
		ii	$\left(\frac{9.81}{0.12}\right) = 81.75$ 82 N m^{-1} given to 2 or 3 significant figures	C1 A1	**Allow** ECF from (a)(i) **Allow** 81.8 N m^{-1} **Note** POT must be correct for given unit **Allow** kg s^{-2}
	b	i	steepest or shallowest line that passes through all the error bars	B1	
		ii	gradient determined: 0.10 m kg^{-1} or 0.13 m kg^{-1}	B1	**Allow ECF** from (b)(i)
		iii	Δgradient (0.13 - 0.12 or 0.12 - 0.10) $\frac{\Delta\text{gradient}}{\text{gradient}} \times 100 = 8.3\%$ or 17% OR Δ*k* (82 – 75 or 98-82) $\frac{\Delta k}{k} \times 100 = 8.5\%$ or 20%	C1 A1 C1 A1	**Allow ECF** from (b)(i) and (ii) **Not** 10% without justification <u>Examiner's Comments</u> In this question, most candidates clearly identified the points on the line that were to be used for the gradient calculation. High achieving candidates clearly showed their working when determining the percentage uncertainty.
			Total	**8**	
21			C	1	
			Total	**1**	
22			D	1	
			Total	**1**	
23			D	1	
			Total	**1**	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a		Arrow vertical down <u>and</u> an arrow opposite to the frictional force. Both arrows labelled correctly.	M1 A1	 **Allow** weight / *mg* / W for the downward arrow <u>and</u> tension / *T* / 'force in rod' / 'force in tow bar' /'driving force' for the 'upward' arrow
	b		(W_s =) 1100 × 9.81 × sin 10° **or** 1100 × 9.81 × cos 80° (W_s = 1874 N or 1900 N)	C1 A0	**Allow** *g* instead of value
	c		force = 1900 + 300 force = 2200 (N)	A1	**Allow** 1870 + 300 = 2170 (N)
	d		(distance =) 120 / sin 10° **or** 691 (m) (work done =) 2200 × 691 work done = 1.5 × 10^6 (J)	C1 C1 A1	 **Allow** ECF from **(c)** **Allow** ECF from an incorrect attempt at first mark.
	e		(*A* =) π × 0.006^2 **or** 1.1 × 10^{-4} (m^2) (stress =) $\frac{2200}{\pi \times 0.006^2}$ <u>and</u> $2.0 \times 10^{11} = \frac{\text{stress}}{\text{strain}}$ x = 4.8 × 10^{-5} (m)	C1 C1 A1	 **Allow** ECF from **(c)** **Allow** $x\ (=FL/EA) = \frac{2174 \times 0.5}{2.0 \times 10^{11} \times 1.1 \times 10^{-4}}$ **Allow** 2 marks for 1.2 × 10^{-5}; 1.2 × 10^{-2} m used as radius **Allow** answer between 4.7 and 5.1 × 10^{-5} (m)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	10	