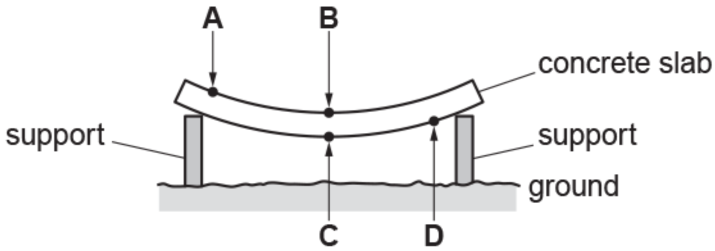
Materials

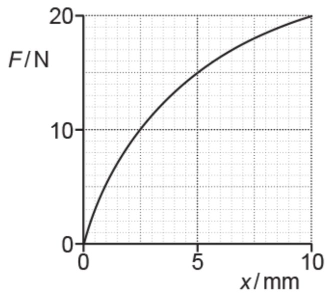
1. A uniform concrete slab is placed on two supports. The slab sags due to its own weight.



Which point, **A**, **B**, **C** or **D**, of the slab is under maximum compression?

Your answer [1]

2. The force F against extension x graph for a material being stretched is shown.



What is best estimate for the energy stored in the material when the extension is 10 mm?

A 0.07 J
B 0.10 J
C 0.13 J
D 0.20 J

Your answer [1]

3. 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]**

4. 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]

5. 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]**

6. Archimedes' principle is written below with one word missing.

The upthrust acting on an object in a fluid is equal to the ___________ of the fluid displaced.

What is the missing word?

A density
B mass
C volume
D weight

Your answer [ ] **[1]**

7. A student investigated four different springs **A, B, C** and **D**.
A mass of different weight is hung from each spring and the extensions are measured.

The results are shown in the table below.

	Weight hung from spring / N	**Extension of spring / cm**
A	2.0	5.2
B	4.0	4.6
C	6.0	3.5
D	8.0	1.5

All of the springs obey Hooke's law.

Which spring has the **largest** elastic potential energy?

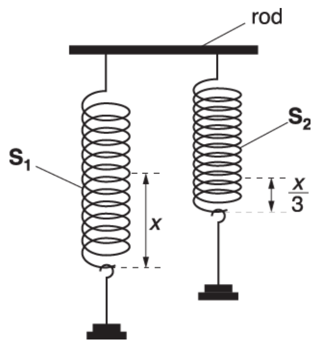
Your answer [ ] **[1]**

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

A strain, elastic potential energy
B strain, force constant
C stress, force constant
D stress, Young modulus

Your answer [ ] **[1]**

9. The top ends of two springs, $\mathbf{S_1}$ and $\mathbf{S_2}$, are attached to a rod.



A mass is hung from the bottom end of $\mathbf{S_1}$. The extension of $\mathbf{S_1}$ is x. The elastic potential energy in the spring is E. The same mass is hung from the bottom end of $\mathbf{S_2}$. The extension of $\mathbf{S_2}$ is $\frac{x}{3}$.

What is the elastic potential energy in the spring $\mathbf{S_2}$?

A $\frac{E}{9}$

B $\frac{E}{3}$

C $3E$

D $9E$

Your answer

[1]

10. 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]**

11. Two guitar strings of equal length, but of different thickness, are under the same tension. The strings are made of the same material.

The thinner string has a diameter of 0.20 mm and the thicker string has a diameter of 0.80 mm.

What is the value of the ratio $\frac{\text{elastic potential energy in the thinner string}}{\text{elastic potential energy in the thicker string}}$?

A 0.125
B 0.25
C 4.0
D 16

Your answer ☐

[1]

12. A student is recording results in a table.
The calculated value for the stress in a wire is 7 260 000 Pa.

Which of the following is correct for the heading in the student's table and the value of the stress written to **2** significant figures?

	Heading in table	Value of stress
A	stress / Pa	7 200 000
B	stress / kPa	730
C	stress / MPa	7.2
D	stress/10^6 Pa	7.3

Your answer ☐ **[1]**

13. The extension of a metal wire is *x* when the tension in the wire is *F*. The table in **Fig. 23.1** shows the results from an experiment, including the stress and the strain values.

F / N	*x* / 10^{-3} m	stress / 10^7 Pa	strain / 10^{-3}
1.9	0.4	1.73	0.20
4.0	0.8	3.50	0.40
5.9	1.2	5.21	0.60
8.0		7.00	0.80
9.0	1.8	7.95	0.90

Fig. 23.1

Complete the table by determining the extension when the tension is 8.0 N.

[1]

14. Explain what is meant by the **ultimate tensile strength** of a material.

[1]

15. One end of a wire is fixed to the ceiling and a 3.0 kg object is suspended from its other end. The wire has diameter 0.62 mm and negligible mass.

What is the tensile stress in the wire?

A 1.5×10^4Pa
B 2.5×10^6Pa
C 2.4×10^7Pa
D 9.7×10^7Pa

Your answer **[1]**

16(a). Fig. 2.1 shows an experiment in the laboratory to investigate the extension of two identical springs connected end to end. A student initially measures the length *L* of the two-spring combination without a load attached.

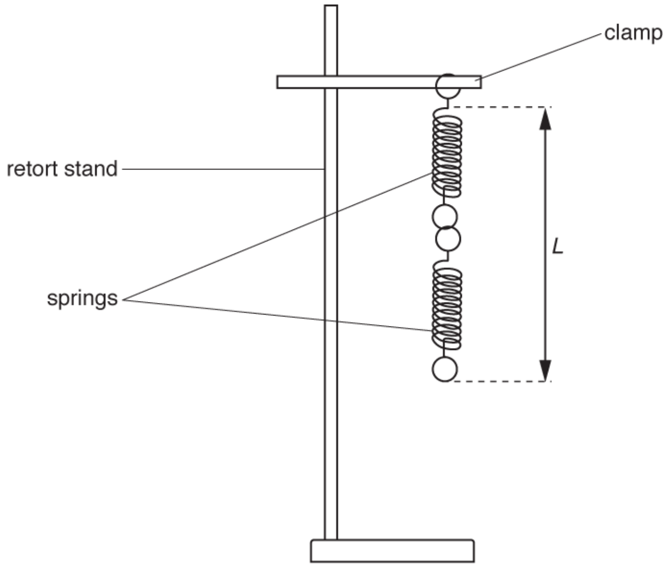


Fig. 2.1

The student adds mass *m* to the lower spring and measures the new length *L* of the two-spring combination.

The student determines the weight *F* of the mass added to the spring.

The student's results are shown in Fig. 2.2.

m/g	*F*/N	*L*/cm	
0	0	12.0	
50	0.49	13.0	
100	0.98	13.8	
150	1.47	14.8	2.8
200	1.96	15.6	3.6
250	2.45	16.6	4.6

Fig. 2.2

Complete the table shown in Fig. 2.2 by calculating and recording values of the extension *e* / cm of the spring combination.

[1]

(b). On Fig. 2.3 plot a graph of *e* / cm (*y*-axis) against *F* / N (*x*-axis). Draw the straight line of best fit.

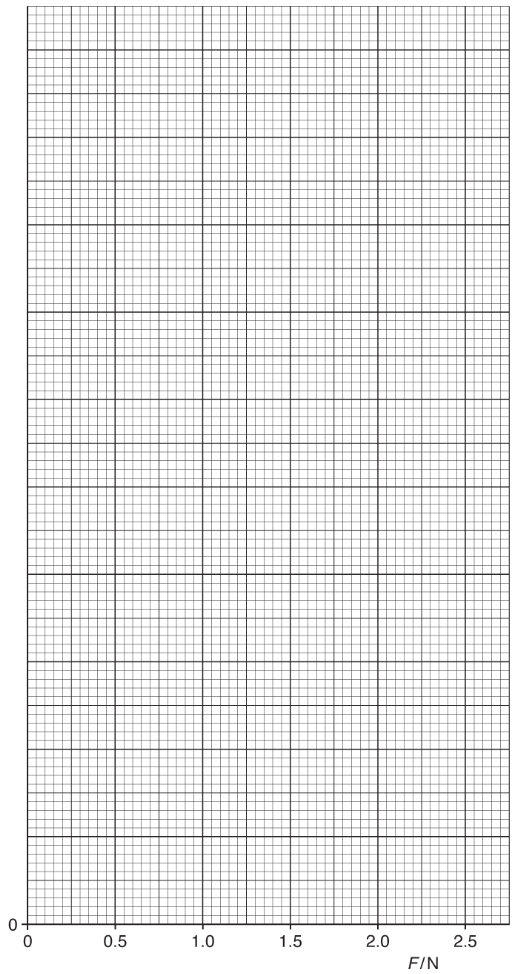


Fig. 2.3. **[4]**

(c). Determine the gradient of the straight line of best fit.

gradient = ... **[1]**

(d). Use your answer to **(c)** to determine the experimental value for the force constant k_2 of the two-spring combination. Include an appropriate unit.

k_2 = ... **[2]**

(e). State and explain whether your graph shows that the spring combination obeys Hooke's law.

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[2]

(f). The experiment is repeated with a third identical spring added to the bottom of the two springs. The force constant of this new three-spring combination is k_3.

Determine the ratio

$$\frac{k_3}{k_2}.$$

$\frac{k_3}{k_2}$ = ... **[2]**

17 (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

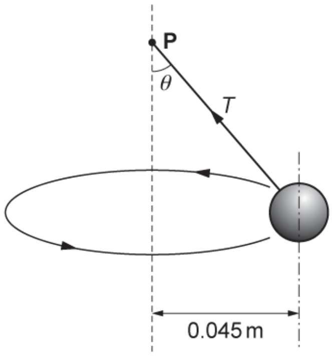

Fig. 6.2 (not to scale)

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).

Resolve the tension T horizontally and vertically and show that the angle θ is 22°.

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[2]

i. 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.

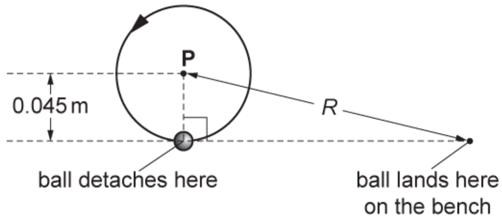

Fig. 6.3

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.

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[2]

18. 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]**

19. The ball-release mechanism of a pinball machine is shown in Fig. 17.1.

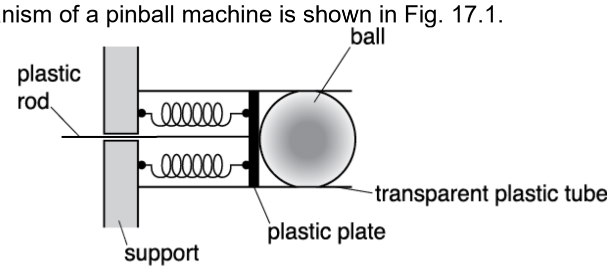

Fig. 17.1

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.*

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[1]

20. 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?

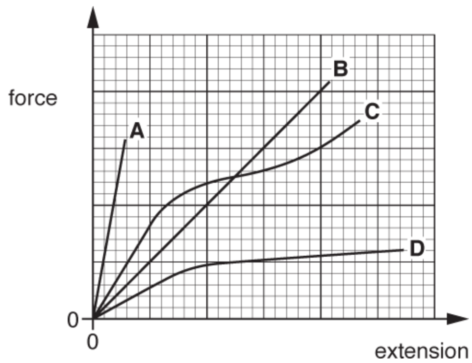
1 Young modulus is equal to the gradient of the stress against strain graph.
2 Force constant is equal to the gradient of the force against extension graph.
3 The graphs of stress against strain have different gradients.

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

Your answer

[1]

21. 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.

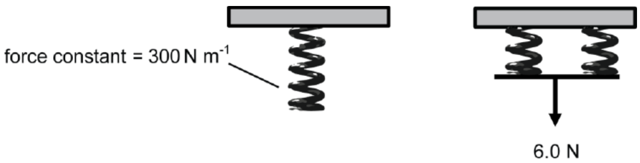


Which material is brittle and has the greatest ultimate tensile strength?

Your answer

[1]

22. 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.



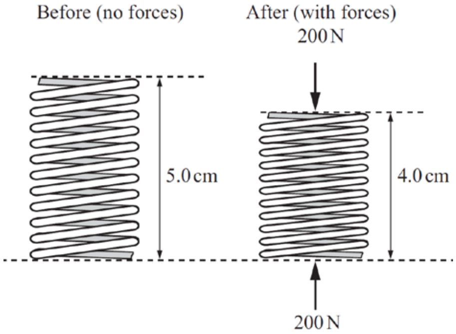
What is the extension of each spring?

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

Your answer

[1]

23. A compression spring is being tested in an engineering laboratory. The diagram shows the spring before and after the forces are applied to its opposite ends.



The initial length of the spring is 5.0 cm and during the application of the forces its length is 4.0 cm.

What is the force constant of this spring?

A. 4.0×10^3 N m^{-1}
B. 5.0×10^3 N m^{-1}
C. 2.0×10^4 N m^{-1}
D. 4.0×10^4 N m^{-1}

Your answer ☐

[1]

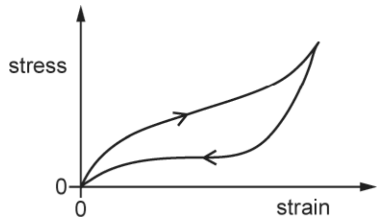
24. A 0.30 kg mass is hung from a spring. The length of the spring is now 16.0 cm.
The length of the spring becomes 17.5 cm when an **additional** 0.20 kg mass is hung from the spring. The spring obeys Hooke's law.

What is the force constant of the spring?

A 11 N m^{-1}
B 12 N m^{-1}
C 130 N m^{-1}
D 330 N m^{-1}

Your answer ☐ **[1]**

25. The stress against strain graph for a particular material is shown below.

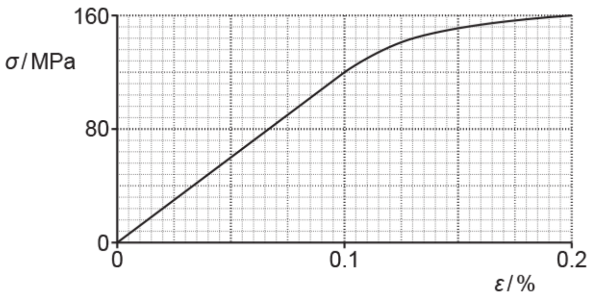


Which term is correct for a property of this material?

A brittle
B ductile
C elastic
D plastic

Your answer [1]

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

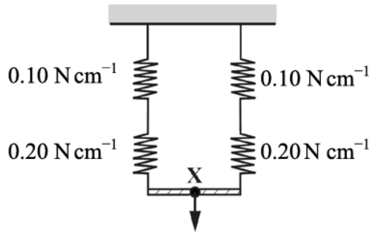


What is the Young modulus of the material?

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]

27. 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.



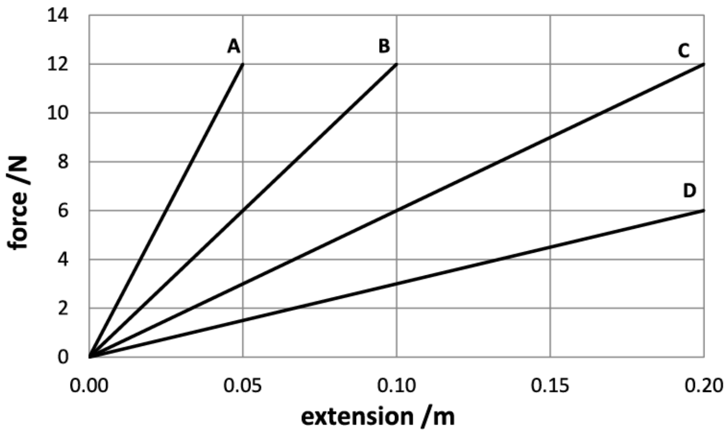
What distance does the point **X** move down when the 0.60 N force is applied?

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

Your answer

[1]

28. The force constant of a spring **X** is 1.2 N cm^{-1}.
The force-extension graphs for four different springs **A, B, C** and **D** are shown below.

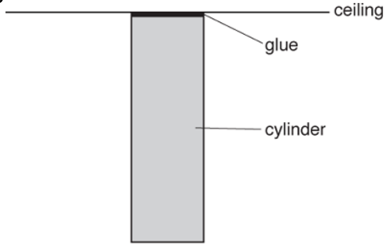


Which spring has a force constant equal to half that of spring **X**?

Your answer

[1]

29. 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]**

30. 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

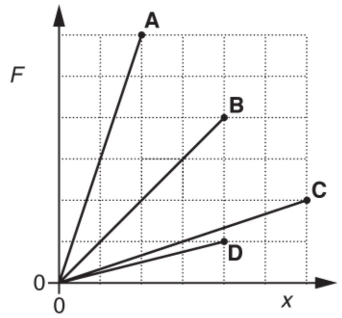
B 0.14 J

C 2.4 J

D 14 J

Your answer **[1]**

31. The force *F* against extension *x* graphs for four different wires **A**, **B**, **C** and **D** up to their breaking points are shown below.



Which wire has the greatest work done on it before it breaks?

Your answer **[1]**

32. 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]

33. 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]

34. Determine the breaking stress σ of a cable with cross-sectional radius 21mm when a force of 2.2kN is applied.
Assume that the cross-sectional area of the cable remains constant during the test.

σ = ... Pa **[2]**

35 (a). A spring of negligible mass and natural length 20 cm has a 0.60 kg mass attached. The mass-spring system oscillates for a short time and then settles in an equilibrium position (Fig. 21).

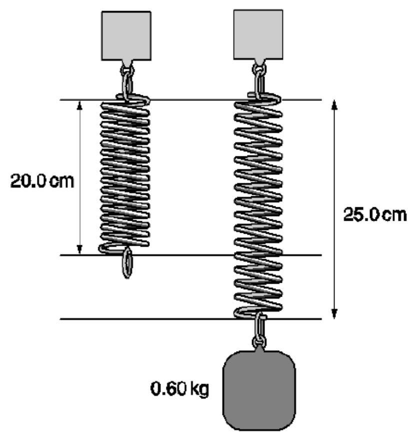


Fig. 21

Calculate the change in gravitational potential energy E_p of the mass when it finally comes to rest in its equilibrium position with length of 25.0 cm.

E_p = ... J **[1]**

(b). Show that the elastic potential energy in the stretched spring in its equilibrium position is 0.15 J.

[2]

(c). A student compares the values calculated in **(a)** and **(b)** and concludes that "energy has not been conserved". State the energy transfers that occur as the spring oscillates and comes to rest and explain why the student is wrong.

[3]

36. 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.

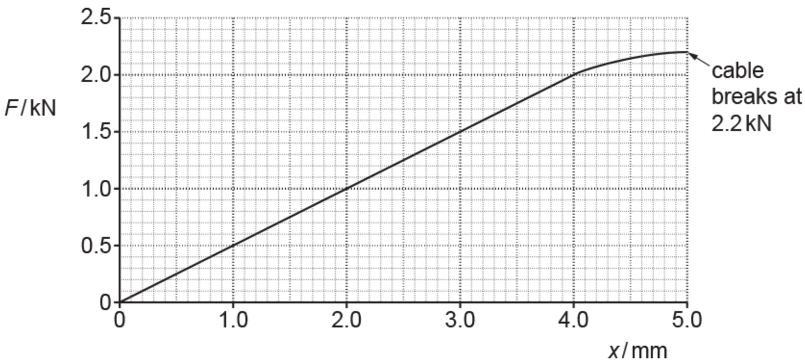


Fig. 16.2

The cable breaks when the force is 2.2 kN.
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]

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

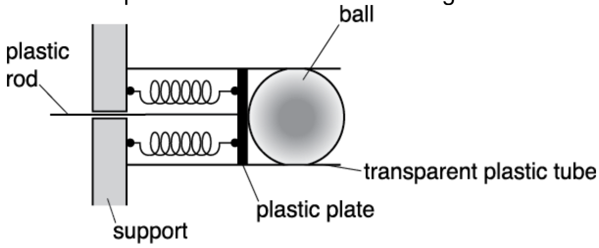


Fig. 17.1

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.

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.

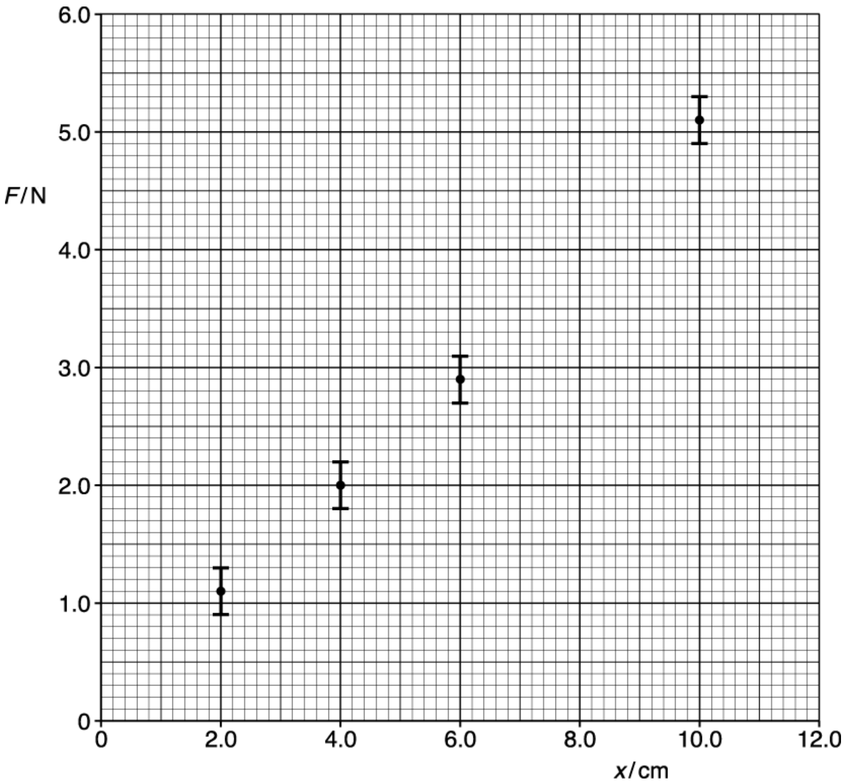


Fig. 17.2

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]**

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

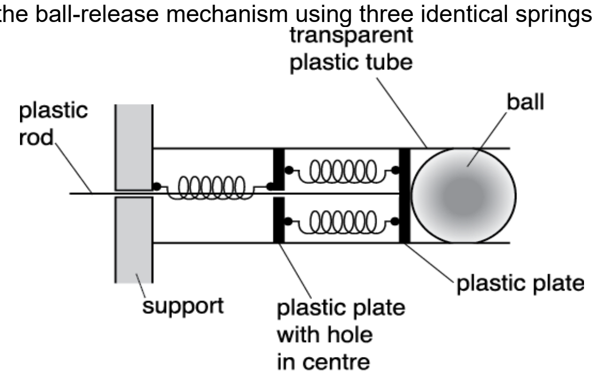


Fig. 17.3

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]

38. A group of students are investigating the loading and unloading of glass and rubber. Glass is a brittle material and rubber is a polymeric material.

Sketch the stress against strain graphs for the loading and unloading of glass and rubber on **Fig. 6**.

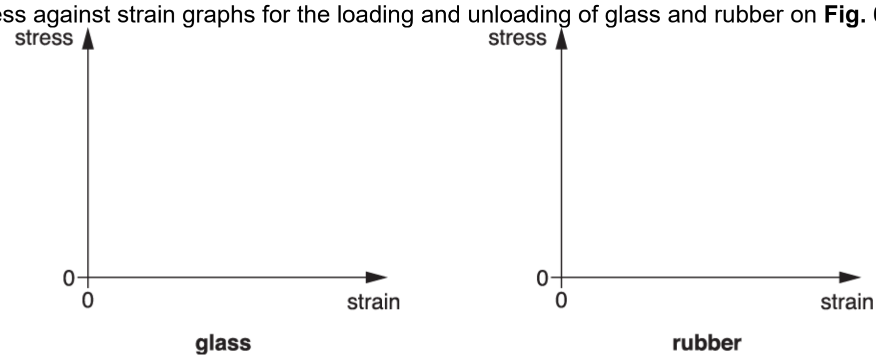


Fig. 6

[2]

39. 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.

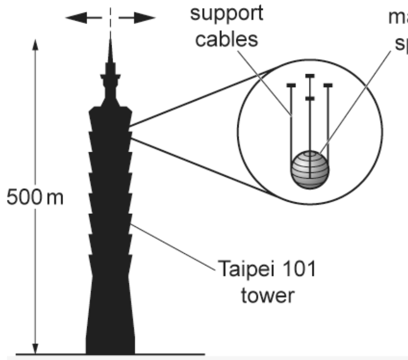


Fig. 2.1

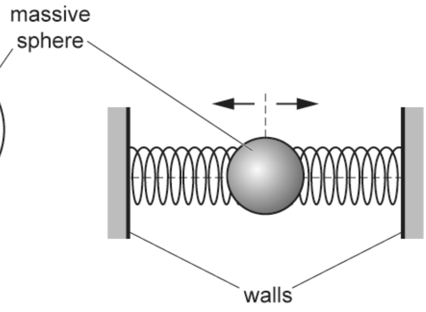


Fig. 2.2

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.

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[2]

40. A metal wire has length 2.2 m and cross-sectional area of 1.4 × 10−7 m^2. One end of the wire is fixed to the ceiling and a load of weight 49 N is attached to the other end so that the wire is vertical. The wire is replaced by a wire of the same metal and length but double the diameter. The same load is attached to the wire.

State and explain the change, if any, to the elastic potential energy of the wire.

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[2]

41 (a). Fig. 22 shows two identical springs supporting an object.

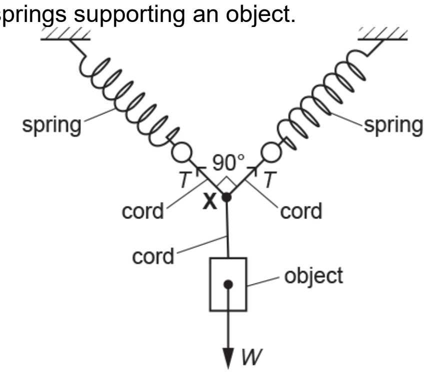


Fig. 22

Three short lengths of cord are tied together at point **X**. The other ends of the cords are attached to the ends of the springs and the object as shown in Fig. 22. The angle between the central axes of the springs is 90°.
The tension in each spring is the same and equal to *T*. The weight *W* of the object is 4.8 N.
The point **X** is in equilibrium.

Show that the tension *T* in each extended spring is 3.4 N.

---

[2]

(b). The force constant of each spring is 24 N m^{-1}.
Calculate the energy stored in each spring.

energy = ... J **[2]**

42 (a). A student measures the diameter of a ball in different directions.

The student's results are:

2.43 cm 2.54 cm 2.59 cm

i. State the name of a suitable measuring instrument to measure the diameter of the ball.

[1]

ii. Calculate the mean diameter *d* of the ball.
Include the absolute uncertainty in *d*.

d = ... ± .... cm **[2]**

iii. Show that the volume of the ball is about 8.4×10^{-6} m^3.

[1]

iv. The mass of the ball is 23 ± 1 g.
Determine the density *ρ* of the ball.
Give your answer to an appropriate number of significant figures.

ρ = ... kg m^{-3} **[2]**

v. Determine the percentage uncertainty in *ρ*.

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

(b). The 23 g mass ball from **(a)** is used in an experiment with a spring.

The student measures the unstretched length L_0 of a spring as shown in Fig. 3.1.

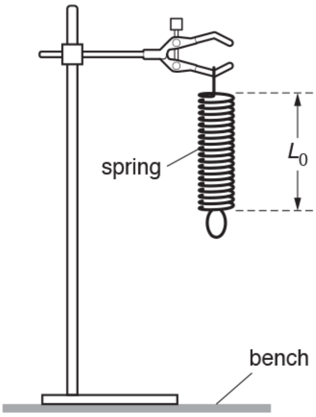


Fig. 3.1

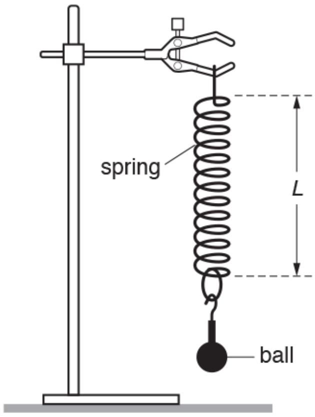


Fig. 3.2

The student then attaches the ball to the spring and measures the length L of the spring as shown in Fig. 3.2.

The student's results are:

L_0 = 0.078 m and L = 0.096 m

Calculate the force constant k of the spring.

k = ... N m^{-1} **[3]**

(c). The 23 g mass ball from **(a)** and the spring from **(b)** are now used in an experiment to investigate upthrust.

The ball attached to the spring is lowered into a beaker containing a liquid so that it is totally submerged. The student measures the new length L_N of the spring, as shown in Fig. 3.3.

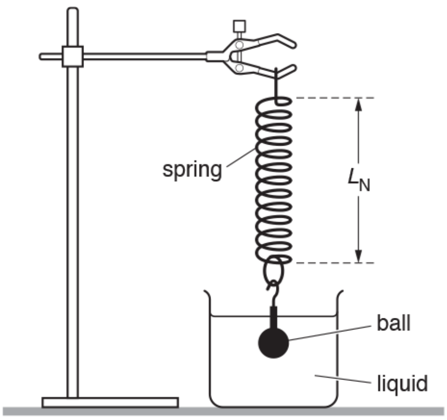


Fig. 3.3

The length L_N of the spring is now 0.088 m.

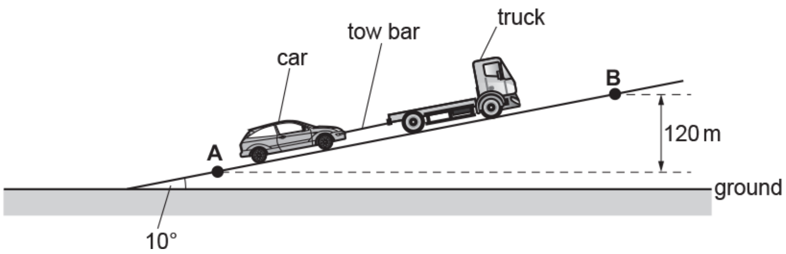
i. Calculate the upthrust on the submerged ball.

upthrust = ... N **[2]**

ii. Calculate the density of the liquid.

density of liquid = ... kg m^{-3} **[2]**

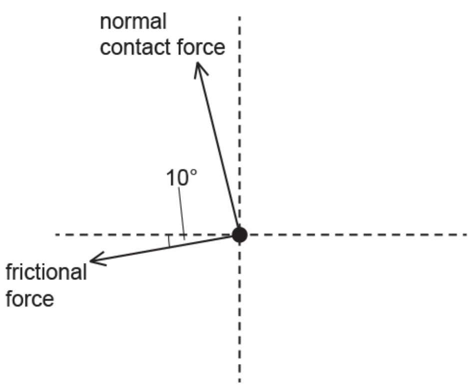
43(a). A truck pulls a car up a slope at a **constant** speed.
The truck and the car are joined with a steel tow bar, as shown in the diagram.



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]**

44 (a). The extension of a metal wire is *x* when the tension in the wire is *F.* The table in **Fig. 23.1** shows the results from an experiment, including the stress and the strain values.

F **/ N**	***x*** **/ 10^{-3} m**	**stress / 10^7 Pa**	**strain / 10^{-3}**
1.9	0.4	1.73	0.20
4.0	0.8	3.50	0.40
5.9	1.2	5.21	0.60
8.0		7.00	0.80
9.0	1.8	7.95	0.90

Fig. 23.1

Fig. 23.2 shows a graph of stress against strain for the metal.

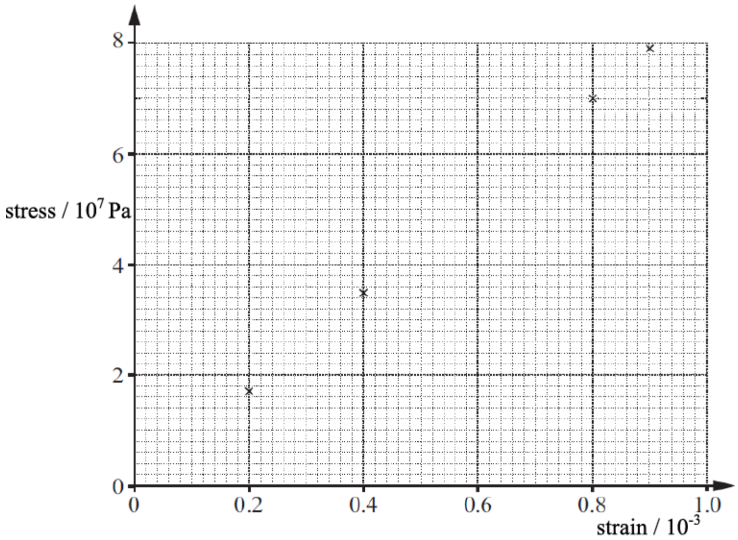


Fig. 23.2

i. On **Fig. 23.2,** plot the data point corresponding to the tension of 5.9 N and draw the line of best fit through all the data points.

[1]

ii. Use **Fig. 23.2** to determine the Young modulus of the metal.

.

Young modulus = ... Pa **[2]**

(b). The micrometer screw gauge used to determine the diameter of the wire had a zero error. The diameter recorded by a student was larger than it should have been.

Discuss how the actual value of the Young modulus would differ from the value calculated in **(b)(ii)**.

---

[3]

45. The stress in a concrete pillar is 1.1×10^5 Pa. The original length of the pillar was 2.3 m. The Young modulus of concrete is 1.4×10^{10} Pa.
Calculate the compression x of the pillar.

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

46. An engineer is investigating the tension in a steel cable supporting a uniform wooden plank as shown in Fig. 4.

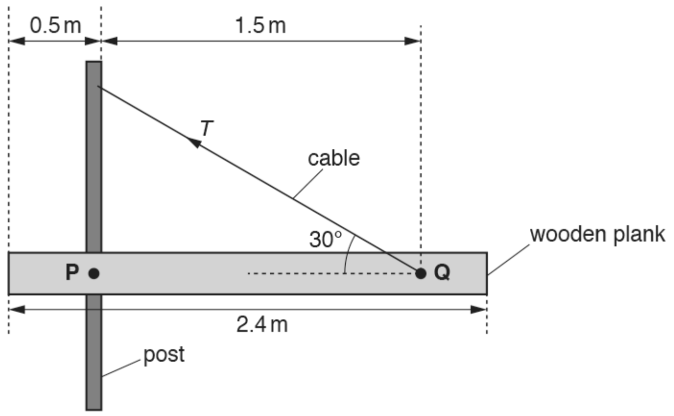


Fig. 4 (not to scale)

The plank is 2.4 m long and has a mass of 50 kg. It is pivoted at point **P** to a vertical post. The cable is fixed to the plank at point **Q** and to the vertical post as shown in Fig. 4. The cable is at an angle of 30° to the plank. The plank is in equilibrium and resting in a horizontal position.

The original length of the steel cable is 1.73 m and it has a cross-sectional area of 11.0 mm^2.
The Young modulus of steel is 210 GPa.

Calculate the extension x of the cable shown in Fig. 4.

x = ________________________________ m **[3]**

47(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.

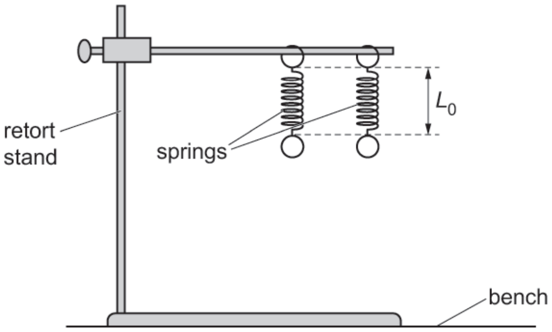


Fig. 3.1

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

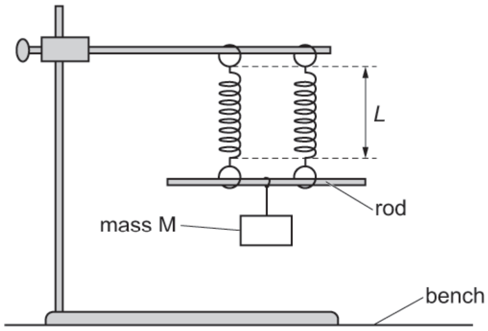
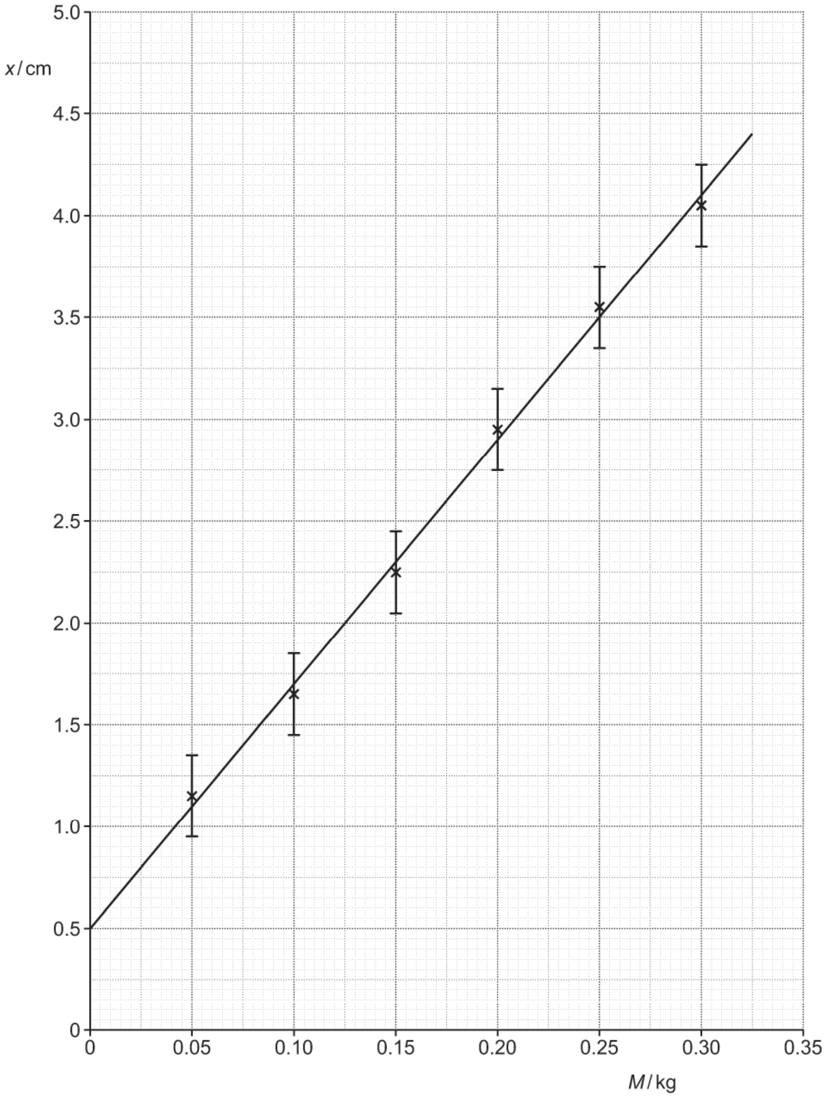


Fig. 3.2

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]**

48 (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.

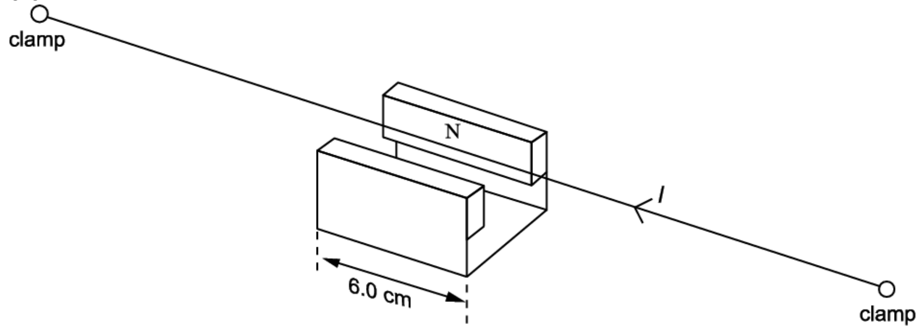


Fig. 5.1

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.

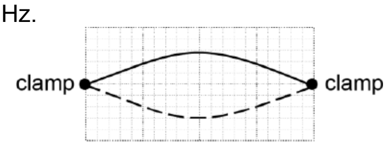


Fig. 5.2

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

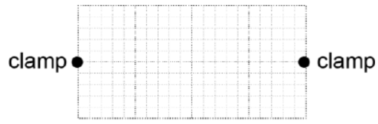


Fig. 5.3

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]

49.

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.

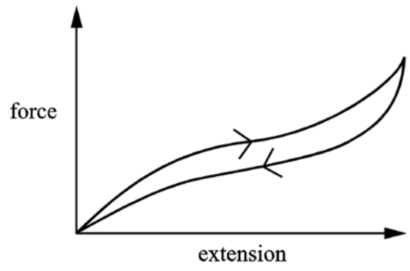
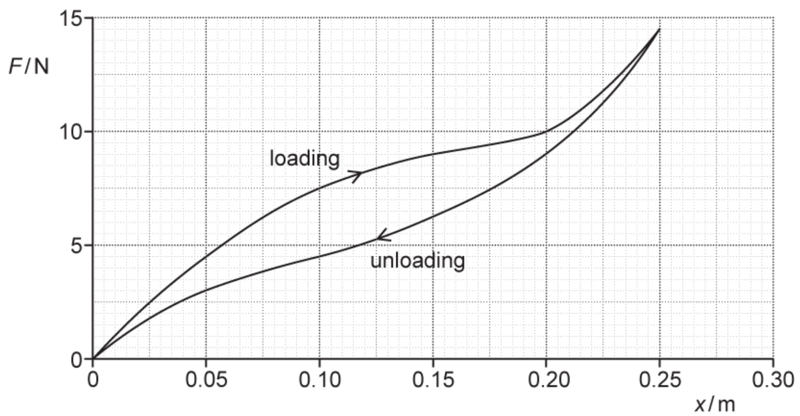


Fig. 18.1

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]**

50. The force *F* against extension *x* graph below shows the loading and unloading of a piece of rubber.



i. State the physical quantity represented by the area under the loading curve.

--- **[1]**

ii. Determine the energy *E* transferred when the rubber is stretched to an extension of 0.25 m.

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

iii. Suggest why the energy transferred by the rubber during unloading is different to your answer in **(ii)**.

----

[1]

51. Fig. 1 shows a high-speed electric train.

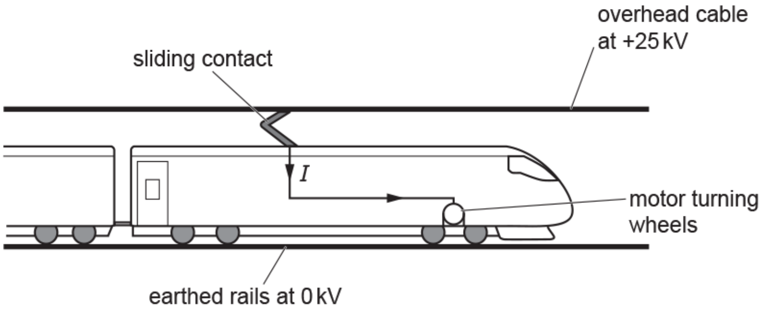


Fig. 1

The overhead cable in **Fig. 1** must be tensioned.
It is constructed from several equal lengths of wire.

Some data for one length of this wire are shown below.

- length = 1500 m
- area of cross-section = 1.1×10^{-4} m^2
- resistivity = 1.8×10^{-8} Ωm
- the Young modulus = 1.2×10^{10} Pa
- strain = 1.3%

i. Calculate the resistance *R* of one length of wire.

R = ... Ω**[2]**

ii. Calculate the tension T in one length of wire.

T = ... N**[3]**

52. 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.

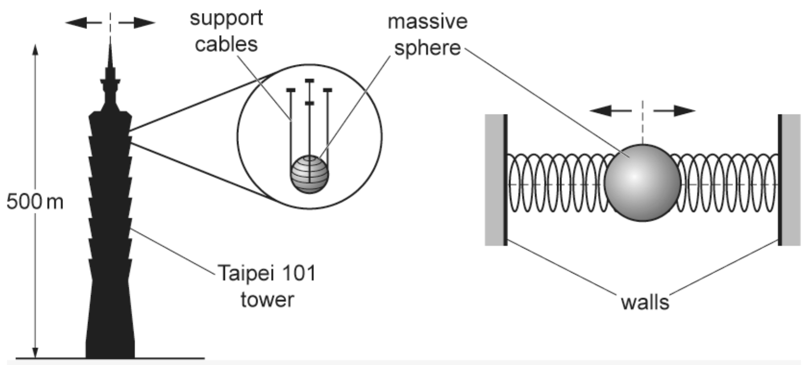


Fig. 2.1 **Fig. 2.2**

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}.

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]**

53. A crane raises a mass of 3000 kg through a height of 12 m in 40 seconds with an efficiency of 60%.

The crane cable is made of an alloy. The stress-strain curve for the cable is shown in Fig. 25.

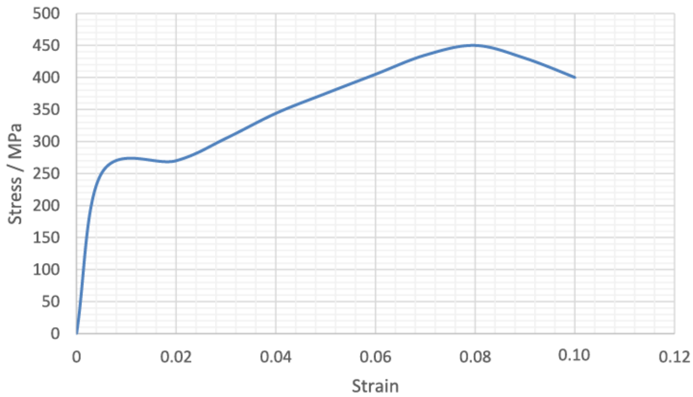


Fig. 25

i. Use the graph to estimate the stress in the cable at its elastic limit.

stress = ... MPa **[1]**

ii. A cable of diameter 0.090 m has a maximum working load allowance of 1.1×10^6 N.

By calculating the maximum tensile stress allowed, suggest and explain why the working load allowance is 1.1×10^6 N.

[4]

54. 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.

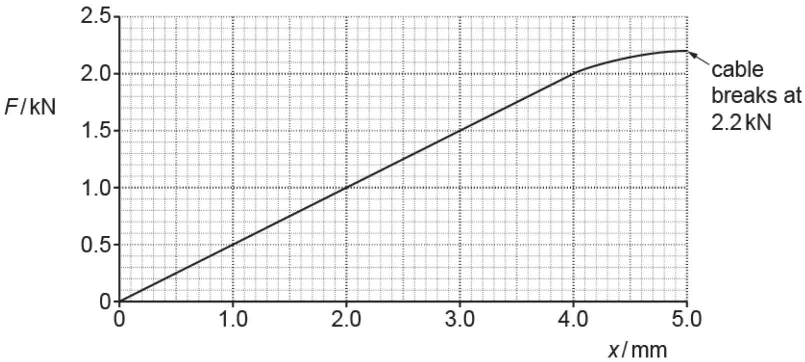


Fig. 16.2

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]**

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

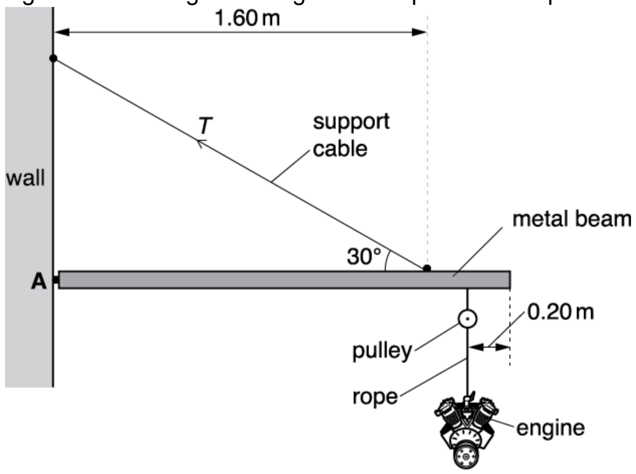


Fig. 18.2 (not to scale)

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]**

56. *A student is investigating the stretching of materials.
The student applies varying loads to material **J** and determines the stress and the strain until the material breaks.
The experiment is then repeated for a second material **K**.
Fig. 2.1 shows how the stress for each material varies with strain.

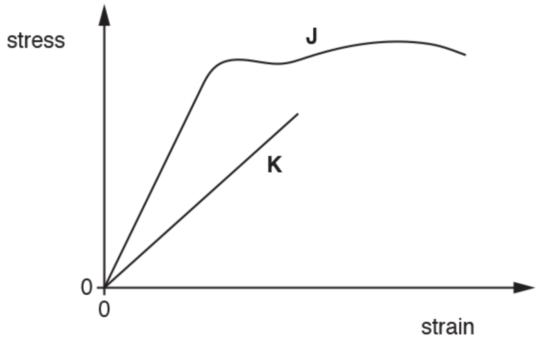


Fig. 2.1

Compare materials **J** and **K** using Fig. 2.1 and the six terms listed below.

brittle **ductile** **elastic** **plastic**

ultimate tensile strength **Young modulus**

Include in your answer an explanation of each term. **[6]**

----

57. * 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.

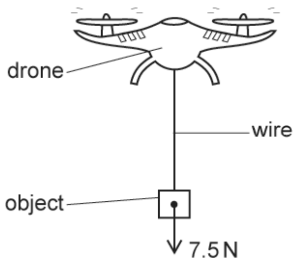
[6]

58. * A student wishes to determine experimentally the breaking stress of a metal in the form of a thin wire.

Describe with the aid of a diagram how this experiment can be safely conducted, and how the data can be analysed to determine the breaking stress of the metal.

[6]

59. The diagram below shows an object of weight 7.5 N hung from a drone using a steel wire.



The drone is now hovering at a fixed position above the ground.

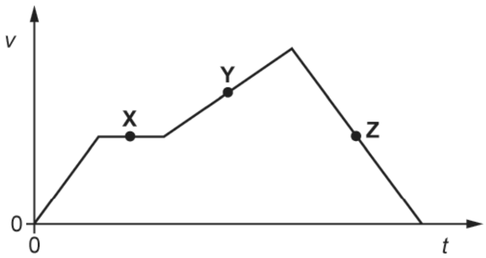
i. The wire has cross-sectional area 8.2×10^{-7} m^2 and original length 62 cm.
The Young modulus of steel is 2.0×10^{11} Pa. The wire obeys Hooke's law.

Calculate the extension *x* of the wire.

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

ii. The drone now moves vertically upwards.

The velocity *v* against time *t* graph for the drone is shown below.



The tension in the wire at **X** is 7.5 N.
Describe and explain how the tension in the wire at **Y** and **Z** compares with 7.5 N.

---

[3]

60. Fig. 21.2 shows a model dolphin in a museum. The dolphin is held in equilibrium by two cables **A** and **B**.

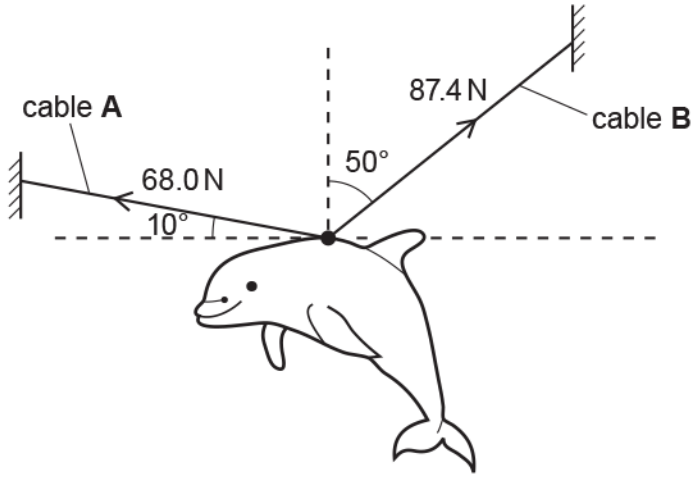


Fig. 21.2

The tension in cable **A** is 68.0 N and it makes an angle of 10° to the horizontal. The tension in cable **B** is 87.4 N and it makes an angle of 50° to the vertical.

i. Calculate the **total** vertical force F supplied by cables **A** and **B** by resolving the tensions in cables **A** and **B**.

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

ii. Use your answer from **(i)** to calculate the mass m of the dolphin.

m = ... kg **[2]**

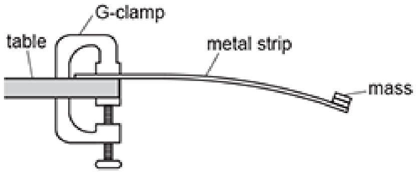
iii. The cables **A** and **B** have the same length and cross-sectional area.
The material of cable **B** has Young modulus 1.29E, where E is the Young modulus of the material of cable **A**.
Both cables obey Hooke's law.

Calculate the ratio $\dfrac{\text{extension of cable } \mathbf{B}}{\text{extension of cable } \mathbf{A}}$.

ratio = ... **[2]**

61. A student wants to determine the Young modulus *E* of a metal strip.

The student clamps the metal strip to the edge of a table using a G-clamp. A mass is **permanently** fixed to the end of the strip as shown.



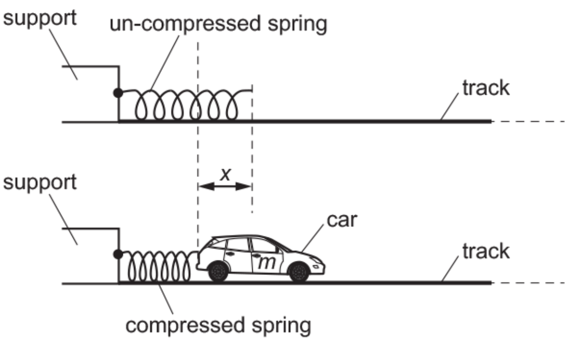
The mass oscillates freely when it is moved away from its equilibrium position and then released.

The Young modulus *E* of the metal can be determined using the equation $E = \frac{16\pi^2 mL^3}{wt^3T^2}$,where *m* is the mass fixed to the end of the strip, *L* is the length of the strip from the end of the table to the centre of the mass, *w* is the width of the strip, *t* is the thickness of the strip, and *T* is the period of oscillations.
Describe how an experiment may be safely conducted, and how the data can be analysed to determine an accurate value for *E*.

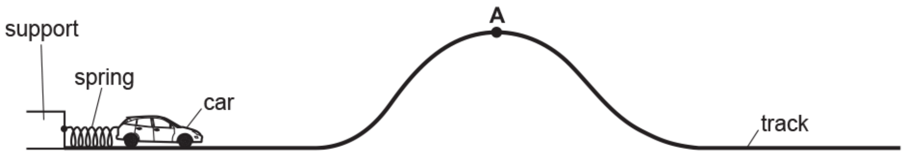
[6]

62. One end of a spring is fixed to a support.
A toy car, which is on a smooth horizontal track, is pushed against the free end of the spring.

The spring compresses. The car is then released. The car accelerates to the right until the spring returns back to its original length.



The arrangement is used to propel the toy car along a smooth track.



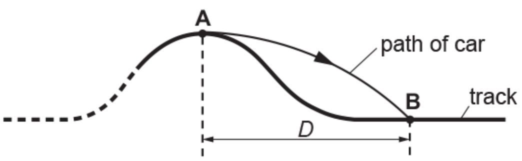
i. Point **A** is at the top of the track.
The launch speed of the car is now adjusted until the car just reaches **A** with zero speed.
The height of **A** is 0.20 m above the horizontal section of the track.

All the elastic potential energy of the spring is transferred to gravitational potential energy of the car.

Calculate the initial compression *x* of the spring.

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

ii. At a specific speed, the car leaves point **A** horizontally and lands on the track at point **B**.
The horizontal distance between **A** and **B** is D.



Air resistance has negligible effect on the motion of the car between **A** and **B**.

1 Explain how the time of flight between **A** and **B** depends on the speed of the car at **A**.

[2]

2 Explain how the distance *D* depends on the speed of the car at **A**.

[2]

63. 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.

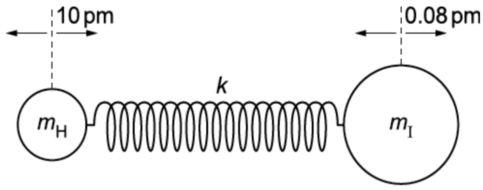


Fig. 3.2

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.

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[4]

64. A metal wire has length 2.2m and cross-sectional area of $1.4 \times 10^{-7} m^2$. One end of the wire is fixed to the ceiling and a load of weight 49N is attached to the other end so that the wire is vertical.
The Young modulus of the metal is 180GPa.

The wire obeys Hooke's law.
Calculate

i. the stress σ in the wire

σ = ... Pa **[2]**

ii. the strain ε of the wire

ε = ... **[2]**

iii. the extension x of the wire

x = ... m **[2]**

iv. the elastic potential energy E of the wire.

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

END OF QUESTION PAPER