SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box.

Answer **all** the questions.

1 Which of the following is a correct unit for gravitational field strength?

A $J\,kg^{-1}$

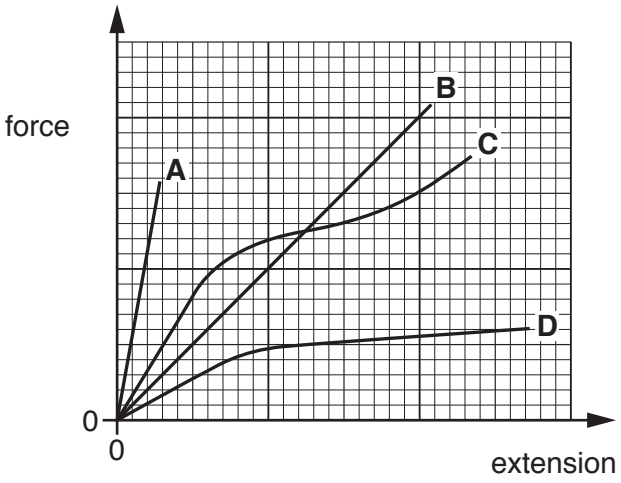
B $N\,kg^{-1}$

C $N\,m^2\,kg^{-2}$

D $kg\,m\,s^{-1}$

Your answer ☐ **[1]**

2 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]**

5 Which is the **best** estimate of the area of a rectangular field of length 98 ± 3 m and width 47 ± 2 m?

A $4600 \pm 5\,m^2$

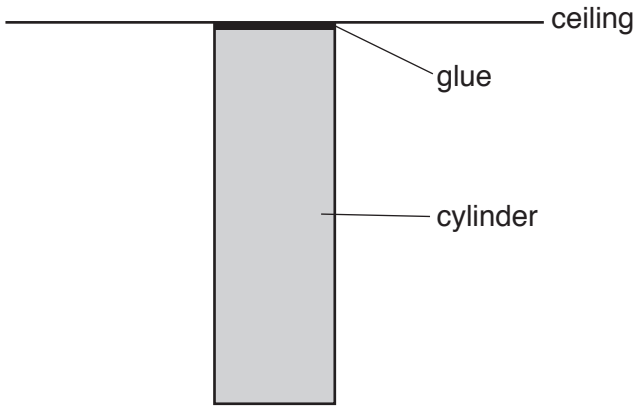
B $4600 \pm 6\,m^2$

C $4600 \pm 300\,m^2$

D $4606 \pm 337\,m^2$

Your answer ☐ **[1]**

6 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 $6.0 \times 10^{-2}\,m^2$

B $6.0 \times 10^{-5}\,m^2$

C $1.7 \times 10^{-2}\,m^2$

D $1.7 \times 10^{1}\,m^2$

Your answer ☐ **[1]**

17 A group of students are conducting an experiment in the laboratory to determine the value of absolute zero by heating a fixed mass of gas. The volume of the gas is kept constant.
Fig. 17.1 shows the arrangement used by the students.

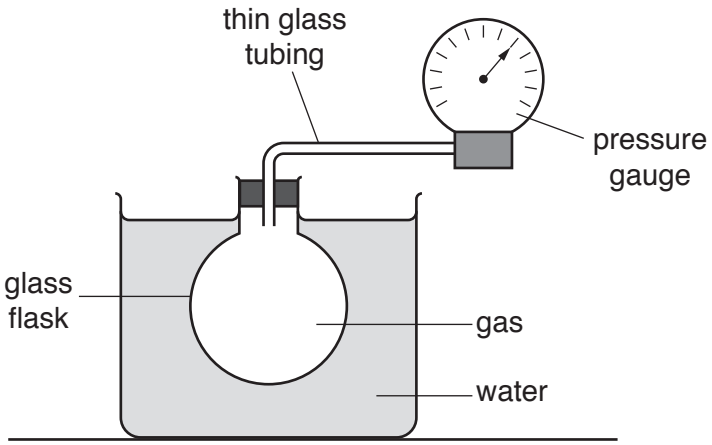


Fig. 17.1

The gas is heated using a water bath. The temperature θ of the water is increased from 5 °C to 70 °C. The temperature of the water bath is assumed to be the same as the temperature of the gas. The pressure p of the gas is measured using a pressure gauge.

The results from the students are shown in a table.

θ / °C	p / kPa
5 ± 1	224 ± 3
13 ± 1	231 ± 3
22 ± 1	238 ± 3
35 ± 1	248 ± 3
44 ± 1	
53 ± 1	262 ± 3
62 ± 1	269 ± 3
70 ± 1	276 ± 3

(a) Describe and explain how the students may have made accurate measurements of the temperature θ.

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..... **[2]**

(b) Fig. 17.2 shows the pressure gauge. Measurements of p can be made using the kPa scale or the psi (pounds per square inch) scale. The students used the psi scale to measure pressure and then converted the reading to pressure in kPa.

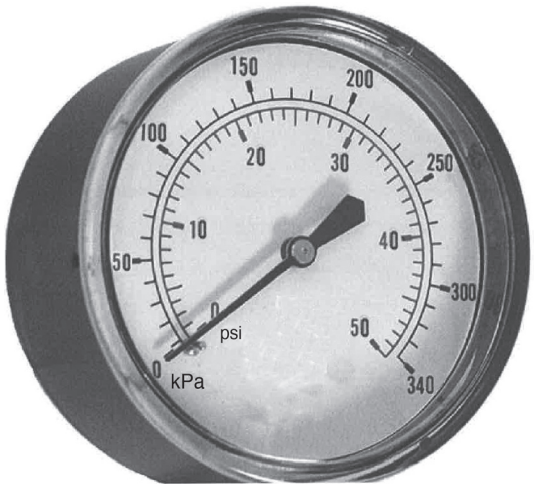

Fig. 17.2

(i) Suggest why it was sensible to use the psi scale to measure p.

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..... **[1]**

(ii) The students made a reading of p of 37.0 ± 0.5 psi when θ was 44 ± 1 °C.
Convert this value of p from psi to kPa. Complete the table for the missing value of p. Include the absolute uncertainty in p.

1 pound of force = 4.448 N
1 inch = 0.0254 m

[2]

(c) Fig. 17.3 shows the graph of p against θ.

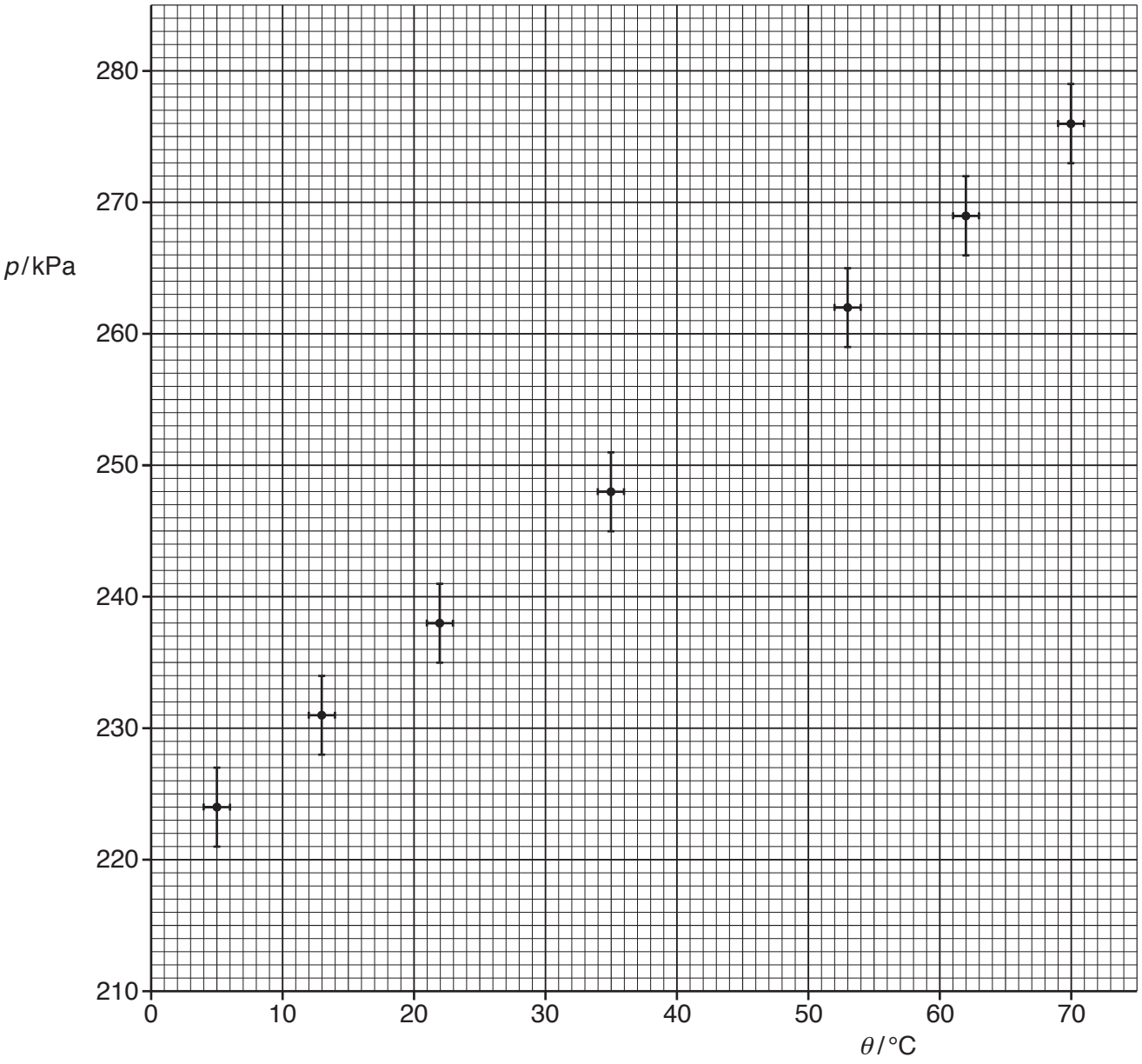

Fig. 17.3

(i) Plot the missing data point and the error bars on Fig. 17.3. **[1]**

(ii)* Explain what is meant by *absolute zero*. Describe how Fig. 17.3 can be used to determine the value of absolute zero.
Determine the value of absolute zero. You may assume that the gas behaves as an ideal gas.

.... **[6]**

(d) Describe, without doing any calculations, how you could use Fig. 17.3 to determine the actual uncertainty in the value of absolute zero in **(c)(ii)**.

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..... **[2]**

(e) The experiment is repeated as the water bath quickly cools from 70 °C to 5 °C. Absolute zero was found to be −390 °C.

Compare this value with your value from **(c)(ii)** and explain why the values may differ. Describe an experimental approach that could be taken to avoid systematic error in the determination of absolute zero.

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SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which of the following units is **not** an S.I. base unit?

A ampere

B mole

C volt

D kilogram

Your answer ☐ **[1]**

2 Which set of quantities are all scalar?

A acceleration, displacement, velocity

B energy, mass, power

C extension, force, gravitational potential energy

D weight, kinetic energy, work done

Your answer ☐ **[1]**

3 A metal block of mass 0.28 kg has an initial temperature of 82 °C. It is dropped into cold water. The temperature of the block after 1.2 minutes is 20 °C.
The specific heat capacity of the metal is 130 $J\,kg^{-1}\,K^{-1}$.

What is the average thermal power transferred away from the metal block?

A 31 W

B 41 W

C 1900 W

D 2700 W

Your answer ☐ **[1]**

SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 Which set of prefixes **A**, **B**, **C** or **D** are in order of **increasing** magnitude?

A micro, milli, centi, kilo

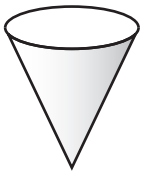
B milli, centi, micro, kilo

C kilo, centi, milli, micro

D centi, micro, milli, kilo

Your answer ☐ **[1]**

2 A paper cone is held above the ground and dropped. It falls vertically and reaches terminal velocity before it hits the ground.



Which statement correctly describes the **resultant** force on the falling cone before it reaches terminal velocity?

A decreasing and upwards

B decreasing and downwards

C increasing and downwards

D increasing and upwards

Your answer ☐ **[1]**

3 A solid cylindrical glass rod has length 20.0 ± 0.1 cm and diameter 5.00 ± 0.01 mm.

What is the percentage uncertainty in the calculated volume of this rod?

A 0.1%

B 0.2%

C 0.7%

D 0.9%

Your answer ☐ **[1]**

4 A simple harmonic oscillator has maximum speed 24 m s^{-1} and amplitude 5.6 cm.

What is its angular frequency?

A 0.23 rad s^{-1}

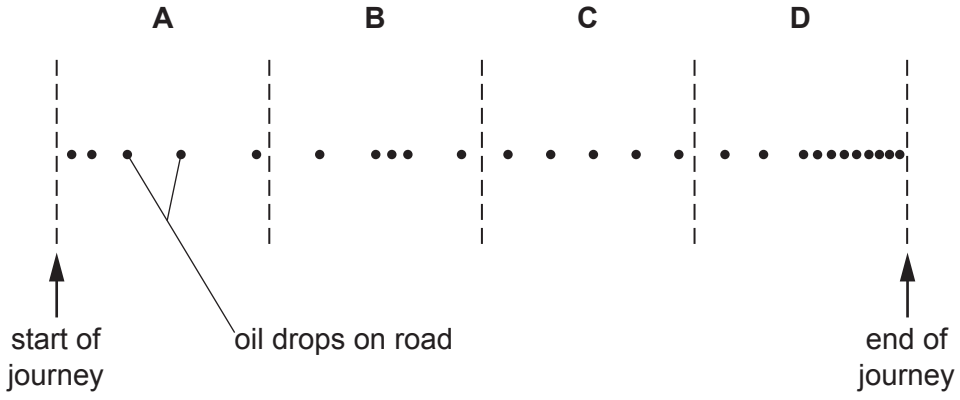
B 21 rad s^{-1}

C 68 rad s^{-1}

D 430 rad s^{-1}

Your answer ☐ **[1]**

5 A car is dripping oil at a steady rate on a straight road.
The road is divided into four sections **A**, **B**, **C**, and **D**.



Which section of the road shows the car travelling at a constant speed?

Your answer ☐ **[1]**

8 An object is falling.
The weight of the object is 4.5 N.
The wind provides a horizontal force of magnitude *F* on the object.
The **resultant** force on the object is 5.8 N.
Air resistance and upthrust on the object are negligible.

What is the value of *F*?

A 1.3 N

B 3.7 N

C 7.3 N

D 13 N

Your answer ☐ **[1]**

9 A solid molecular substance is supplied with energy and it starts to melt.

Which of the following pairs of quantities remains the same as the substance melts?

A Kinetic energy of molecules and internal energy of molecules.

B Potential energy of molecules and internal energy of molecules.

C Kinetic energy of molecules and temperature of substance.

D Potential energy of molecules and temperature of substance.

Your answer ☐ **[1]**

10 Which of the following shows the correct base units for pressure?

A $kg\,m^{-2}$

B $kg\,m^{-2}\,s^{-2}$

C $kg\,m^{-1}\,s^{-2}$

D $kg\,m^{2}\,s^{-3}$

Your answer ☐ **[1]**

19 (a) A car is travelling along a straight road at $18\,m\,s^{-1}$.
The driver sees an obstacle and after 0.50 s applies the brakes.
The **stopping** distance of the car is 38 m.

Calculate the magnitude of the deceleration of the car when the brakes are applied.

deceleration = ... $m\,s^{-2}$ **[3]**

(b)* A student rolls a marble at different speeds on a carpet to model the braking of a car.

The student wishes to investigate how the total distance x travelled before the marble stops (braking distance) depends on its initial speed v.

The speed v and distance x are related by the equation $\frac{1}{2}mv^2 = Fx$ where m is the mass of the marble and F is the constant frictional force acting on the marble.

- Describe how an experiment can be conducted in the laboratory to investigate the relationship between v and x.
- Explain how the data can be analysed to determine F. **[6]**

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Additional answer space if required.

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SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 An athlete is running at a speed of about $5\,m\,s^{-1}$.

What is a reasonable estimate for the kinetic energy of this athlete?

A 12 J

B 100 J

C 900 J

D 800 000 J

Your answer ☐ **[1]**

2 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]**

3 A tennis ball is hit with a racket. The force applied by the racket on the ball is *F*. The ball has a vertical path through the air.

Which statement is correct when the ball is at its **maximum** height?

A The ball has a downward acceleration.

B The force acting on the ball is *F*.

C The ball experiences greatest drag.

D The weight of the ball is equal to the drag.

Your answer ☐ **[1]**

19* A student makes a pendulum using a length of string with a ball of adhesive putty which acts as a bob. The mass of this bob is M.
A similar second pendulum is constructed with the same length of string but with a bob of a smaller mass. The mass of this bob is m.

The arrangement of the pendulums is shown below.

before collision after collision

The bob of mass M is pulled back to a vertical height of H from its rest position. It is released and collides with the bob of mass m. The two bobs then stick together and reach a maximum vertical height h from the rest position.

The height h is given by the equation $h = \left(\frac{M}{M+m}\right)^2 H$.

Describe how to perform an experiment to test the validity of this equation and how the data can be analysed. **[6]**

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Additional answer space if required

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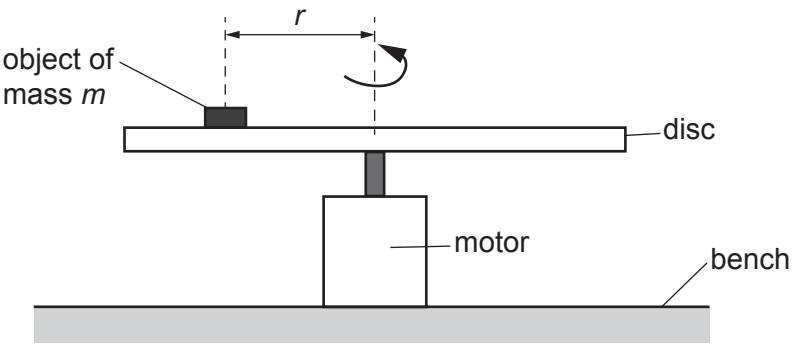
20 A small object of mass m is placed on a rotating horizontal metal disc at a distance r from the centre of the disc.



The frequency of rotation is adjusted using a motor attached to the disc.

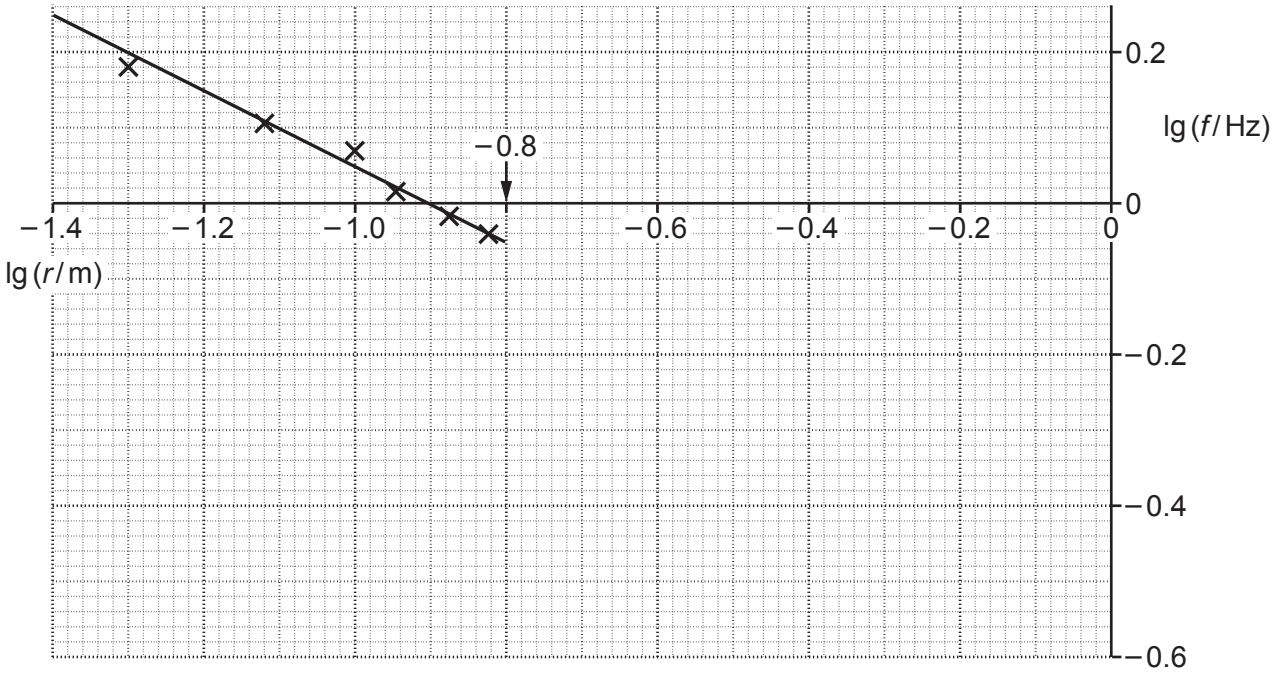
The frequency of rotation of the disc is slowly increased from zero, until the object slips off. At this point, the friction F acting on the object is equal to the centripetal force.

The friction F is given by the expression $F = kmg$, where k is a constant and g is the acceleration of free fall. The constant k has no units.

(a) Show that the frequency f at which the object slips off is given by the equation $f^2 = \left(\frac{gk}{4\pi^2}\right) \times \frac{1}{r}$.

[3]

(b) A student plots a graph of lg (*f* / Hz) against lg (*r* / m).



For this graph: *y*-intercept = $\frac{1}{2} \times \lg\left(\frac{gk}{4\pi^2}\right)$

Use the graph to determine the constant *k*. Write your answer to 2 significant figures.

k = ... **[4]**

SECTION A

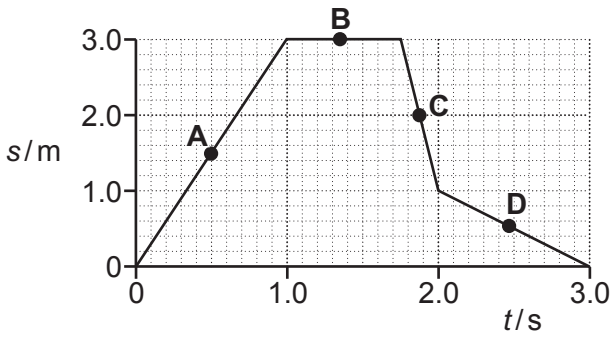
You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 An object is moving in a straight line.

The displacement *s* against time *t* graph for this object is shown below.



At which point **A**, **B**, **C** or **D**, does the object have the **greatest** speed?

Your answer ☐ **[1]**

2 Which one of the following prefixes represents the **smallest** multiplication factor?

A femto (f)

B micro (μ)

C nano (n)

D pico (p)

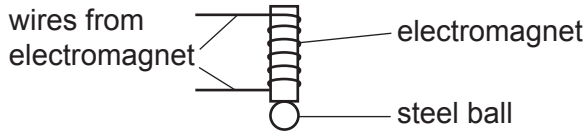
Your answer ☐ **[1]**

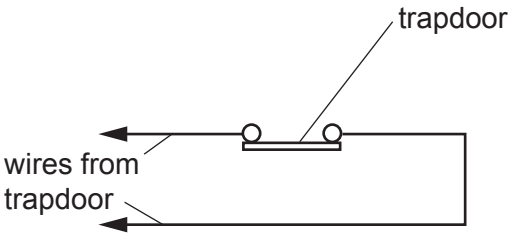
SECTION B

Answer **all** the questions.

16 A student wants to determine the value of the acceleration of freefall g.

(a) The diagram below shows part of the arrangement which the student used.





A steel ball is dropped from an electromagnet. The ball falls vertically. The ball hits a trapdoor and opens the trapdoor.
The ball travels a distance s from the bottom of the electromagnet to the trapdoor in a time t.
The student uses the equation $s = \frac{1}{2} gt^2$ to determine g.

(i) Show that the equation $s = \frac{1}{2} gt^2$ is homogeneous, with both sides of the equation having the same base units.

[2]

(ii) Describe how the student could use standard laboratory equipment to take accurate measurements of the distance s and the time t.

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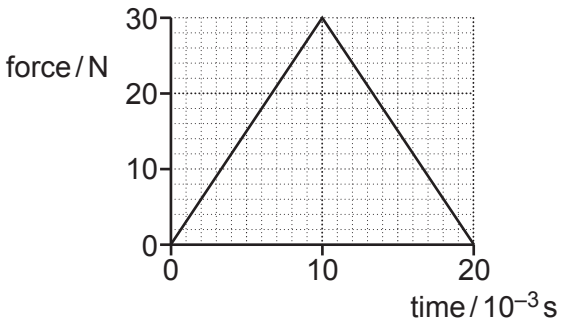
..... **[4]**

(b) The trapdoor falls downwards when the ball hits it.
The ball collides **elastically** with the trapdoor with a speed of $4.4\,m\,s^{-1}$.

The graph of force acting on the ball against time is shown below.



The mass of the ball is 0.050 kg.

(i) Calculate the initial momentum p_1 of the ball just before it hits the trapdoor.

p_1 = ... $kg\,m\,s^{-1}$ **[1]**

(ii) Use the graph to calculate the magnitude of the final momentum p_2 of the ball immediately after the collision.

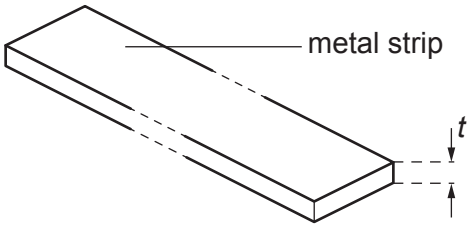
p_2 = ... $kg\,m\,s^{-1}$ **[3]**

(iii) The mass of the trapdoor is 100 g.

Calculate the final speed v of the trapdoor immediately after the collision.

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

17 (a) A metal strip has thickness *t*, as shown below.



Five measurements of the thickness *t* at different positions along the length of the strip are shown below.

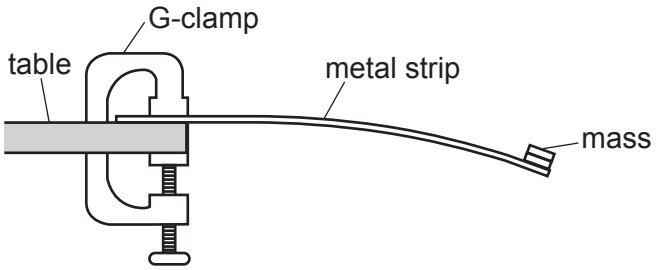
1.86 mm 1.88 mm 1.85 mm 1.89 mm 1.88 mm

Determine the percentage uncertainty in the thickness *t*.

percentage uncertainty = ... % **[3]**

(b)* A student wants to determine the Young modulus *E* of the metal of the strip in **(a)**.

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.

13

Describe how an experiment may be safely conducted, and how the data can be analysed to determine an accurate value for *E*. **[6]**

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Additional answer space if required.

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SECTION A

You should spend a maximum of 30 minutes on this section.

Write your answer to each question in the box provided.

Answer **all** the questions.

1 A student has constructed the table below of possible scalar and vector quantities.

	Scalar	Vector
A	acceleration	momentum
B	displacement	amplitude
C	frequency	wavelength
D	mass	centripetal force

Which row is correct?

Your answer ☐ **[1]**

2 The diameter of a wire is measured in five different places along its length.
The results are shown below.

1.92 mm 1.88 mm 1.90 mm 1.86 mm 1.89 mm

What is the absolute uncertainty in the diameter of this wire?

A 0.01 mm

B 0.03 mm

C 0.05 mm

D 0.06 mm

Your answer ☐ **[1]**

9 A container has 1.0 mole of gas at pressure 100 kPa.
The root mean square (r.m.s.) speed of the gas particles is 500 m s^{-1}. The mass of each gas particle is 4.7×10^{-26} kg.

What is the volume of the container?

A $3.9 \times 10^{-26}\,m^3$

B $4.7 \times 10^{-5}\,m^3$

C $2.4 \times 10^{-2}\,m^3$

D $4.7 \times 10^{-2}\,m^3$

Your answer ☐ **[1]**

10 A mass is attached to the bottom end of a spring which is fixed at its top end.
The mass is displaced vertically, and then released. The mass oscillates with a simple harmonic motion.

Which row correctly describes the energy of this spring-mass system when the mass is at its **lowest** point in its oscillations?

	Elastic potential energy	**Gravitational potential energy**	**Kinetic energy**
A	Maximum	Maximum	Maximum
B	Maximum	Minimum	Zero
C	Minimum	Maximum	Zero
D	Minimum	Minimum	Maximum

Your answer ☐ **[1]**

11 Which pair of quantities do **not** have the same, or equivalent, units?

A acceleration, gravitational field strength

B angular frequency, angular velocity

C gravitational potential, kinetic energy

D impulse, momentum

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 **(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.

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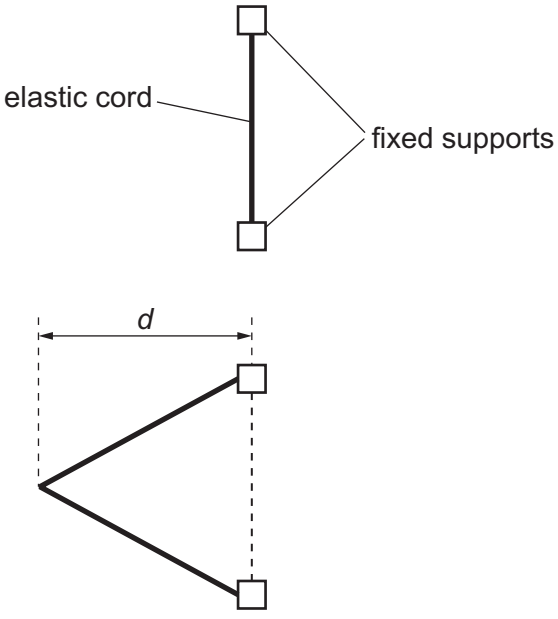
(b) A simple catapult is made by an elastic cord fixed to two supports, as shown below.

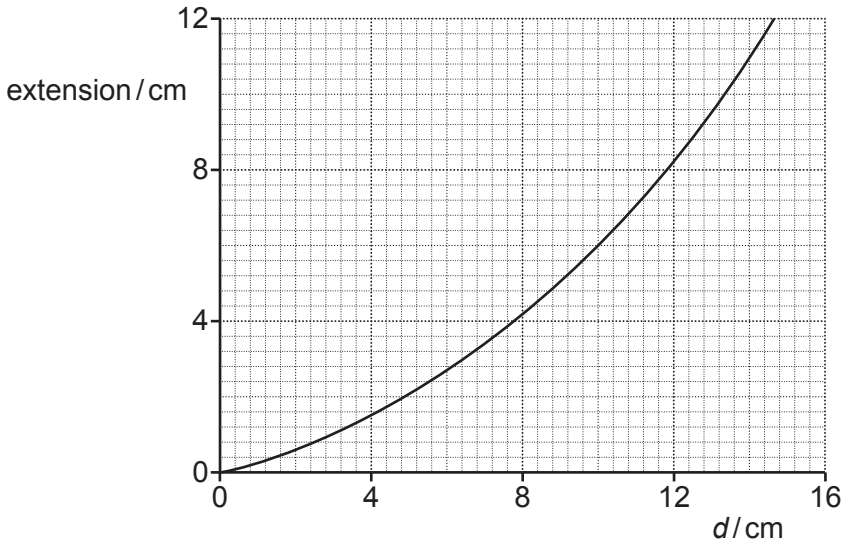


The unstretched length of the cord is the same as the distance between the supports.
The distance that the centre of the cord has been pulled back is d.

The cord has a force constant of $500\,\text{N}\,\text{m}^{-1}$.

11

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 m s^{-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.

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..... **[2]**

Section A

You should spend a **maximum** of **30 minutes** on this section.

Write your answer to each question in the box provided.

1 Which row contains **only** scalar quantities?

A Absolute temperature, displacement, moment

B Acceleration, force, momentum

C Gravitational potential, kinetic energy, mass

D Kinetic energy, mass, momentum

Your answer ☐ **[1]**

2 Forces are applied to a circular shaft of diameter d.

Which diagram shows a torque of a couple with magnitude Fd?

A **B** **C** **D**

Your answer ☐ **[1]**

18* A student is attempting to determine the value of g, the acceleration due to gravity, by two different methods.

Method 1. Vertical drop method

Measuring the time of fall of a small dense ball being dropped from rest from different heights.

Method 2. Rolling ball method

Measuring the time it takes for the same ball to roll 1.900 m down a ramp, set at different angles.

Single sets of results are shown below. The times were measured using a standard stopwatch operated by the student.

Compare and discuss the uncertainties of the two values of g that could be obtained using these single measurements.

Describe how the student would analyse both sets of data when a full range of results has been taken.

Vertical drop method

Drop height / m	Time taken / s
1.20	0.50

Rolling ball method

Length of ramp / m	Angle / °	Time taken / s
1.900	30	0.90

[6]

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21 (a) **Fig. 21.1** 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 **Fig. 21.2**. 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.

Fig. 21.1

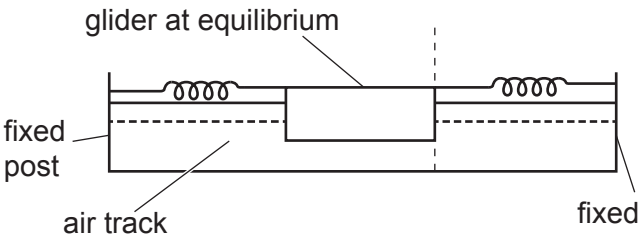
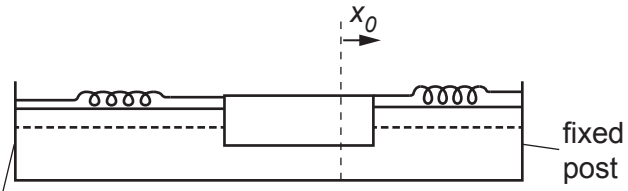


Fig. 21.2



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 $F = 2kx$ where x is the displacement at any time.

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..... **[2]**

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

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..... **[2]**

(b) Masses are added to the glider, and the measurement of $20T$ repeated.

The results table is below.

m/kg	$20T$/s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(i) Describe **two** different errors in the table.

1 .....

.....

2 .....

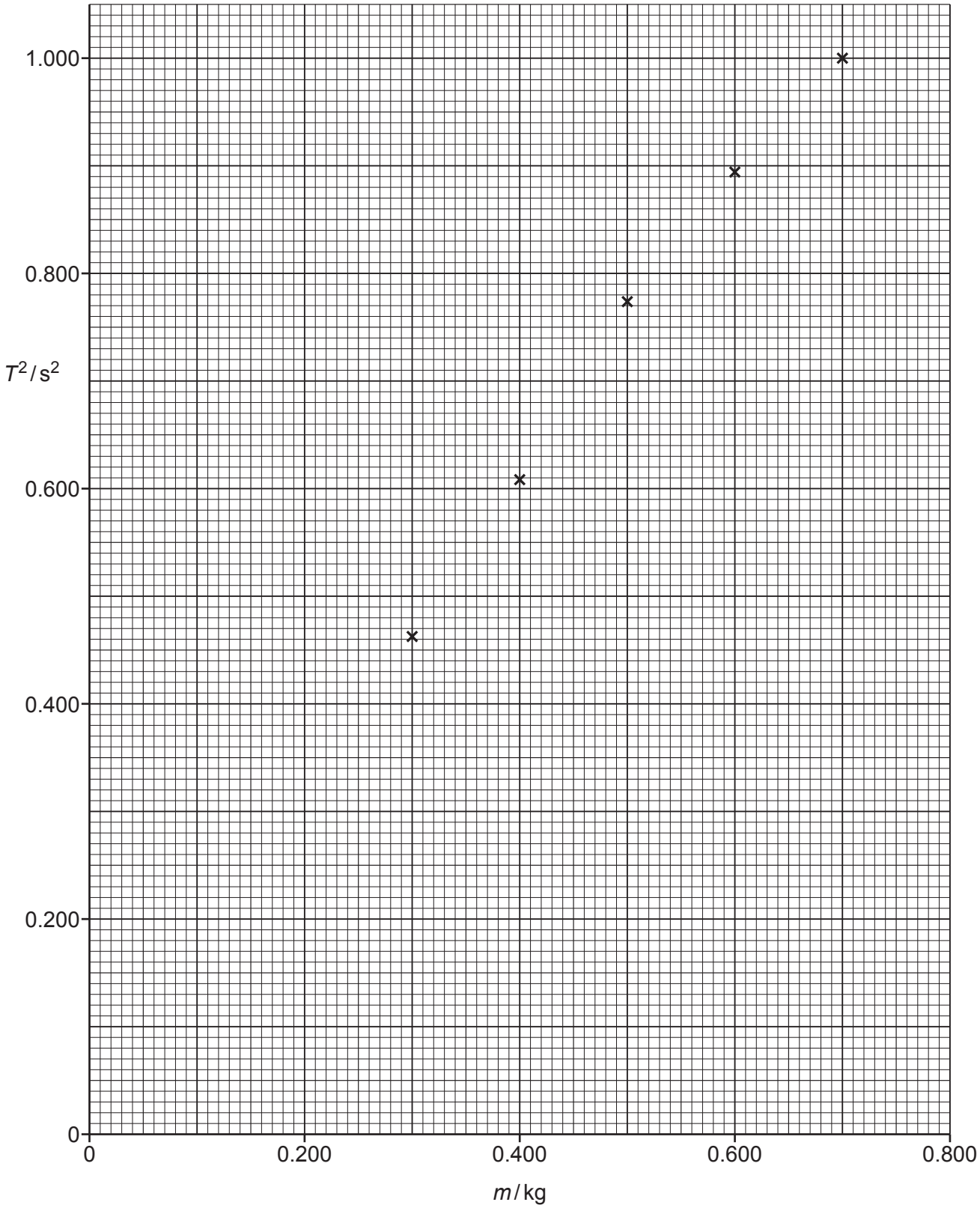
.....

[2]

(ii) Plot the **first** data point from the table on the graph below.

The other points have all been plotted. The table of results is repeated on the opposite page.

Include on your graph a line of best fit. **[2]**



m/kg	$20T$/s	T	T^2
0.200	12.2	0.61	0.372
0.300	13.6	0.68	0.462
0.400	15.6	0.78	0.608
0.500	17.6	0.88	0.774
0.600	18.9	0.945	0.893
0.700	20.0	1	1

(iii) Use the graph to determine the value of k.

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

(c) 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.

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..... **[4]**