SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 An ampere can be expressed as

☒ **A** $C\ s^{-1}$

☒ **B** $J\ C^{-1}$

☒ **C** $V\ W^{-1}$

☒ **D** $V\ \Omega$

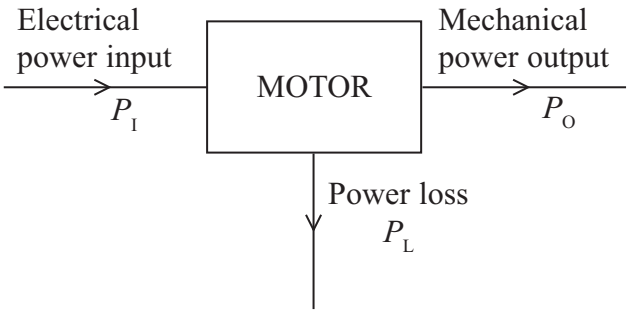
(Total for Question 1 = 1 mark)

2 Which of the following summarises the change in wave characteristics when going from ultraviolet to infrared in the electromagnetic spectrum?

	Frequency	Speed (in a vacuum)
☒ **A**	decreases	decreases
☒ **B**	decreases	stays the same
☒ **C**	increases	decreases
☒ **D**	increases	stays the same

(Total for Question 2 = 1 mark)

3 Electrical power is transferred in a motor as shown.



What is the efficiency of the motor?

☒ **A** $\frac{P_O + P_L}{P_I}$

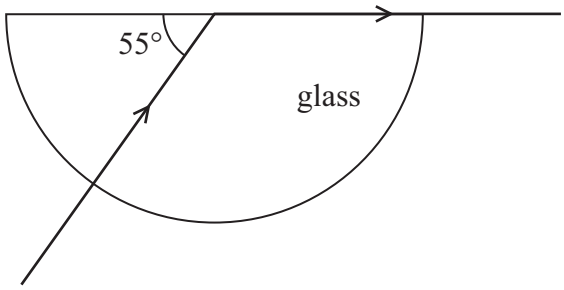
☒ **B** $\frac{P_I}{P_O}$

☒ **C** $\frac{P_L}{P_I}$

☒ **D** $\frac{P_O}{P_I}$

(Total for Question 3 = 1 mark)

4 A ray of monochromatic light passes into a glass block as shown.



The refractive index of the glass for this light is

☒ **A** 0.57

☒ **B** 0.81

☒ **C** 1.22

☒ **D** 1.74

(Total for Question 4 = 1 mark)

5 An electron is accelerated from rest through a potential difference of 5.0 kV.

The kinetic energy gained by the electron is

☒ **A** 8.0×10^{-16} J

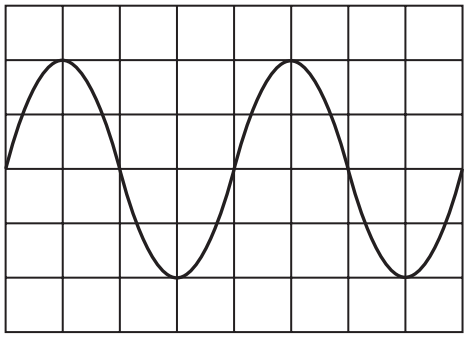
☒ **B** 8.0×10^{-19} J

☒ **C** 3.2×10^{-20} J

☒ **D** 3.2×10^{-23} J

(Total for Question 5 = 1 mark)

6 A particular sound is investigated by connecting a microphone to an oscilloscope. The diagram shows the trace of a sound wave on the oscilloscope. The screen of the oscilloscope has a grid on it. On the x-axis 1 division represents 5 ms.



The frequency of the sound wave is

☒ **A** 0.05 Hz

☒ **B** 0.1 Hz

☒ **C** 50 Hz

☒ **D** 100 Hz

(Total for Question 6 = 1 mark)

7 Two coherent sources emit waves of wavelength λ which are in phase. The two waves meet at a point, having travelled slightly different distances. The waves now have a phase difference of 180° (π radians).

Which of the following could be the path difference at this point?

☒ **A** $\frac{\lambda}{4}$

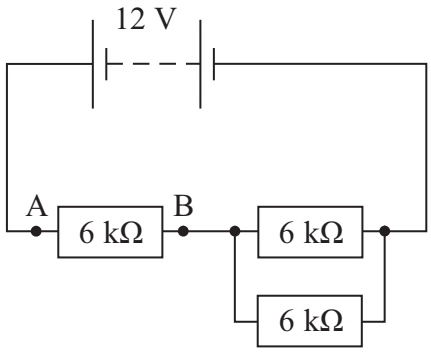
☒ **B** $\frac{\lambda}{2}$

☒ **C** $\frac{3\lambda}{4}$

☒ **D** λ

(Total for Question 7 = 1 mark)

8 A combination of resistors is connected to a 12 V supply of negligible internal resistance.



The potential difference between points A and B is

☒ **A** 4 V

☒ **B** 6 V

☒ **C** 8 V

☒ **D** 12 V

(Total for Question 8 = 1 mark)

9 Ultrasound is used to investigate the blood in an artery in a human body by detecting a Doppler shift. This Doppler shift is used to measure the

☒ **A** diameter of the artery.

☒ **B** size of the particles in the blood.

☒ **C** temperature of the blood.

☒ **D** velocity of the blood.

(Total for Question 9 = 1 mark)

10 The effect of diffraction is more noticeable, in everyday life, with sound than with light. This is because

☒ **A** sound has a much longer wavelength than light.

☒ **B** sound is a longitudinal wave, light is a transverse wave.

☒ **C** sound is a mechanical wave, light is an electromagnetic wave.

☒ **D** sound travels more slowly in air than light does.

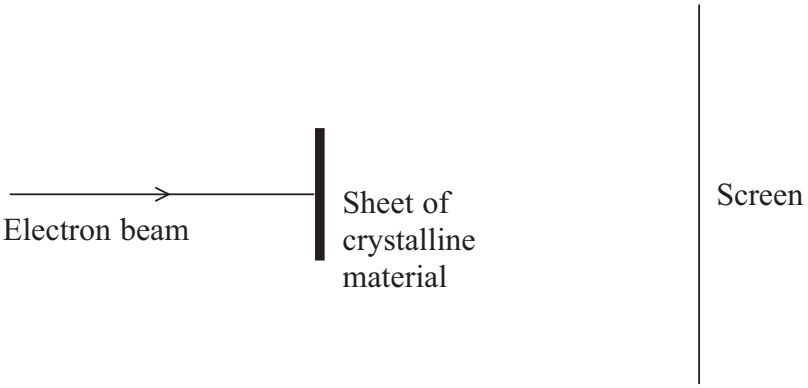
(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

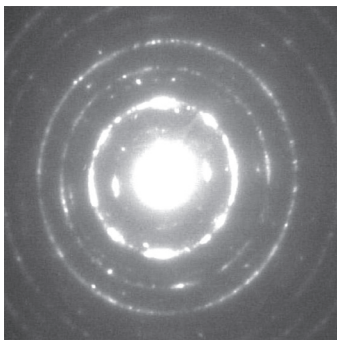
SECTION B

Answer ALL questions in the spaces provided.

11 The diagram shows a beam of electrons being fired towards a thin sheet of crystalline material. The screen detects electrons after they have passed through the sheet.



The photograph shows the positions at which electrons strike the screen.



Explain what can be deduced about the behaviour of electrons from the formation of this pattern.

(3)

(Total for Question 11 = 3 marks)

12 A thermistor has a negative temperature coefficient. With reference to the equation $I = nqvA$, explain what happens to the resistance of the thermistor when its temperature increases.

(3)

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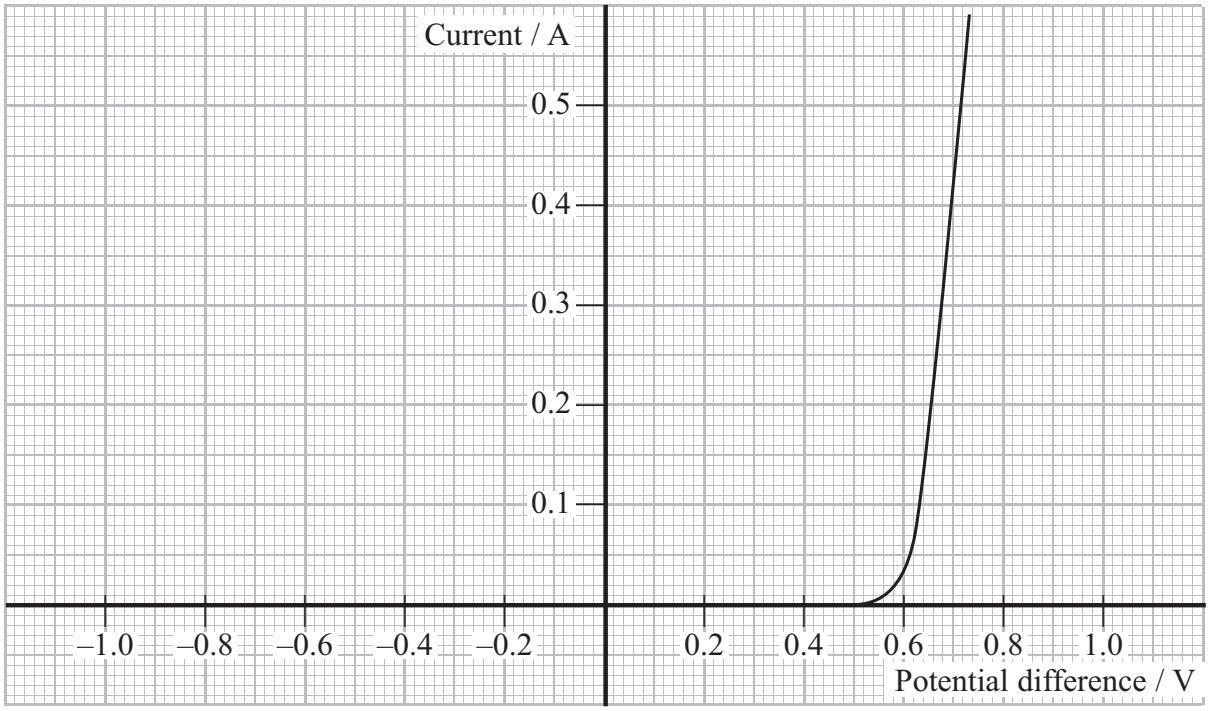
(Total for Question 12 = 3 marks)

13 The graph shows the current–potential difference characteristic for an electrical component.



(a) State the name of the component.

(1)

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(b) State the resistance of the component when the potential difference is – 0.7 V.

(1)

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(c) Calculate the resistance of the component when the potential difference is + 0.7 V.

(2)

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Resistance = ...

(d) State a practical use for this component.

(1)

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(Total for Question 13 = 5 marks)

14 (a) Explain what is meant by the work function of a metal.

(1)

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*(b) Observations of the photoelectric effect support the particle theory of light.

State **one** such observation and explain how it supports the particle theory of light.

(3)

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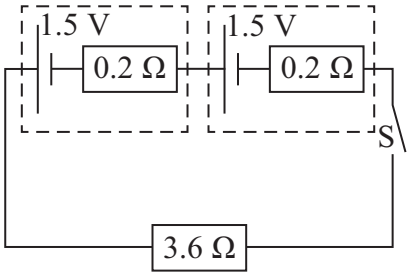
(Total for Question 14 = 4 marks)

15 Electrically heated gloves are used by skiers and climbers to provide extra warmth for their hands.

Each glove has a heating element of resistance 3.6 Ω. Two cells each of e.m.f. 1.5 V and internal resistance 0.2 Ω are used to operate each heating element.



(a) When the switch is closed:

(i) Calculate the total resistance in the circuit

(1)

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Total resistance = ...

(ii) Calculate the current in the heating element

(2)

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Current = ...

(iii) Calculate the power output from the heating element.

(2)

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Power output = ...

(b) When in use the internal resistance of each cell gradually increases.

State and explain the effect this will have on the power output of the heating element.

(3)

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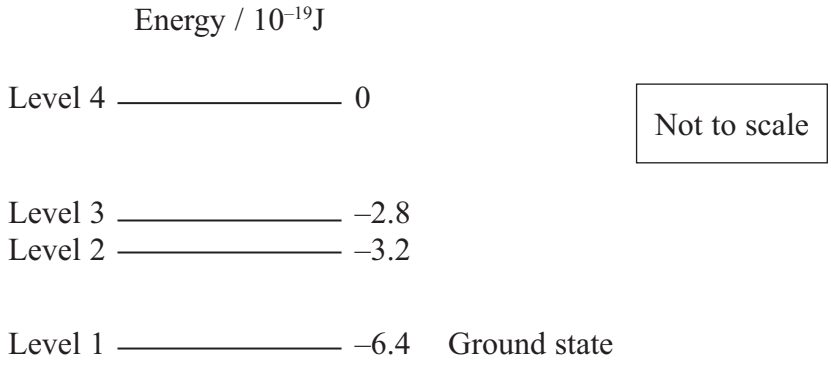
(Total for Question 15 = 8 marks)

16 The diagram shows four energy levels for an electron in a particular atom.



(a) State what is meant by an energy level.

(1)

(b) Draw on the diagram **two** arrows to indicate two different transitions that would result in emitted radiation of the same frequency.

(2)

(c) A gas consisting of these atoms can emit a line spectrum.

Explain how this happens.

(3)

(d) One of these atoms in its ground state absorbs 3.6×10^{-19} J of energy from a collision with an electron.

Calculate the smallest frequency of radiation that the atom may subsequently emit.

(3)

Smallest frequency = ...

(e) Calculate how much energy in eV would be required to ionise the atom in its ground state.

(2)

Energy = ...

(Total for Question 16 = 11 marks)

17 When tidying a prep room, a teacher discovers a tray of resistance wires that have lost their labels. She decides to ask her students to carry out experiments to determine the material that each wire is made of by measuring the resistivity of the wires.

(a) Explain why the teacher asks the students to measure the resistivity and not the resistance of the wires.

(2)

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*(b) You are to describe a method to determine accurately the resistivity of one of the metal wires.

Your description should include:

- the circuit diagram you would use
- the quantities you would measure
- the graph you would plot
- how you would determine the resistivity.

(9)

(Total for Question 17 = 11 marks)

18 If certain crystals are subjected to a mechanical stress, a potential difference is generated across them. This is called the piezoelectric effect. These crystals can be produced as very thin films.

Below is a photograph of a T-shirt with a built-in phone charger, which is being tested at a music festival. The white rectangle is a piezoelectric film.

(a) By considering how a sound wave travels through the air, explain how sound can cause a piezoelectric film to generate a potential difference.

(4)

(b) Explain why the crystals used in the T-shirt need to be in the form of a large, thin film.

(3)

(c) When the T-shirt is used at a music festival the sound levels are sufficient to generate about 20 kJ over ten hours. This is enough to charge one phone.

Calculate the electrical power output.

(3)

Power output = ...

(d) Give **one** advantage and **one** disadvantage of this charger compared with a conventional charger.

(2)

(Total for Question 18 = 12 marks)

19 The 2010 Football World Cup was held in South Africa and is remembered for the noise of the vuvuzelas.

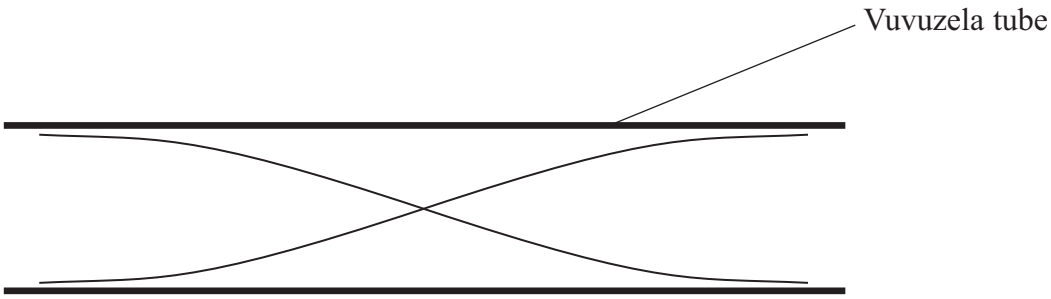
The vuvuzela is a musical instrument which works by making the air inside the vuvuzela vibrate so that a standing wave is produced.

*(a) Explain how a standing wave is produced.

(3)

(b) The vuvuzela makes a noise because it is producing standing waves of different frequencies.

The diagram shows the standing wave with the lowest frequency.



Calculate the frequency of this standing wave.

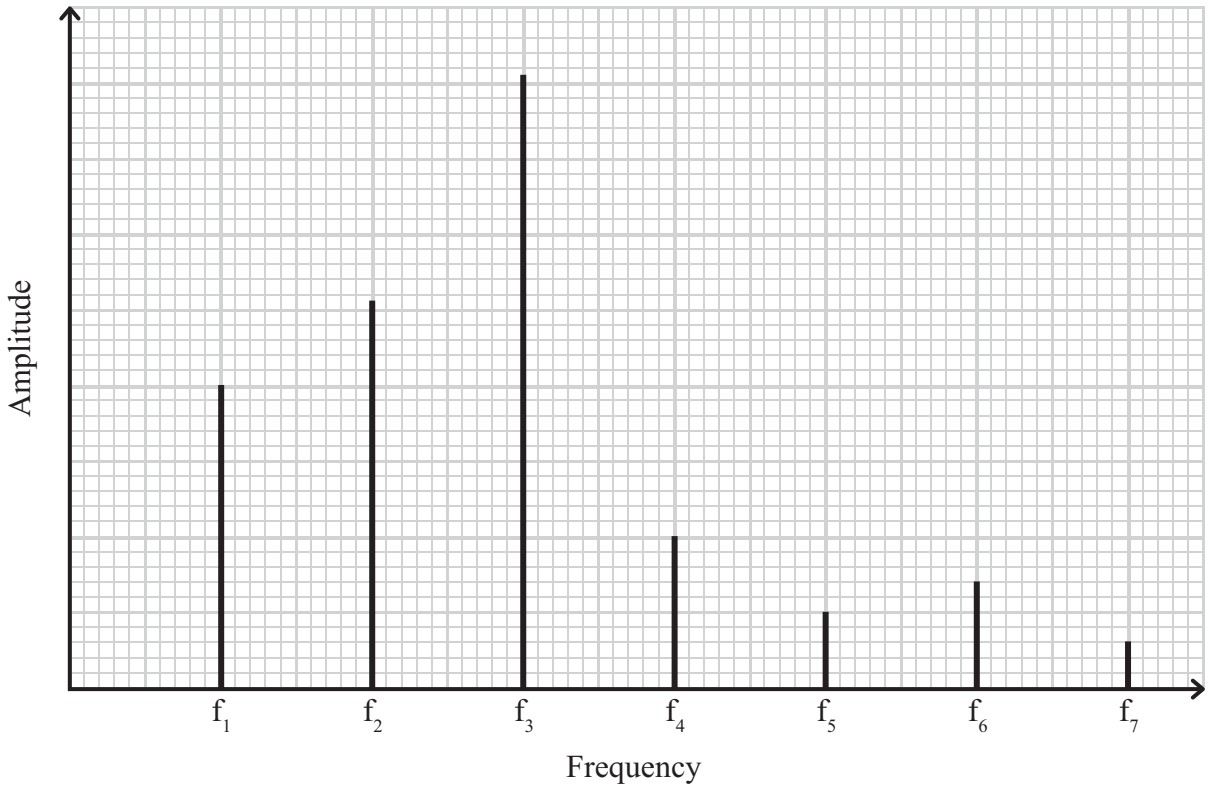
length of the vuvuzela = 60 cm

speed of sound in air = 330 m s^{-1}

(3)

Frequency = ...

(c) Human speech contains a continuous range of frequencies.
When the vuvuzela's sound is analysed it is found to contain only certain fixed frequencies which can be heard by humans.



At the Football World Cup the noise of the vuvuzelas made it difficult for the television commentators to be heard. A solution was to use a filter that removed some of the frequencies produced by the vuvuzelas.

Suggest which **two** frequencies it would be best to remove, the effect this would have and the disadvantage of removing all of the frequencies.

(3)

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(d) Noise cancelling headphones work by detecting a sound and producing another sound that is in antiphase and so causing destructive interference.

(i) Explain what is meant by antiphase and destructive interference.

(3)

(ii) Explain why the headphones could not be used to cancel the noise of the vuvuzelas.

(1)

(Total for Question 19 = 13 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

Do not write outside the box

Answer **all** questions in the spaces provided.

1 (a) (i) State **two** vector quantities.

vector quantity 1 .....

vector quantity 2 .....

1 (a) (ii) State **two** scalar quantities.

scalar quantity 1 .....

scalar quantity 2 .....

(2 marks)

1 (b) The helicopter shown in **Figure 1a** is moving horizontally through still air. The lift force from the helicopter's blades is labelled **A**.

Figure 1a

not to scale

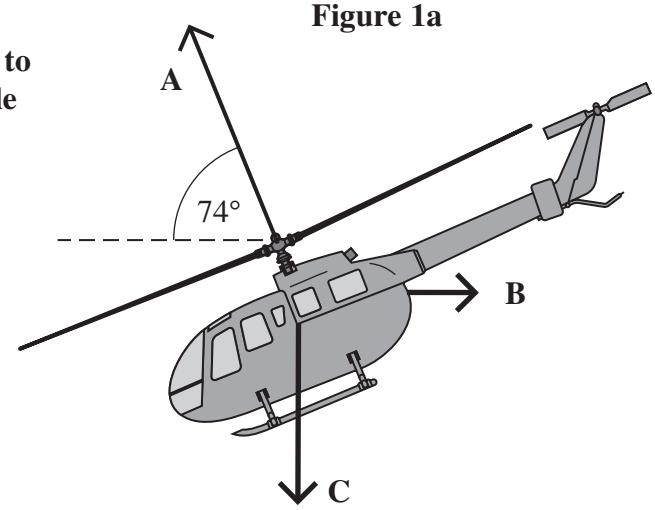

Figure 1b

1 (b) (i) Name the two forces **B** and **C** that also act on the helicopter.

B .....

C .....

(2 marks)

1 (b) (ii) The force vectors are also shown arranged as a triangle in **Figure 1b**.

State and explain how **Figure 1b** shows that the helicopter is moving at a constant velocity.

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(2 marks)

1 (c) The lift force, **A**, is 9.5 kN and acts at an angle of 74° to the horizontal.

Calculate the weight of the helicopter. Give your answer to an appropriate number of significant figures.

answer = ... N

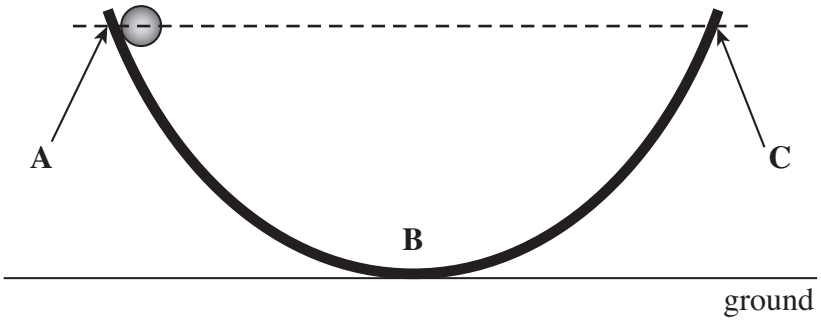
(3 marks)

9

Turn over for the next question

2 In the 17th century, when thinking about forces, Galileo imagined a ball moving in the absence of air resistance on a frictionless track as shown in **Figure 2**.

Figure 2



2 (a) Galileo thought that, under these circumstances, the ball would reach position **C** if released from rest at position **A**. Position **C** is the same height above the ground as **A**.

Using ideas about energy, explain why Galileo was correct.

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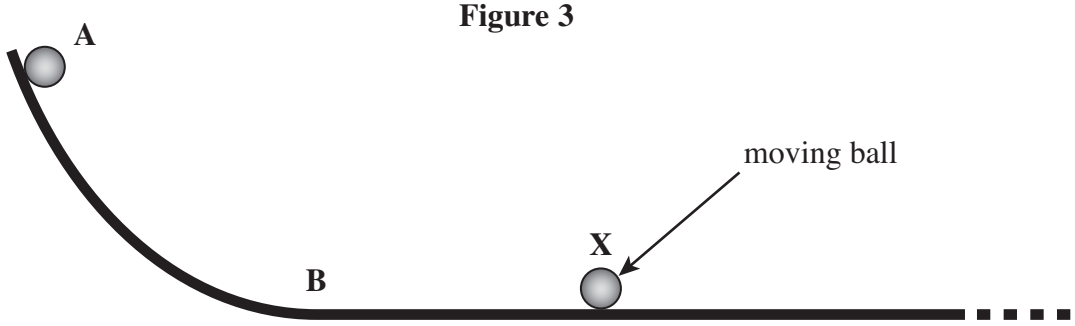
(3 marks)

Do not write outside the box

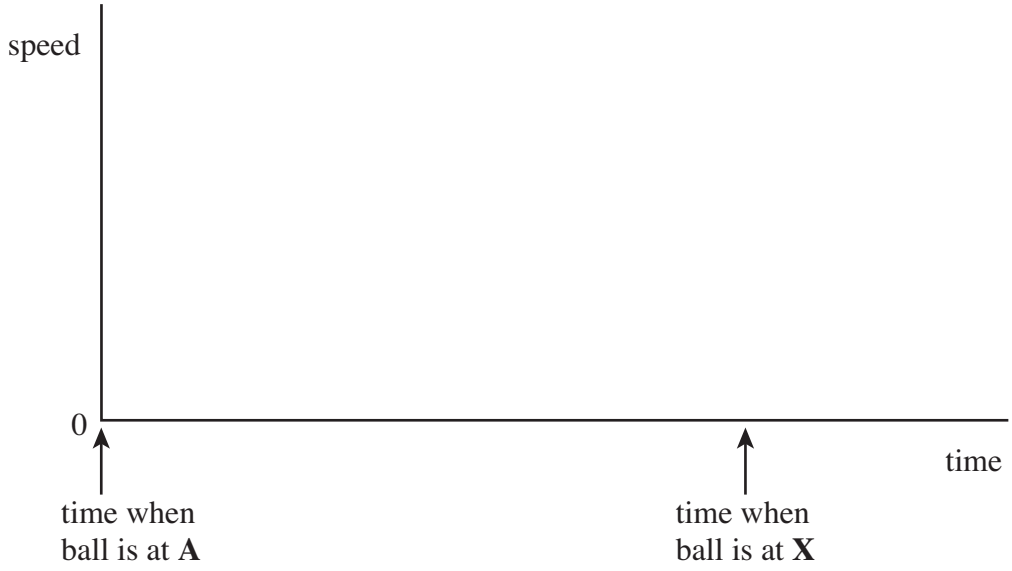
2 (b) Galileo then imagined that the track was changed, as shown in **Figure 3**.

Figure 3



The slope beyond **B** was now horizontal.

On the axes below, sketch a speed – time graph for the ball from its release at **A** until it reaches the position **X** shown in **Figure 3**. Indicate on your graph the time when the ball is at **B**.



(3 marks)

2 (c) Newton later published his three laws of motion.

Explain how Newton's first law of motion is illustrated by the motion of the ball between **B** and **X**.

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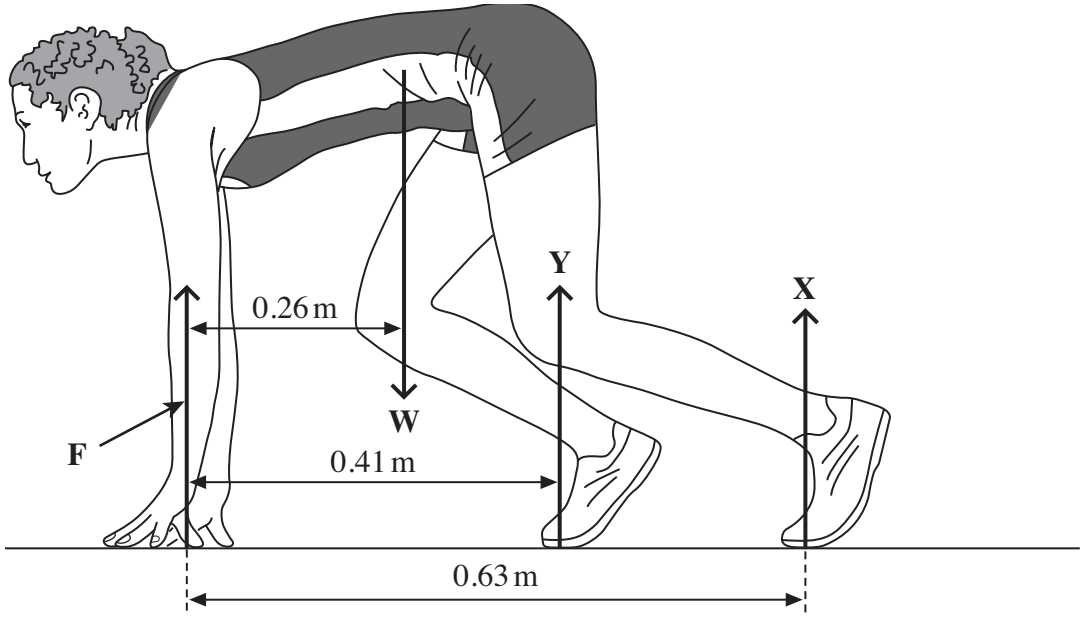
(2 marks)

8

Do not write outside the box

3 A sprinter is shown before a race, stationary in the 'set' position, as shown in **Figure 4**. Force **F** is the resultant force on the sprinter's finger tips. The reaction force, **Y**, on her forward foot is 180 N and her weight, **W**, is 520 N. **X** is the vertical reaction force on her back foot.

Figure 4



3 (a) (i) Calculate the moment of the sprinter's weight, **W**, about her finger tips.
Give an appropriate unit.

answer = ... unit .....
(2 marks)

3 (a) (ii) By taking moments about her finger tips, calculate the force on her back foot, marked **X**.

answer = ...N
(3 marks)

Do not write outside the box

3 (a) (iii) Calculate the force **F**.

answer = ...N
(1 mark)

3 (b) The sprinter starts running and reaches a horizontal velocity of 9.3 m s^{-1} in a distance of 35 m.

3 (b) (i) Calculate her average acceleration over this distance.

answer = ...m s^{-2}
(2 marks)

3 (b) (ii) Calculate the resultant force necessary to produce this acceleration.

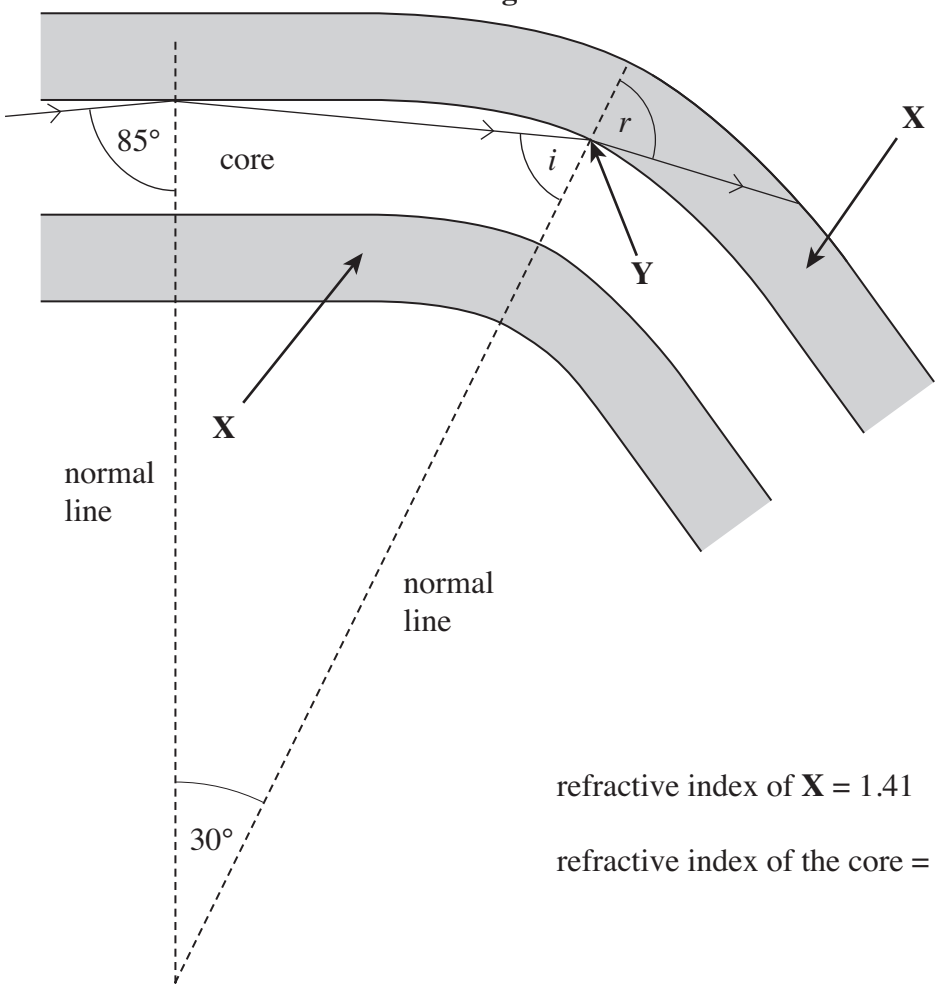
answer = ...N
(2 marks)

10

Do not write outside the box

4 **Figure 5** shows a cross-section through an optical fibre used for communications.

Figure 5



4 (a) (i) Name the part of the fibre labelled **X**.

.....

(1 mark)

4 (a) (ii) Calculate the critical angle for the boundary between the core and **X**.

answer = ...degrees

(2 marks)

Do not write outside the box

4 (b) (i) The ray leaves the core at **Y**. At this point the fibre has been bent through an angle of 30° as shown in **Figure 5**.

Calculate the value of the angle *i*.

answer = ...degrees
(1 mark)

4 (b) (ii) Calculate the angle *r*.

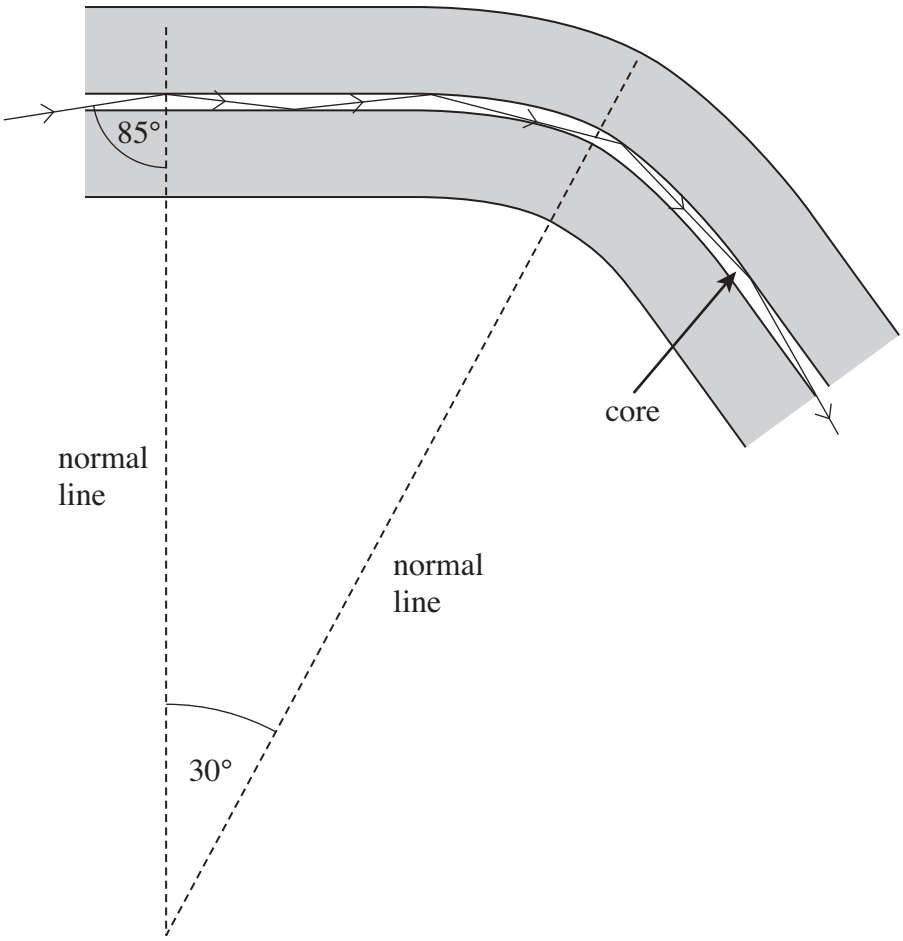
answer = ...degrees
(2 marks)

Question 4 continues on the next page

Do not write outside the box

4 (c) The core of another fibre is made with a smaller diameter than the first, as shown in **Figure 6**. The curvature is the same and the path of a ray of light is shown.

Figure 6



4 (c) State and explain **one** advantage associated with a smaller diameter core.

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(2 marks)

8

Do not write outside the box

5 (a) Describe an experiment to accurately determine the spring constant k of a spring that is thought to reach its limit of proportionality when the load is about 20 N.

Include details of the necessary measurements and calculations and describe how you would reduce uncertainty in your measurements. A space is provided for a labelled diagram should you wish to include one.

The quality of your written communication will be assessed in this question.

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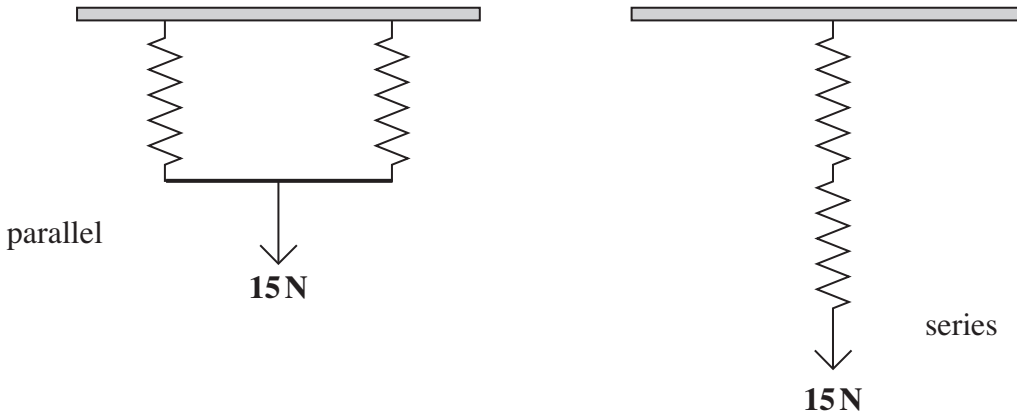
(6 marks)

5 (b) Two identical springs, each having a spring constant of $85\,N\,m^{-1}$, are shown arranged in parallel and series in **Figure 7**.

Figure 7



A load of 15 N is attached to each arrangement.

5 (b) (i) Calculate the extension for the parallel arrangement when the load is midway between the lower ends of the springs.

answer = ... m

(2 marks)

5 (b) (ii) Calculate the extension for the series arrangement.

answer = ... m

(2 marks)

5 (b) (iii) Calculate the energy stored in the parallel arrangement.

answer = ... J

(2 marks)

5 (b) (iv) Without further calculation, discuss whether the energy stored in the series arrangement is less, or greater, or the same as in the parallel arrangement.

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(3 marks)

15

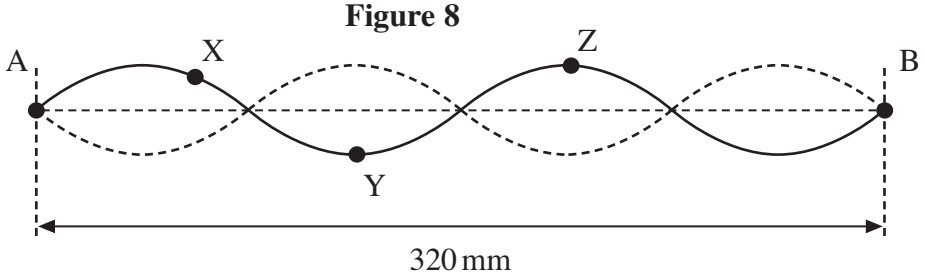
Turn over for the next question

Do not write outside the box

6 When a note is played on a violin, the sound it produces consists of the fundamental and many overtones.

Figure 8 shows the shape of the string for a stationary wave that corresponds to one of these overtones. The positions of maximum and zero displacement for one overtone are shown. Points **A** and **B** are fixed. Points **X**, **Y** and **Z** are points on the string.

Figure 8



6 (a) (i) Describe the motion of point **X**.

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.....

(2 marks)

6 (a) (ii) State the phase relationship between

X and **Y** .....

X and **Z** .....

(2 marks)

6 (b) The frequency of this overtone is 780 Hz.

6 (b) (i) Show that the speed of a progressive wave on this string is about 125 m s^{-1}

(2 marks)

Do not write outside the box

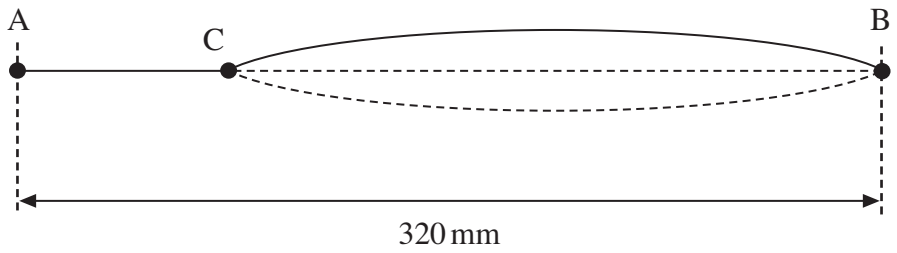
6 (b) (ii) Calculate the time taken for the string at point **Z** to move from maximum displacement back to zero displacement.

answer = ... s

(3 marks)

6 (c) The violinist presses on the string at **C** to shorten the part of the string that vibrates. **Figure 9** shows the string between **C** and **B** vibrating in its fundamental mode. The length of the whole string is 320 mm and the distance between **C** and **B** is 240 mm.

Figure 9



6 (c) (i) State the name given to the point on the wave midway between **C** and **B**.

.....

(1 mark)

6 (c) (ii) Calculate the wavelength of this stationary wave.

answer = ...m

(2 marks)

Do not write outside the box

6 (c) (iii) Calculate the frequency of this fundamental mode. The speed of the progressive wave remains at $125\,m\,s^{-1}$.

13

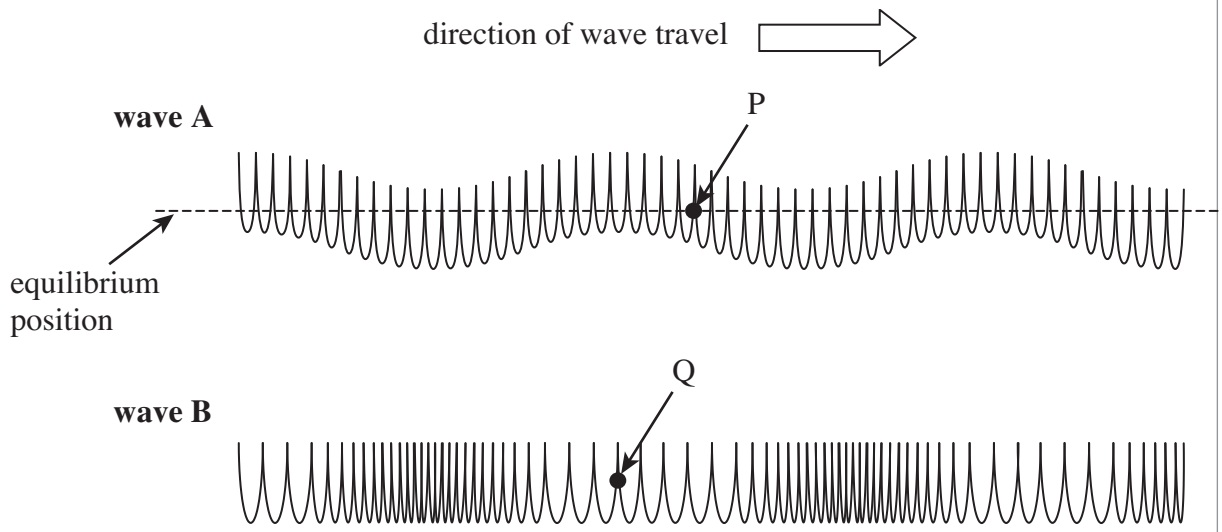
answer = ...Hz

(1 mark)

Do not write outside the box

7 **Figure 10** shows two ways in which a wave can travel along a slinky spring.

Figure 10



7 (a) State and explain which wave is longitudinal.

.....

.....

(2 marks)

7 (b) On **Figure 10**,

7 (b) (i) clearly indicate and label the wavelength of **wave B**

(1 mark)

7 (b) (ii) use arrows to show the direction in which the points **P** and **Q** are about to move as each wave moves to the right.

(2 marks)

7 (c) Electromagnetic waves are similar in nature to **wave A**.

Explain why it is important to correctly align the aerial of a TV in order to receive the strongest signal.

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(2 marks)

END OF QUESTIONS

7

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which pair of quantities does **not** contain a vector and a scalar?

☒ **A** acceleration and time

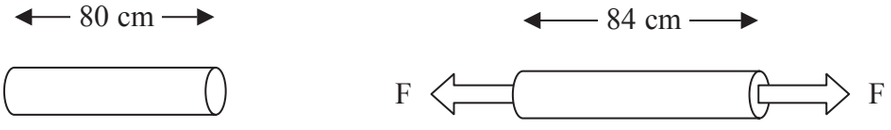
☒ **B** force and displacement

☒ **C** mass and acceleration

☒ **D** velocity and time

(Total for Question 1 = 1 mark)

2 A wire of length 80 cm has a force F applied. The new length of the wire is 84 cm.



The strain is given by

☒ **A** $\frac{4}{84}$

☒ **B** $\frac{4}{80}$

☒ **C** $\frac{80}{84}$

☒ **D** $\frac{84}{80}$

(Total for Question 2 = 1 mark)

3 Which of the following is a derived SI quantity?

☒ **A** force

☒ **B** length

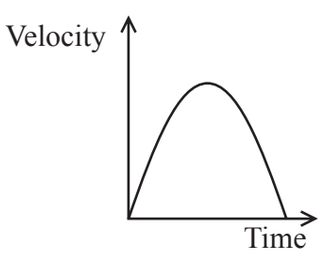
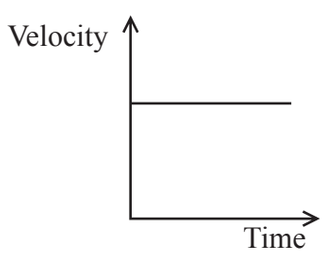
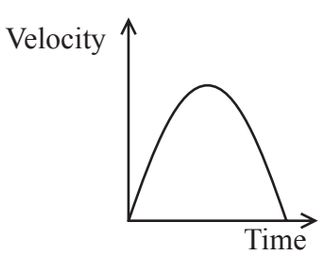
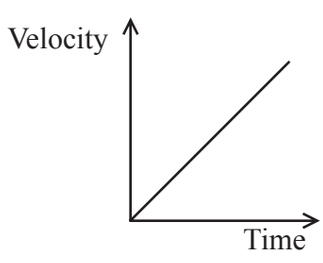
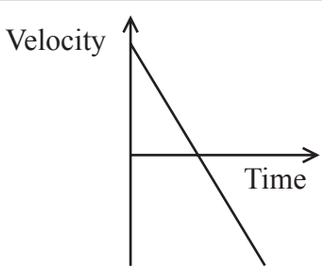
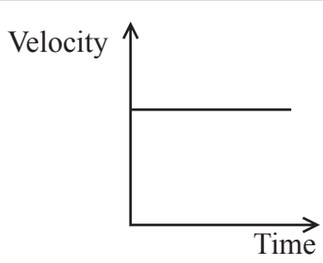
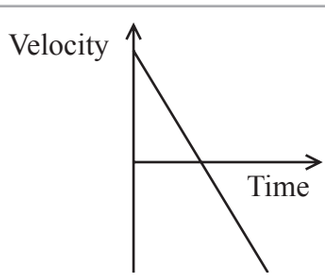
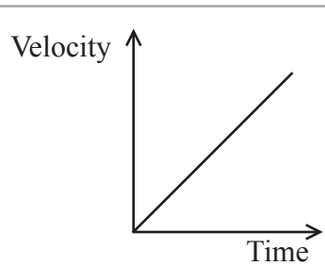
☒ **C** second

☒ **D** watt

(Total for Question 3 = 1 mark)

4 A projectile is launched at an angle of 45° to the horizontal.

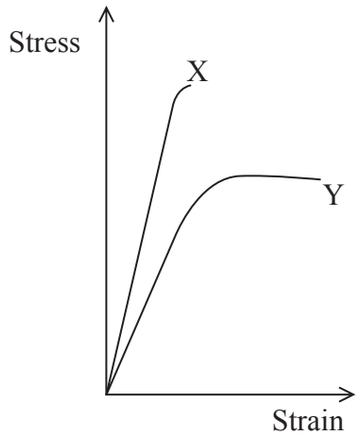
Ignoring air resistance, which pair of graphs correctly shows how the vertical and horizontal components of velocity vary with time for the projectile until it lands?

	Vertical component	Horizontal component
☒ **A**		
☒ **B**		
☒ **C**		
☒ **D**		

(Total for Question 4 = 1 mark)

Turn over ▶

5 The graph shows stress against strain up to the breaking point for two materials X and Y.

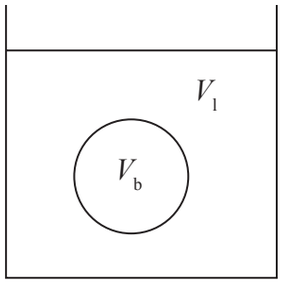


Which row in the table correctly identifies the behaviour of each material?

	X	**Y**
☒ **A**	brittle	ductile
☒ **B**	ductile	brittle
☒ **C**	ductile	hard
☒ **D**	brittle	hard

(Total for Question 5 = 1 mark)

6 A ball of volume V_b and density ρ_b is released in a volume V_l of liquid with density ρ_l.



The upthrust on the ball is given by

☒ **A** $V_b \rho_b g$

☒ **B** $V_b \rho_l g$

☒ **C** $V_l \rho_b g$

☒ **D** $V_l \rho_l g$

(Total for Question 6 = 1 mark)

7 A hanging basket of weight W is supported by three chains of equal length, each at an angle θ to the vertical.

The tension, T, in each chain is given by

☒ **A** $T = \dfrac{3W}{\cos\theta}$

☒ **B** $T = \dfrac{3W}{\sin\theta}$

☒ **C** $T = \dfrac{W}{3\cos\theta}$

☒ **D** $T = \dfrac{W}{3\sin\theta}$

(Total for Question 7 = 1 mark)

Turn over ▶

8 Which of the following descriptions of a material implies that it undergoes significant plastic deformation?

☒ **A** brittle

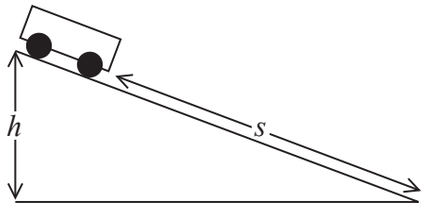
☒ **B** hard

☒ **C** malleable

☒ **D** stiff

(Total for Question 8 = 1 mark)

9 A trolley rolls down a slope from rest. The trolley moves through a vertical height h while rolling a distance s along the slope.



The maximum possible speed is given by

☒ **A** $2gs$

☒ **B** $2gh$

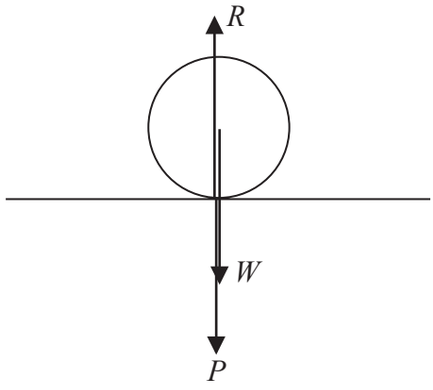
☒ **C** $\sqrt{(2gs)}$

☒ **D** $\sqrt{(2gh)}$

(Total for Question 9 = 1 mark)

10 An apple is at rest on the ground.

The diagram shows three forces of equal magnitude.



W = weight of apple

P = push of apple on ground

R = normal contact force of ground on apple

Which row in the table shows Newton's first and third laws being applied correctly.

	Newton's first law	Newton's third law
☒ **A**	$P = W$	$R = P$
☒ **B**	$R = P$	$W = R$
☒ **C**	$W = R$	$P = W$
☒ **D**	$W = R$	$R = P$

(Total for Question 10 = 1 mark)

TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 Viscosity is sometimes given units of kg m^{-1} s^{-1} and sometimes Pa s.

Show that these are equivalent.

(2)

.....

.....

.....

.....

.....

(Total for Question 11 = 2 marks)

12 (a) State what is meant by centre of gravity.

(1)

.....

.....

.....

(b) The picture shows a snooker cue. It is made from wood of uniform density and takes the form of a rod with decreasing diameter towards one end.

(i) On the picture, mark the position of the centre of gravity of the snooker cue.

(1)

(ii) State a simple method to test if this is the correct position.

(1)

.....

.....

(Total for Question 12 = 3 marks)

Turn over ▶

13 Queues of cars often form behind cyclists on narrow, rural roads.

Sometimes cars that would normally travel at 65 km hour^{-1} may be limited to about 20 km hour^{-1} by a cyclist.

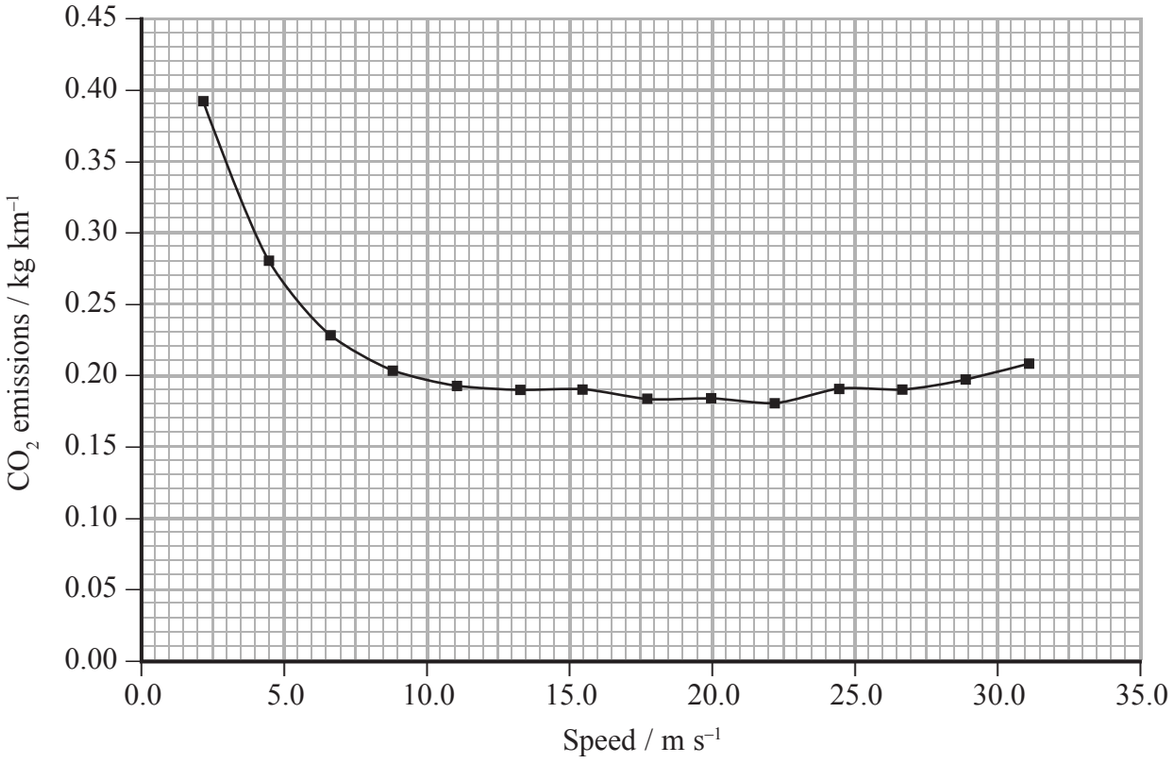
(a) Show that 65 km hour^{-1} is about 18 m s^{-1}.

(1)

.....

.....

(b) The graph shows the amount of carbon dioxide emitted per kilometre by a typical car at different speeds.



During a 10 minute journey a cyclist, travelling at 5 m s^{-1}, has an average of three cars queuing behind him. The cars would otherwise be travelling at 18 m s^{-1}. The cars emit more carbon dioxide because they are travelling slowly.

(i) Calculate the extra carbon dioxide emitted by the 3 cars due to travelling at this reduced speed for 10 minutes.

(4)

Extra carbon dioxide emitted = ...

(ii) If the cyclist had made the same journey in his car at 18 m s^{-1}, his car would have emitted 0.54 kg of carbon dioxide. Comment on the significance of this.

(1)

(Total for Question 13 = 6 marks)

Turn over ▶

14 The gravitational field strength on the Moon is about 1/6 of the gravitational field strength on the Earth.

(a) On the Moon, an astronaut dropped a golf ball. He later wrote "When I dropped the ball, it took about three seconds to land."

Show that the astronaut would need to be over 7 m tall for the ball to take 3 s to land.

(2)

(b) The astronaut hit the ball with a golf club. He wrote "The ball, which would have gone thirty to forty yards on the Earth, went over two hundred yards. The ball stayed up in the black sky for almost thirty seconds."

Assume an initial velocity of 18 m s^{-1} at 34° to the horizontal.

(i) Show that the astronaut's suggested time of flight of 30 s is over twice the actual value.

(3)

(ii) Show that the value given for the initial velocity leads to a value for the horizontal distance travelled by the ball in agreement with his stated value.

200 yards = 183 m

(3)

*(c) A projectile would have a greater range on the Moon than the Earth because of the lower gravitational field strength and because of the lack of an atmosphere.

Explain how each of these factors would increase the range of the projectile.

(3)

(Total for Question 14 = 11 marks)

Turn over ▶

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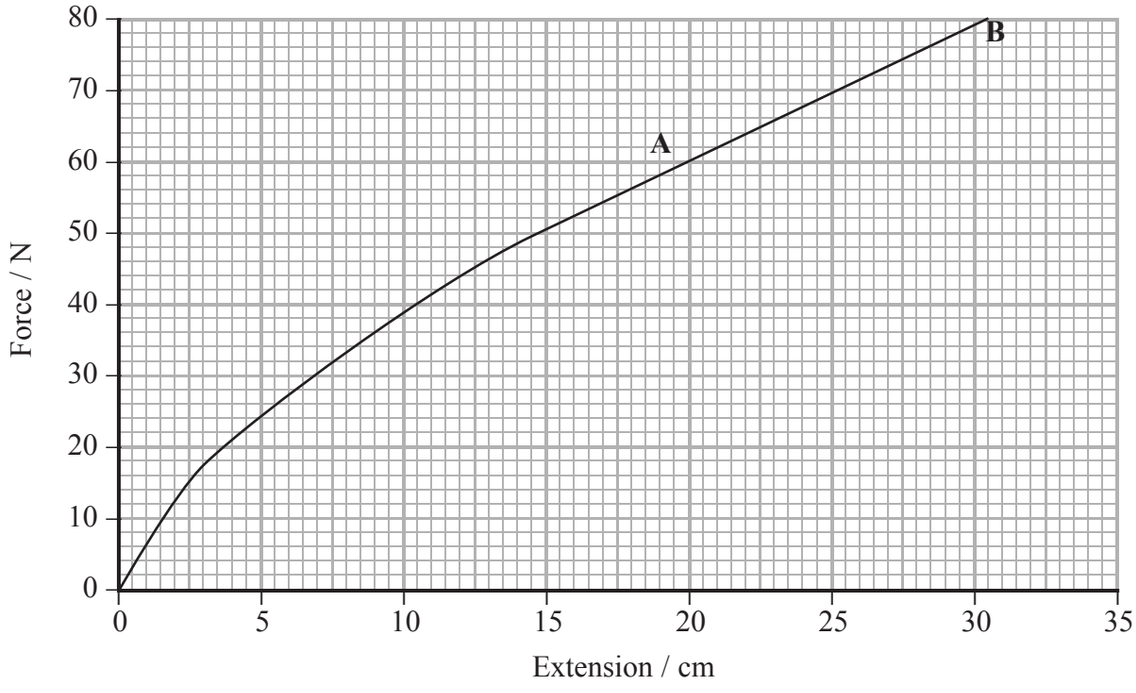
15 The photographs show an exercise device and someone using it. The device contains two rubber cords which are extended when the device is used.

A student investigates the properties of the device by hanging weights on it and measuring the extension.

The student obtains the following graph for her results.



Turn over ▶

(a) The student notices that her graph is a straight line between A and B and concludes that the device obeys Hooke's law.

Comment on this conclusion.

(2)

.....

.....

.....

(b) (i) Describe how the student could use the graph to obtain an estimate of the total work done.

(2)

.....

.....

.....

.....

(ii) The student sets up a spreadsheet to investigate the work done in stretching the device each time a weight is added.

	A	B	C	D
1	Total stretching force / N	Extension / cm	Change in extension / m	Work done (force × change in extension) / J
2	0	0.0	0.000	0.00
3	10	1.6	0.016	0.16
4	20	3.5	0.019	0.38
5	30	7.0	0.035	1.05
6	40	10.5	0.035	1.40
7	50	14.5	0.040	2.00
8	60	20.0	0.055	3.30
9	70	25.2	0.052	3.64
10	80	30.5	0.053	4.24
11			Total work done	16.17

Explain why this spreadsheet results in an over-estimate for the total work done.

(2)

(c) The student eats a packet of crisps and then uses the exercise device. The energy content in a packet of crisps is 540 kJ. During exercise this energy is converted and 25% of it is transferred to mechanical work.

The student extends the device fully 15 times in 1 minute. An accurate value for the work done in fully extending the device is 14.7 J.

Calculate the time it would take the student, working at this rate, to transfer 25% of the energy from the crisps to mechanical work.

(3)

Time = ...

(d) Explain whether more or less work would be done applying the same maximum total stretching force to a similar exercise device with rubber cords of twice the cross-sectional area.

(2)

(Total for Question 15 = 11 marks)

Turn over ▶

16 The 'Stealth' roller coaster at the Thorpe Park theme park is advertised as reaching 135 km hour^{-1} from rest in 2.3 seconds.

Most roller coasters are driven slowly up to the top of a slope at the start of the ride. However the carriages on 'Stealth' are initially accelerated horizontally from rest at ground level by a hydraulic launch system, before rising to the top of the first slope.

(a) (i) Calculate the average acceleration of the carriages.

135 km hour^{-1} = 37.5 m s^{-1}

(2)

Average acceleration = ...

(ii) Calculate the minimum average power which must be developed by the launch system.

mass of carriages and passengers = 10 000 kg

(3)

Minimum average power = ...

(iii) Suggest why the power in (ii) is a minimum value.

(1)

*(b) The force required to launch 'Stealth' is not always the same. The ride is monitored and the data from preceding launches is used to calculate the required force.

If the mass of the passengers for a particular ride is significantly more than for preceding launches, this can lead to 'rollback'. This is when the carriages do not quite reach the top of the first slope and return backwards to the start.

Explain why 'rollback' would occur in this situation.

(3)

(c) Suggest why roller coasters may have a greater acceleration when the lubricating oil between the moving parts has had time to warm up.

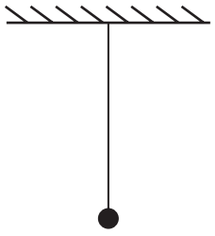
(2)

(Total for Question 16 = 11 marks)

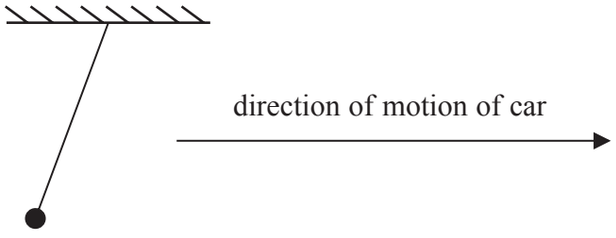
Turn over ▶

17 Many hand held devices such as smartphones and tablet computers contain accelerometers. These allow changes in orientation of the device to be tracked.

A student models a simple accelerometer by attaching a small mass on a string to the roof of a car.



When the car starts moving, the string is seen to change position as shown below.



(a) (i) Complete a free body force diagram for the mass when the car starts moving.

(2)

(ii) Draw a vector diagram, in the space below, to show how the resultant force on the mass is produced.

(2)

(iii) When the string is at 7° to the vertical, show that the acceleration of the car is about 1 m s^{-2}.

(2)

(b) Sketch the positions of the mass and string when the car is moving in the same direction and is:

(i) moving with constant velocity,

(ii) undergoing a much greater acceleration than in (a)(iii),

(iii) decelerating.

(3)

(i) moving with constant velocity,	(ii) undergoing a much greater acceleration than in (a)(iii),	(iii) decelerating.
		

(c) Explain why the string would **not** become horizontal, however great the acceleration.

(2)

(d) Suggest why many devices contain 3 accelerometers, arranged at right angles to each other.

(1)

(Total for Question 17 = 12 marks)

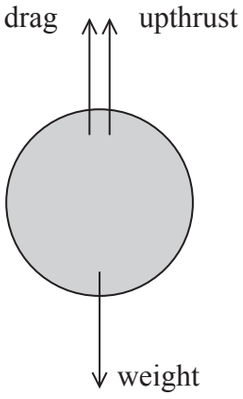
Turn over ▶

18 The Greek philosopher Aristotle (4th Century BC) stated that heavy objects fall more quickly than lighter objects.

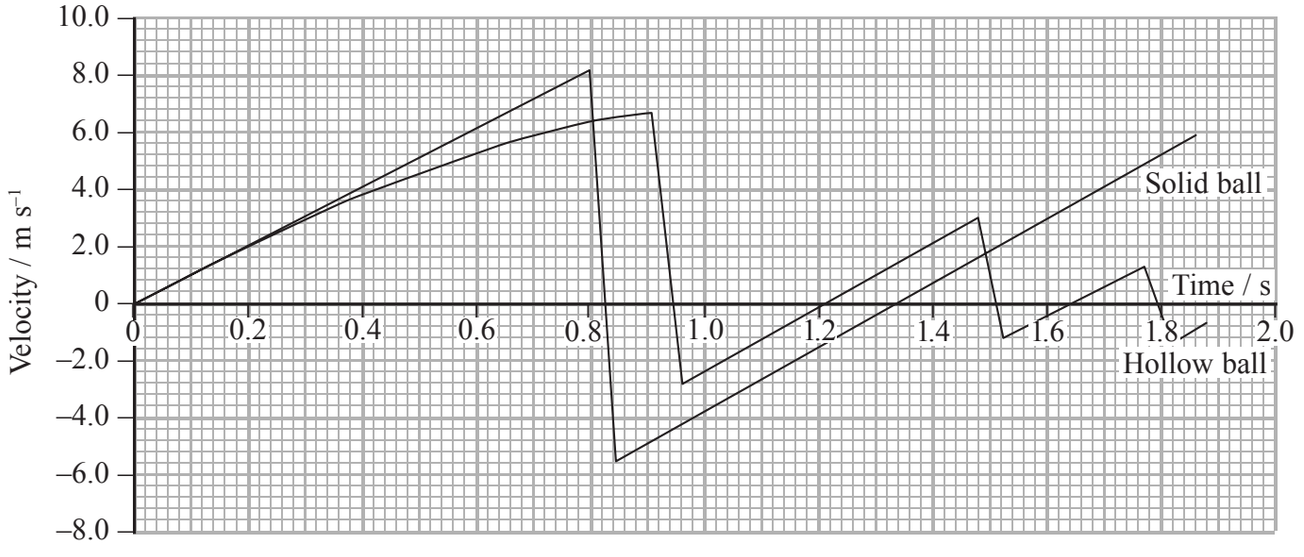
In the 17th Century Galileo reported that a cannon ball and a much smaller musket ball, dropped at the same time, reached the ground together.

A student carries out an experiment, dropping two balls of the same size at the same time. One of the balls is hollow and the other is solid.

The diagram shows the forces acting on each ball as it falls.



The velocity-time graph shows the motion of the two balls from the time they are dropped.



(a) State how the graphs show that neither ball reaches terminal velocity.

(1)

.....

.....

.....

(b) (i) By drawing a tangent to the graph, show that the acceleration of the hollow ball at time $t = 0.60$ s is about $7\,ms^{-2}$.

(2)

(ii) Show that the resultant force on the hollow ball at $t = 0.60$ s is about 0.02 N.

mass of hollow ball = 2.4 g

(2)

(iii) Show that the drag force on the hollow ball at $t = 0.60$ s is about 0.01 N. You may neglect upthrust.

(2)

(iv) Demonstrate that the Stokes' law force is **not** sufficient to produce this drag force.

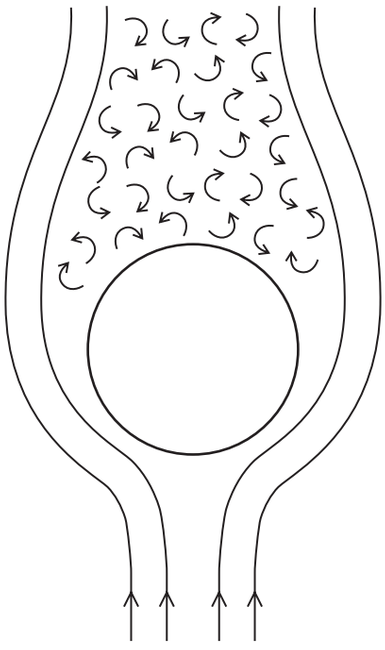
radius of hollow ball = 2.0 cm

viscosity of air = 1.8×10^{-5} Pa s

(2)

Turn over ▶

(c) The diagram shows the air flow around the hollow ball as it falls.



(i) Add labels to show laminar flow and turbulent flow.

(1)

(ii) Suggest why the drag is much greater than the Stokes' law force.

(1)

(d) Without further calculation, use the graph to describe the motion of the solid ball.

(3)

(Total for Question 18 = 14 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

SECTION A

Answer ALL questions.

For questions 1–10, in Section A, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Which of the following is a vector quantity?

☒ **A** kinetic energy

☒ **B** mass

☒ **C** power

☒ **D** velocity

(Total for Question 1 = 1 mark)

---

2 Which of these statements about work is **not** correct?

☒ **A** For work to be done a force must always be applied.

☒ **B** When work is done energy is transferred.

☒ **C** Work done is the product of force and distance moved perpendicular to the force.

☒ **D** Work done is a scalar quantity.

(Total for Question 2 = 1 mark)

---

3 Concrete pillars may be used to support heavy roofs.

Concrete is used because it has a

☒ **A** high compressive strength.

☒ **B** high tensile strength.

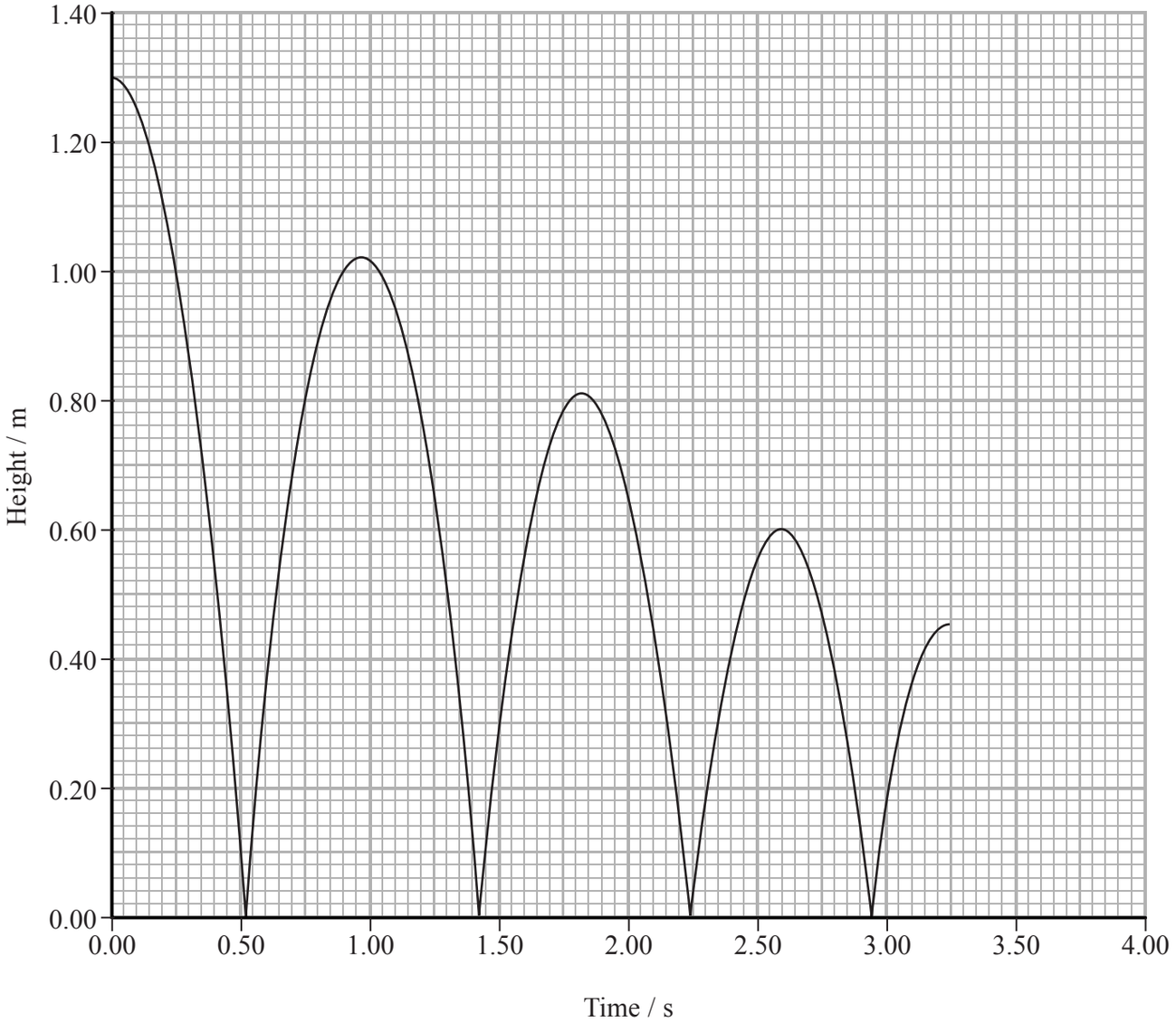
☒ **C** low stiffness.

☒ **D** low Young modulus.

(Total for Question 3 = 1 mark)

Questions 4, 5 and 6 refer to the graph below.

A ball is dropped from a height of 1.3 m. The graph shows how the height above the ground varies with time for several bounces.



4 At 2.6 s the magnitude of the displacement from the starting position is

- ☒ **A** 0.20 m
- ☒ **B** 0.60 m
- ☒ **C** 0.70 m
- ☒ **D** 1.30 m

(Total for Question 4 = 1 mark)

5 How can the velocity of the ball at time $t = 2.5$ s be determined from the graph?

☒ **A** Calculate the area between the graph and the time axis up to $t = 2.5$ s.

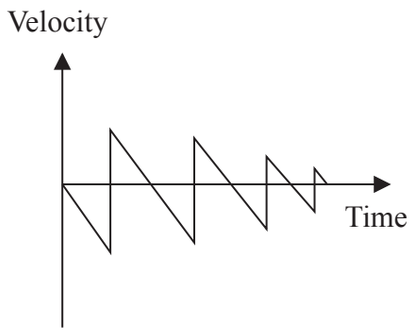
☒ **B** Divide the displacement at $t = 2.5$ s by 2.5 s.

☒ **C** Divide the height at $t = 2.5$ s by 2.5 s.

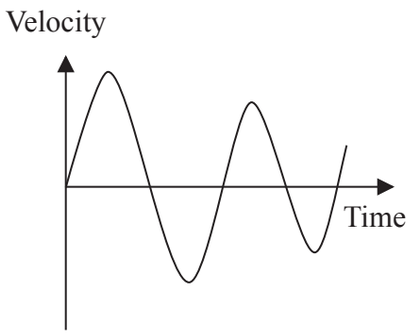
☒ **D** Draw a tangent to the graph at $t = 2.5$ s and calculate its gradient.

(Total for Question 5 = 1 mark)

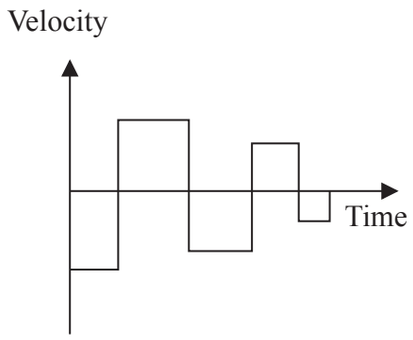
6 Which of the following graphs could be the velocity-time graph for the ball?



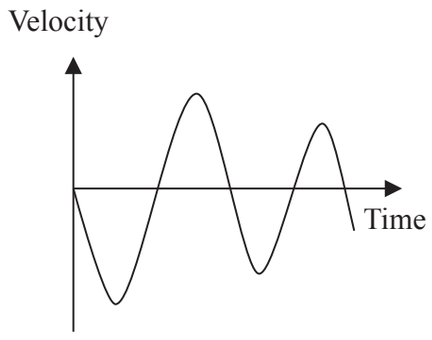
A



B



C



D

☒ **A**

☒ **B**

☒ **C**

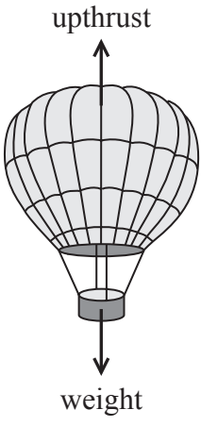
☒ **D**

(Total for Question 6 = 1 mark)

Turn over ▶

Questions 7 and 8 refer to the diagram below.

The diagram shows the forces acting on a hot air balloon when at a constant height.

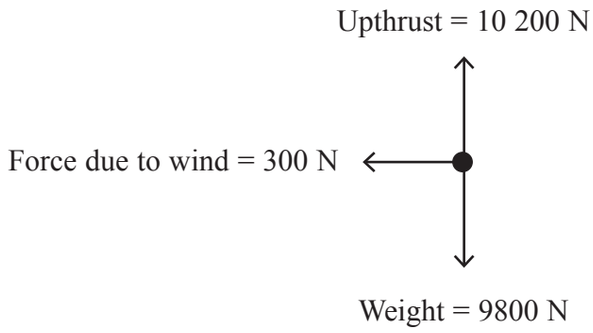


7 Select the row in the table that correctly describes the situation when the air in the balloon is heated.

	Observation	Reason
☒ **A**	Balloon rises	Weight > Upthrust
☒ **B**	Balloon falls	Weight > Upthrust
☒ **C**	Balloon rises	Weight < Upthrust
☒ **D**	Balloon falls	Weight < Upthrust

(Total for Question 7 = 1 mark)

8 Below is a free-body force diagram for the balloon when a wind is blowing.



The magnitude of the resultant force acting on the balloon is

☒ **A** 400 N

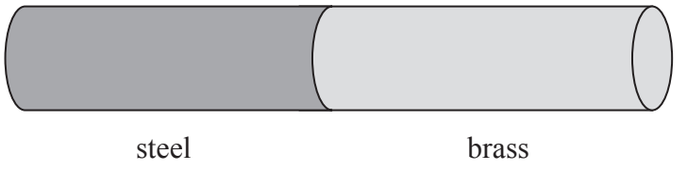
☒ **B** 500 N

☒ **C** 700 N

☒ **D** 9 805 N

(Total for Question 8 = 1 mark)

9 A steel wire and a brass wire, with identical cross sectional areas and lengths, are fused together. The Young modulus for steel is approximately twice that of brass.



The combined wire is stretched.

The ratio $\frac{\text{extension of steel wire}}{\text{extension of brass wire}}$ is approximately

☒ **A** 2.0

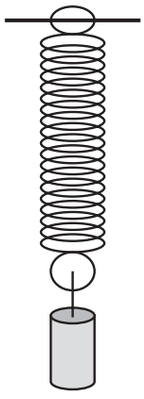
☒ **B** 1.0

☒ **C** 0.50

☒ **D** 0.25

(Total for Question 9 = 1 mark)

10 A spring is suspended from a bar. When a load of 6.0 N is added to the bottom of the spring, its length changes from 0.040 m to 0.13 m.



To find the spring constant of the spring you would use

☒ **A** $\frac{0.13\,\text{m}}{6.0\,\text{N}}$

☒ **B** $\frac{6.0\,\text{N}}{0.13\,\text{m}}$

☒ **C** $\frac{6.0\,\text{N}}{0.090\,\text{m}}$

☒ **D** $\frac{0.090\,\text{m}}{6.0\,\text{N}}$

(Total for Question 10 = 1 mark)

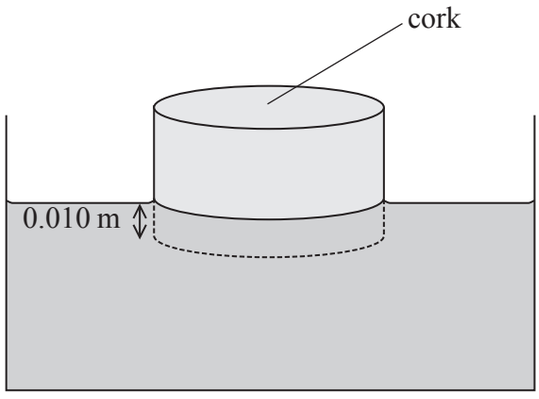
TOTAL FOR SECTION A = 10 MARKS

SECTION B

Answer ALL questions in the spaces provided.

11 A cylinder of cork of cross-sectional area 5.0×10^{-3} m^2 floats on water with its axis vertical. The length of the cork below the surface of the water is 0.010 m.

density of water = 1000 kg m^{-3}



(a) Show that the weight of water displaced by the cork is about 0.5 N.

(3)

(b) State the weight of the cork and justify your answer.

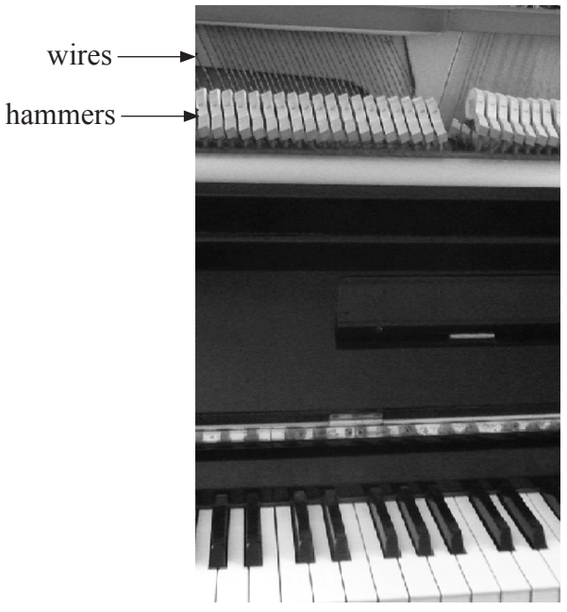
(2)

(Total for Question 11 = 5 marks)

Turn over ▶

12 When a note is played on a piano, a soft hammer is made to hit a wire. This causes the wire to vibrate creating a sound.

The wires used in pianos are hard, stiff and have a high tensile strength.



(a) Explain the meaning of the terms hard, stiff and high tensile strength.

(i) Hard

(1)

(ii) Stiff

(1)

(iii) High tensile strength

(1)

*(b) It is important that a piano wire has a high elastic limit.

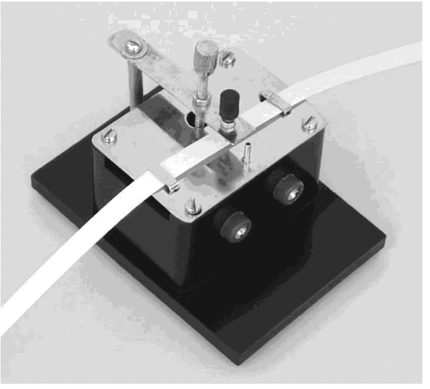
Explain why this is important.

(3)

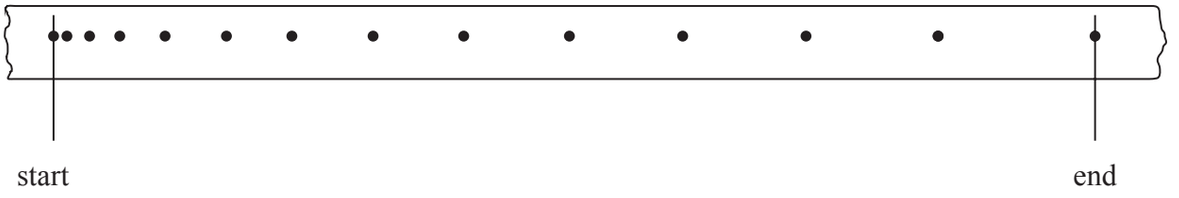
(Total for Question 12 = 6 marks)

Turn over ▶

13 A trolley moves down a ramp from rest. Attached to the trolley is a strip of paper which is pulled through a ticker tape timer. The ticker tape timer makes 50 dots each second on the strip of paper.



The strip of paper is shown below. The start and the end of the journey are indicated.



(a) (i) Using measurements from the tape show that the final velocity of the trolley is about 1 m s^{-1}

(2)

(ii) Hence calculate the average acceleration of the trolley.

(2)

Average acceleration = ...

(b) Using a ticker tape timer is one method of measuring the speed of a moving object in a laboratory. Another method is to use a light gate with a data logger and computer.

Suggest an advantage of using the light gate method rather than using a ticker tape timer.

(1)

(Total for Question 13 = 5 marks)

Turn over ▶

14 The picture shows a track for racing toy electric cars. A guide pin fits in a groove in the track to keep the car on the track. A small electric motor in the car is controlled, with a hand-controller, via contacts in the track.

A child places a car of mass 95 g on the track. She adjusts the controller to a power of 4.2 W so the car accelerates from rest for 0.40 s.

(a) (i) Show that the energy transferred by the motor in 0.40 s is about 2 J.

(2)

.....

.....

.....

(ii) Calculate the speed of the car at 0.40 s.

(2)

.....

.....

.....

Speed = ...

(iii) Suggest why the actual speed of the car is less than the calculated speed.

(1)

.....

.....

(b) At high speed the guide pin may become disengaged from the groove.

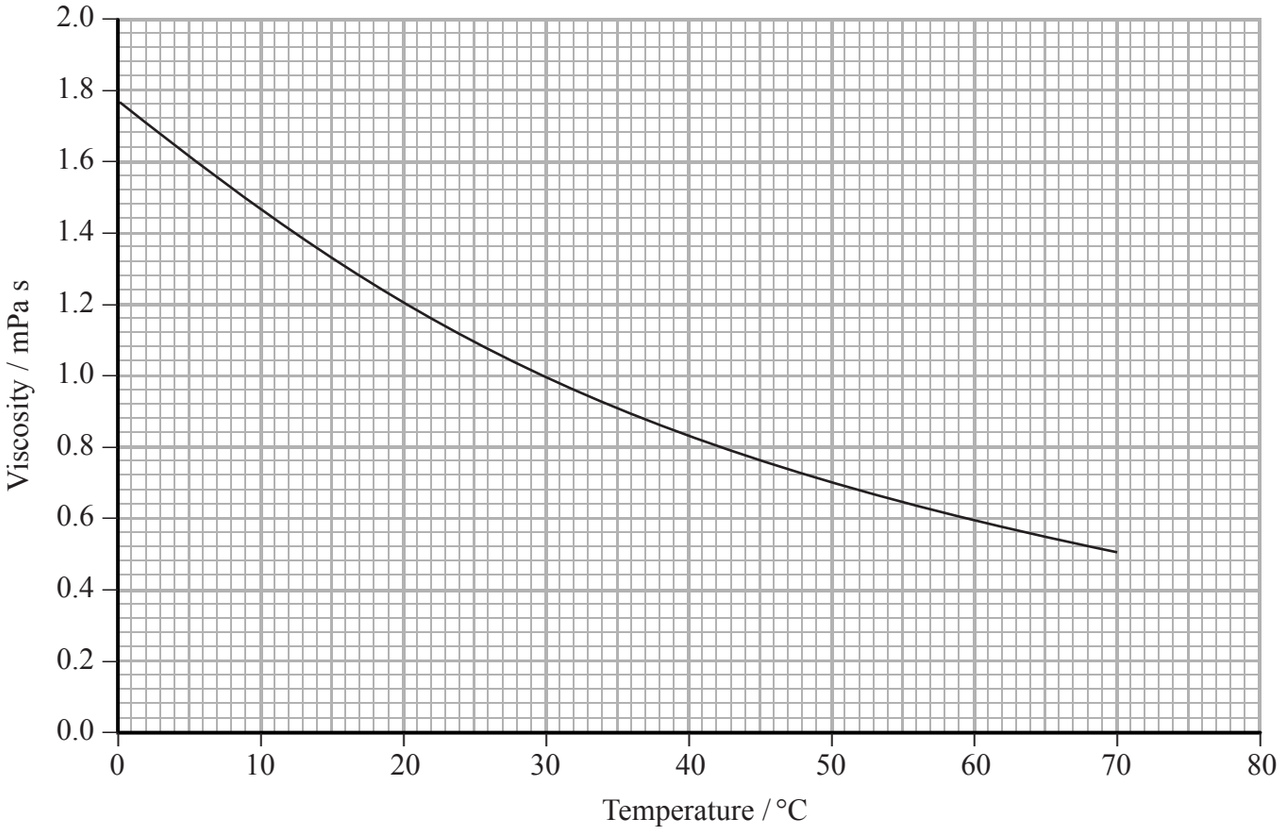
Use Newton's first law to explain why the car would then leave the track at a corner.

(2)

(Total for Question 14 = 7 marks)

Turn over ▶

15 The graph shows how the viscosity of ethanol varies with temperature.



(a) Describe how the viscosity of ethanol varies with temperature.

(2)

(b) (i) Use Stoke's law to show that the SI unit of viscosity is Pa s.

(2)

(ii) A small sphere is dropped into a large volume of ethanol at 24 °C.

Show that, if the drag were due to viscous forces alone, the terminal velocity would be about 4 ms^{-1}.

Assume that upthrust is negligible.

radius of sphere = 5.0×10^{-4} m

room temperature = 24 °C

mass of sphere = 4.0×10^{-6} kg

(3)

Turn over ▶

*(c) Diesel is used as the fuel in some vehicles. Diesel is not renewable, so alternatives are being researched. Biodiesel is a fuel made from vegetable oil; biodiesel on its own is not suitable for use in vehicles.

The table gives some information about diesel, biodiesel and ethanol.

	Viscosity / mPa s at 0 °C	**Viscosity / mPa s at 40 °C**	**Energy / MJ kg^{-1}**	**Freezing point / °C**
Diesel	4.9	2.6	43	–30
Biodiesel	17.3	4.6	39	–12
Ethanol	1.8	0.9	27	–114

Blends of biodiesel with ethanol are being researched as a renewable alternative to diesel fuels for use in vehicles all year round.

Using the information in the table, suggest why these blends are being researched.

(3)

(Total for Question 15 = 10 marks)

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Turn over ▶

16 The photograph shows an athlete performing a long jump.

At take-off his horizontal speed is 8.0 m s^{-1} and his vertical speed is 2.8 m s^{-1}.

(a) Show that the total time the athlete spends in the air is about 0.6 s.

Assume that his centre of gravity is at the same height at take-off and landing.

(3)

(b) Calculate the horizontal distance jumped by the athlete.

(2)

Horizontal distance = ...

(c) In reality, when the athlete lands his centre of gravity is 50 cm lower than its position at take-off.

Calculate the extra horizontal distance this enables the athlete to jump.

(4)

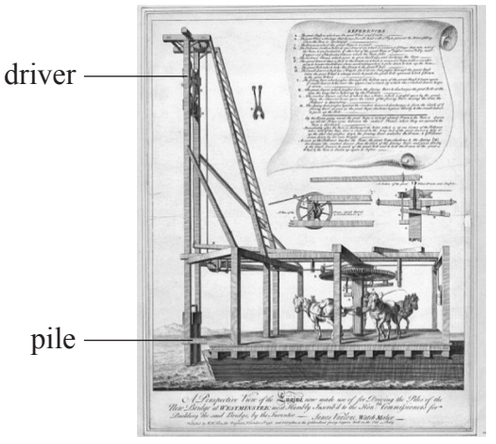
Extra horizontal distance = ...

(Total for Question 16 = 9 marks)

Turn over ▶

17 Pile drivers have been used for centuries to push piles into the ground for use as foundations of buildings and other structures. A large mass (the driver) is raised and then dropped onto an object (the pile) which is pushed into the ground.

The picture shows the pile driver that was used to build a London bridge in the 17th century.



(a) (i) The driver on the pile driver above had a mass of 810 kg and could be dropped a maximum distance of 6.0 m onto the pile.

Show that the energy transferred from the driver is about 50 kJ.

(2)

.....

.....

.....

(ii) In one instance, 40% of this energy is used usefully to drive in the pile. The pile moves 0.20 m into the ground.

Determine the average resistive force acting on the pile as it moves through the ground.

(3)

.....

.....

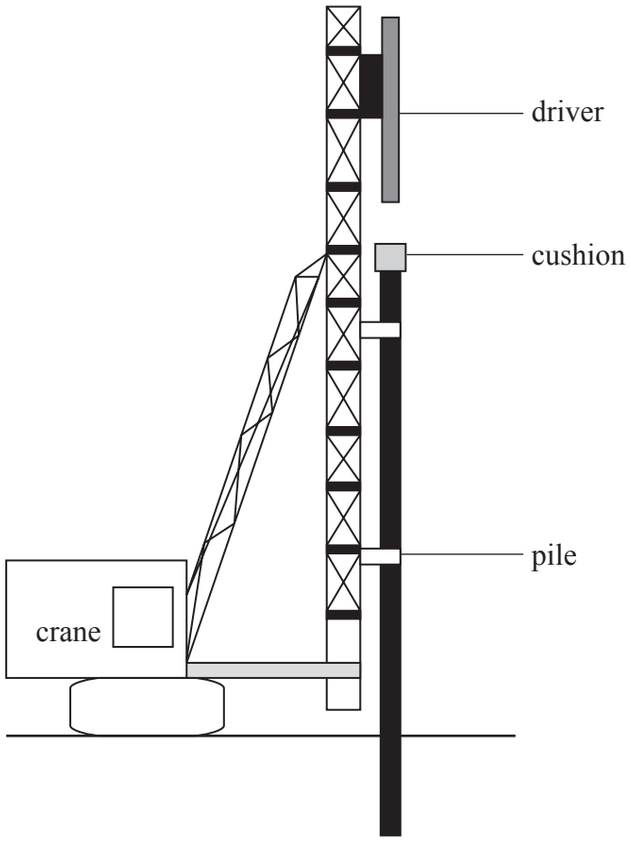
.....

.....

.....

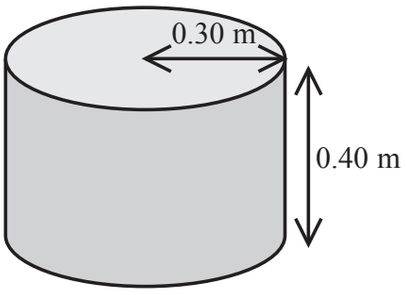
Average resistive force = ...

(b) In order to protect the driver on modern pile drivers, a cushion made of wood is placed on the pile.



Turn over ▶

The cushion is a cylindrical piece of wood of Young modulus = 120 MPa



The cushion is compressed when hit by the driver.

(i) The maximum compressive force applied to the wood during impact is 7.0×10^5 N. Show that the compression of the cushion is about 0.01 m.

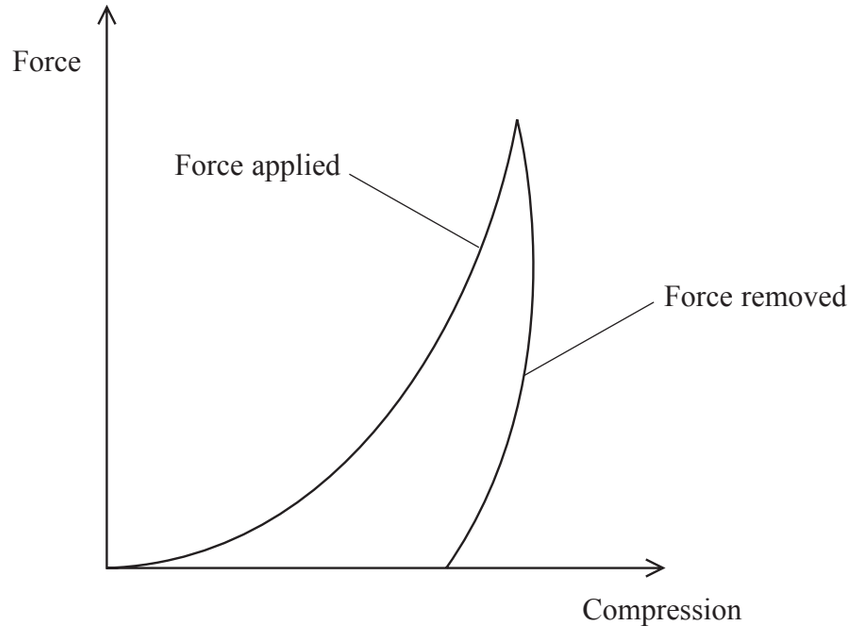
(3)

(ii) Calculate the energy stored in the cushion under compression.

(2)

Energy stored = ...

*(iii) The graph shows how the compression of the wooden cushion varies with force, as the force is applied and removed during an impact.



Use the graph to explain the following:

1. the wooden cushion has to be replaced after a few hundred impacts,

(2)

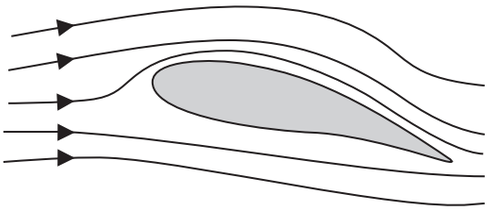
2. with each impact the temperature of the wooden cushion rises slightly.

(1)

(Total for Question 17 = 13 marks)

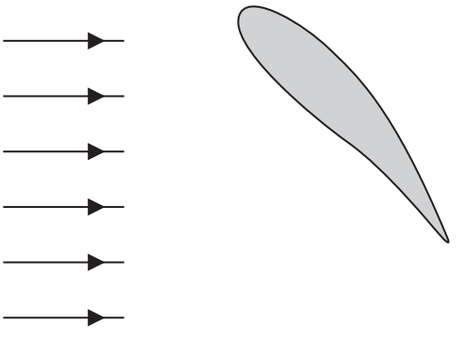
Turn over ▶

18 The cross section of the wing of a bird is an aerofoil shape.



Direction of flight ←

In order to fly higher, a bird can tilt its wings more. If it tilts them too much, as shown in the diagram below, the air flow above the wing becomes turbulent.



Direction of flight ←

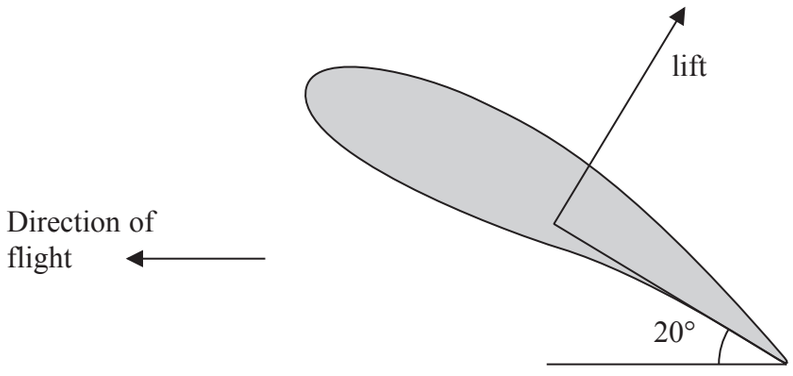
(a) Complete the diagram above to show the airflow around the wing.

(2)

(b) The tilting of the wing results in the air exerting a force on the wing which is called lift. The lift force acts perpendicular to the wing.

The total vertical component of the lift produced by both wings when tilted at an angle of 20° to the horizontal is enough to keep the bird flying at a constant height.

mass of bird = 0.063 kg



(i) Show that the total lift acting on the bird is about 1 N.

(3)

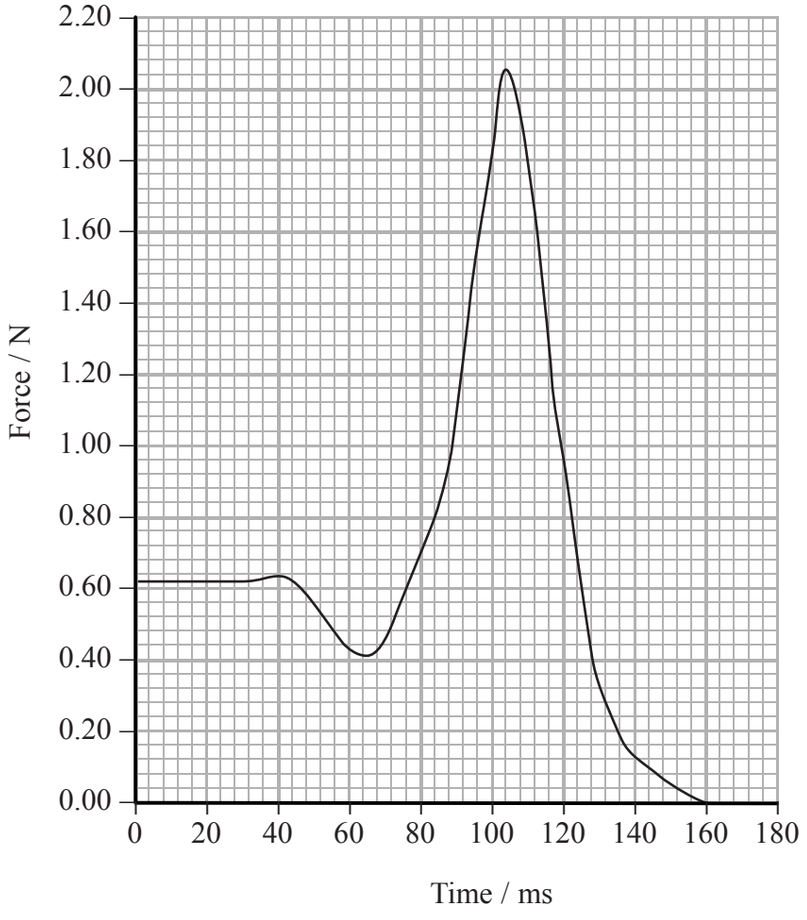
(ii) Assuming that the only forces acting on the bird are the weight and lift, calculate its acceleration at this instant.

(3)

Acceleration = ...

(c) When some birds take off from the ground there is no lift initially. These birds push off from the ground with their legs.

The following graph shows the downward force exerted by the leg on the ground during take off.



(i) With reference to Newton's laws explain how the downward force from the leg enables the bird to take off.

(4)

(ii) Use the graph to calculate the maximum acceleration of the bird during take off.

mass of bird = 0.063 kg

(3)

Maximum acceleration = ...

(Total for Question 18 = 15 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS