OCR
Oxford Cambridge and RSA

A Level Physics A

H556/01 Modelling physics

Thursday 15 June 2017 – Morning

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formula and Relationship Booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

First name	
Last name	
Centre number	Candidate number

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **32** pages.

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 $J\,kg^{-1}$

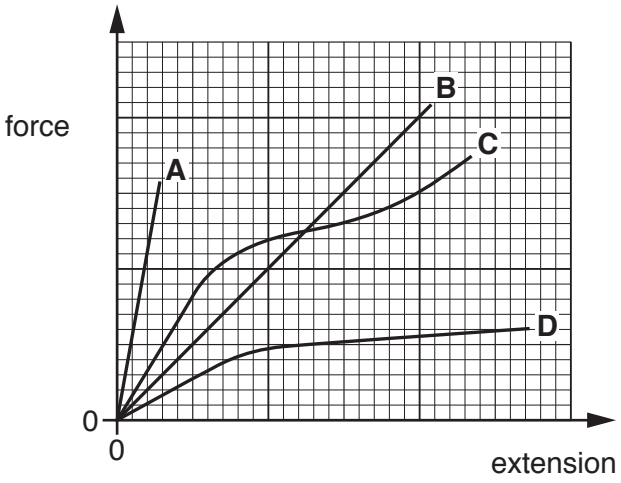
B $N\,kg^{-1}$

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]**

3 The braking distance of a car is directly proportional to its initial kinetic energy.

The braking distance of a car is 18 m when its initial speed is $10\,m\,s^{-1}$.

What is the braking distance of the car, under the same conditions, when its initial speed is $25\,m\,s^{-1}$?

A 7.2 m

B 45 m

C 113 m

D 222 m

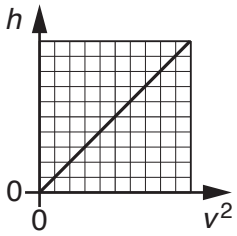
Your answer ☐ **[1]**

4 A ball is dropped from rest above the ground. Air resistance has negligible effect on the motion of the ball.

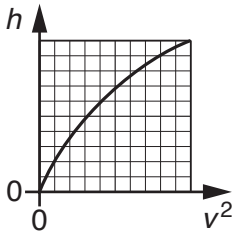
The speed of the ball is v after it has fallen a distance h from its point of release.

Which graph is correct for this falling ball?

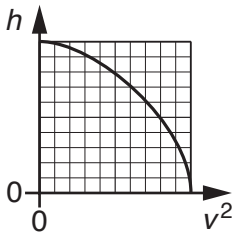
A



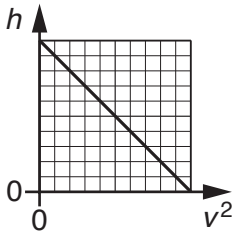
B



C



D



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 $4600 \pm 5\,m^2$

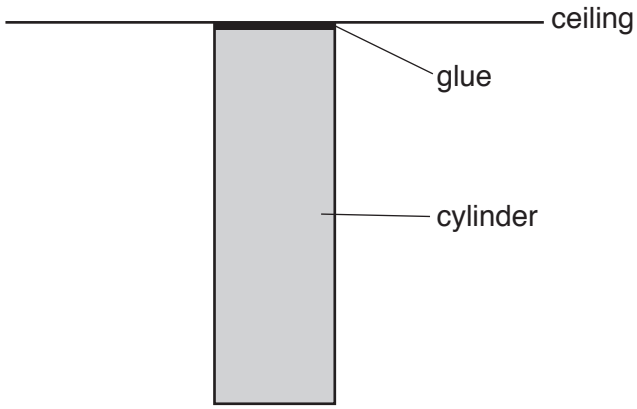
B $4600 \pm 6\,m^2$

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]**

7 The intensity against wavelength graph of an object at 750 °C peaks at a wavelength of λ. The temperature of the object is raised to 960 °C.

What is the wavelength now at the new peak intensity in terms of λ?

A 0.78λ

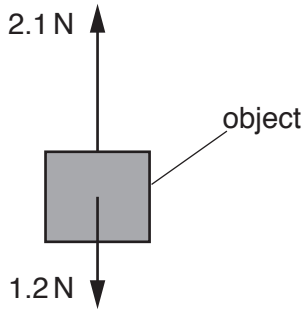
B 0.83λ

C 1.2λ

D 1.3λ

Your answer ☐ **[1]**

8 The diagram shows two opposite vertical forces of magnitude 1.2 N and 2.1 N acting on an object.



Which of the following statements could be correct?

1 The object is accelerating and moving up.
2 The object is decelerating and moving down.
3 The magnitude of the resultant force is 0.9 N.

A Only 3

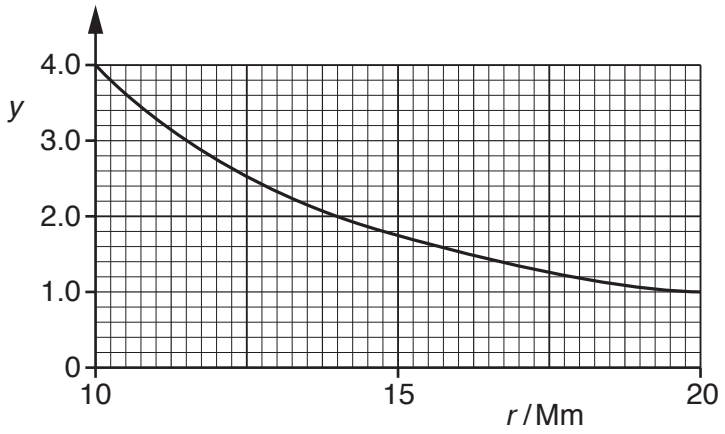
B Only 1 and 3

C Only 2 and 3

D 1, 2 and 3

Your answer ☐ **[1]**

9 A graph of y against distance r from the centre of a planet is shown below.



The graph shows that y is inversely proportional to r^2.

Which quantity is best represented on the y-axis of the graph?

A Period of a satellite orbiting the planet.

B Gravitational potential of the planet.

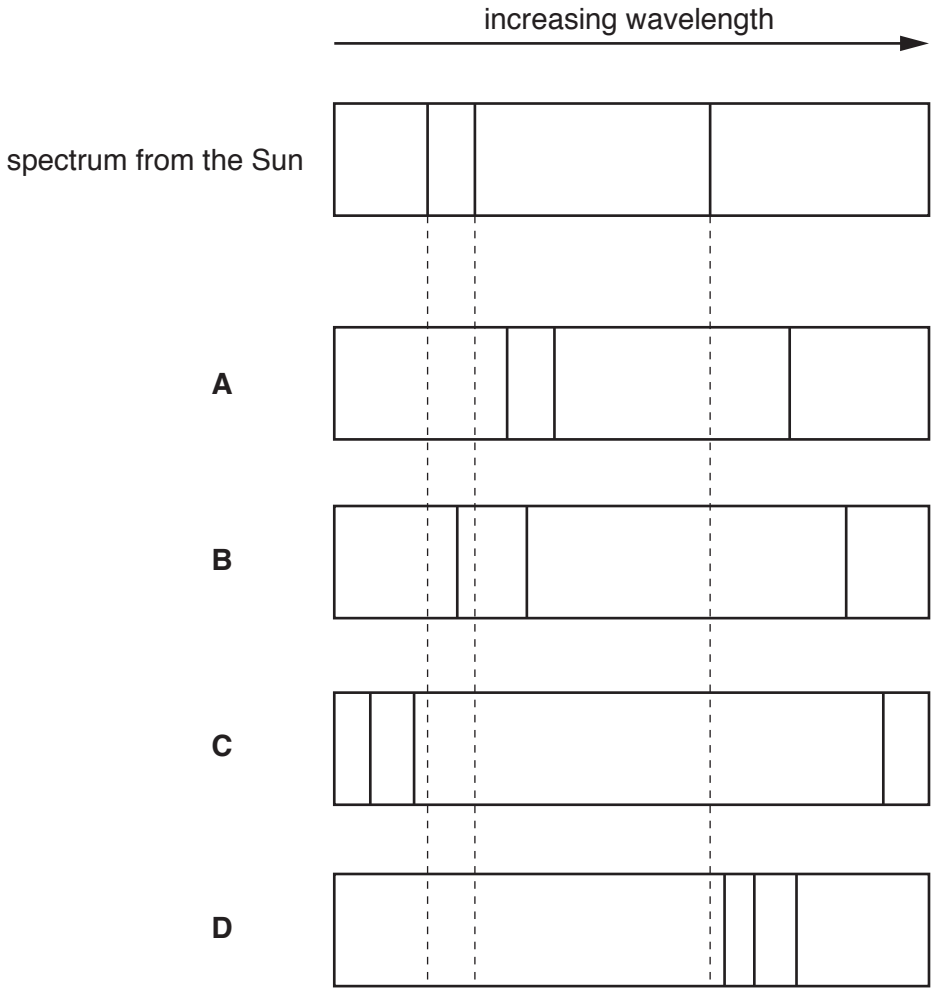
C Gravitational field strength of the planet.

D Kinetic energy of a satellite orbiting the planet.

Your answer ☐ **[1]**

10 Part of the line spectrum for light from the Sun is shown below.

Which spectrum best shows light from a similar star to the Sun?



Your answer ☐ **[1]**

11 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]**

12 An object above the ground is released from rest at time $t = 0$.

Air resistance is negligible.

What is the distance travelled by the object between $t = 0.20\,s$ and $t = 0.30\,s$?

A 0.20 m

B 0.25 m

C 0.44 m

D 0.49 m

Your answer ☐ **[1]**

13 A puck of mass 0.16 kg is sliding on ice with a constant velocity of $11.0\,m\,s^{-1}$. A hockey stick exerts a force on the puck, for a short period of time, in the **opposite** direction to the velocity of the puck. The momentum of the puck changes by $2.0\,kg\,m\,s^{-1}$.

Ignore friction.

What is the speed of the puck when it leaves the hockey stick?

A $1.5\,m\,s^{-1}$

B $3.8\,m\,s^{-1}$

C $12.5\,m\,s^{-1}$

D $23.5\,m\,s^{-1}$

Your answer ☐ **[1]**

14 A container has an ideal gas. The mean square speed of the gas molecules in the container is $3.0 \times 10^5 \text{m}^2\text{s}^{-2}$.

Over a period of time, a third of the gas molecules escape from the container. The pressure and volume of the gas in the container remain the same.

What is the mean square speed of the molecules left in the container?

A $1.0 \times 10^5 \text{m}^2\text{s}^{-2}$

B $2.0 \times 10^5 \text{m}^2\text{s}^{-2}$

C $4.5 \times 10^5 \text{m}^2\text{s}^{-2}$

D $9.0 \times 10^5 \text{m}^2\text{s}^{-2}$

Your answer ☐ **[1]**

15 Which two quantities are related in Hubble's law?

A Distance and mass of galaxies.

B Velocity and intensity of galaxies.

C Distance and velocity of galaxies.

D Distance and red shift of stars in our galaxy.

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 Fig. 16 shows a hydraulic jack used to lift a car which has a mass of 1200 kg. A mechanic exerts a downwards force of 400 N on the handle of the jack, moving it 80.0 cm downwards. As he moves the handle, the car rises 2.0 cm.

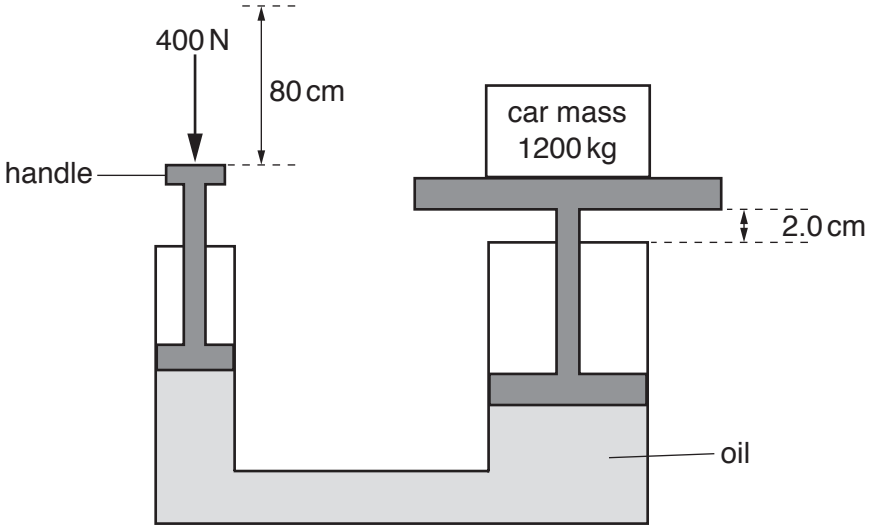


Fig. 16

(a) Calculate the work done by the 400 N force exerted by the mechanic.

work done = ... J **[2]**

(b) Calculate the ratio

$$\frac{\text{speed of handle moving down}}{\text{speed of car moving up}}.$$

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

(c) Calculate the useful work done on the car and hence the percentage efficiency of the jack.

efficiency = ... % **[2]**

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.

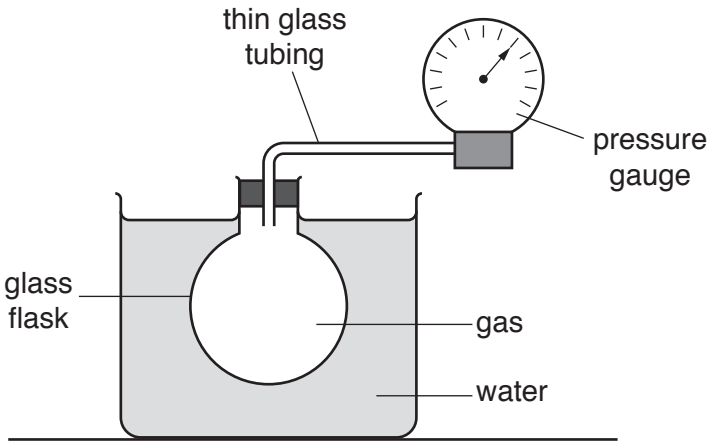


Fig. 17.1

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.

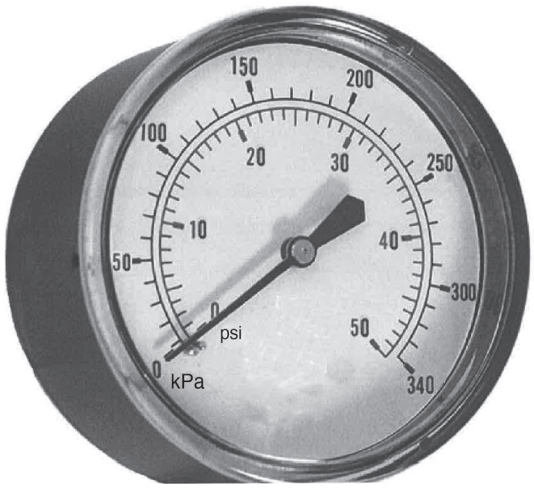

Fig. 17.2

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

.....

..... **[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.

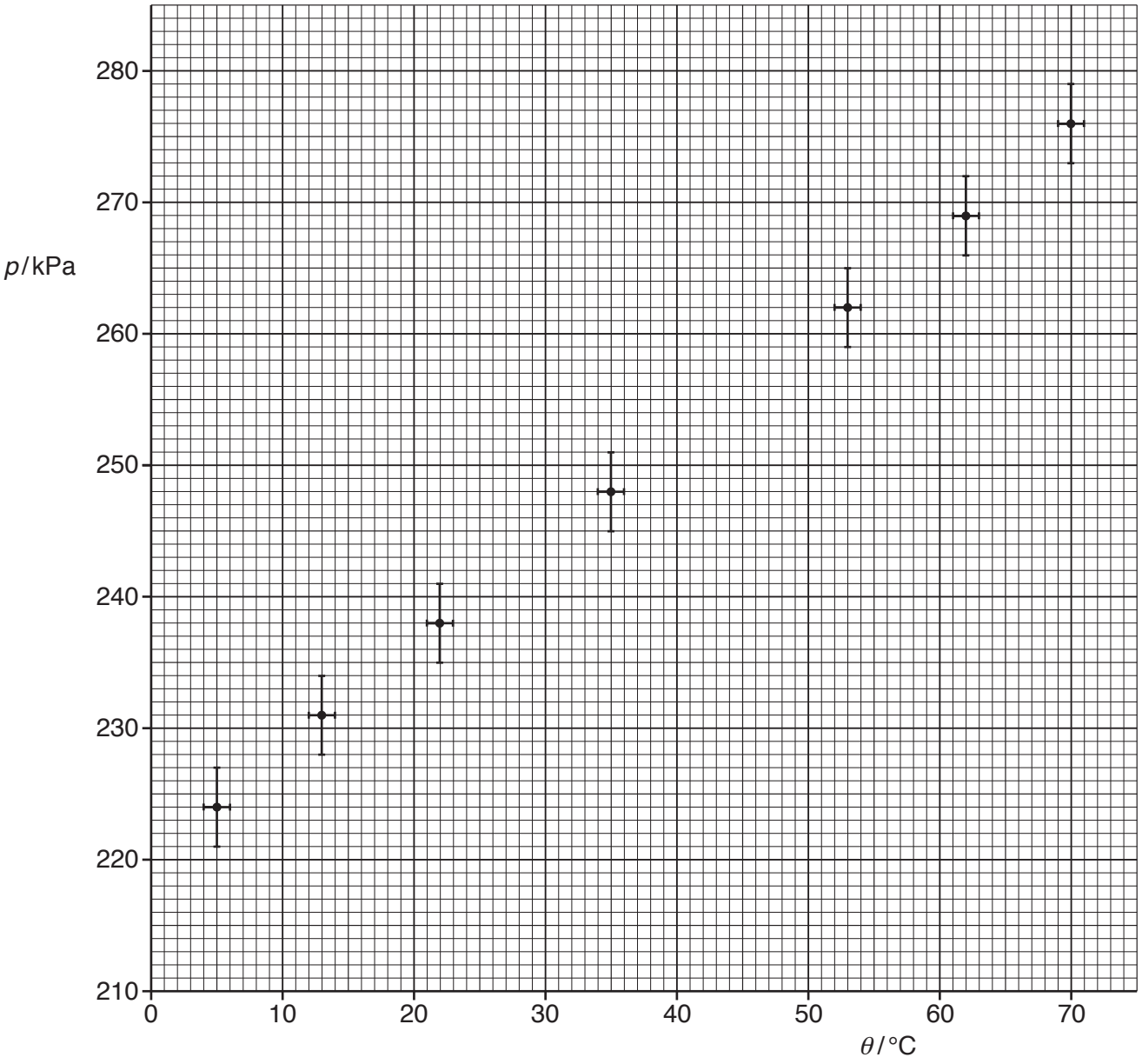

Fig. 17.3

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

18 A swimming pool designer investigates the depth *d* below a water surface reached by a diver when diving from a height *h* above the water surface. The designer models the diver as a uniform wooden cylinder. The experimental arrangement is shown in Fig. 18.1.

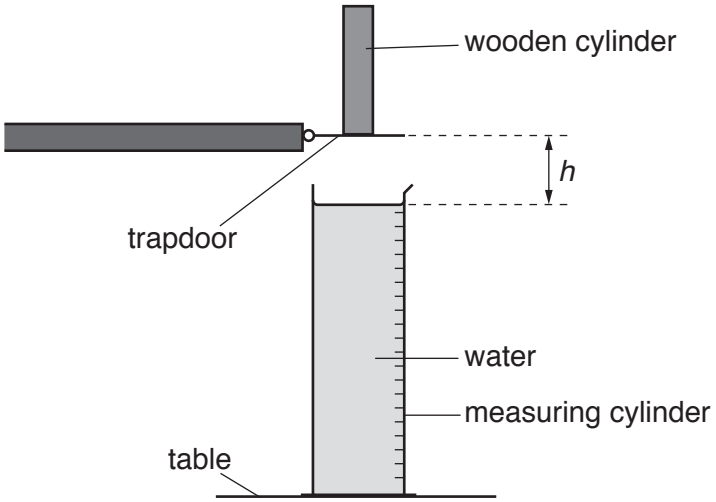

Fig. 18.1

(a) The wooden cylinder has mass 5.0×10^{-3} kg, diameter 1.0×10^{-2} m and length 7.0×10^{-2} m.

(i) Calculate the density of the wood.

density = ... $kg\,m^{-3}$ **[2]**

(ii) Suggest why wood is an appropriate material to model the depth reached by a diver.

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

(b) The cylinder is released from **rest** from a trapdoor. The base of the cylinder is at a height $h = 0.30\,\text{m}$ above the water surface.
Calculate the speed of the cylinder just before the base hits the water. Ignore air resistance.

speed = ... m s^{-1} **[2]**

(c) Fig. 18.2 shows the cylinder fully submerged under the water surface before it has come to rest. The cylinder is moving vertically **down**.

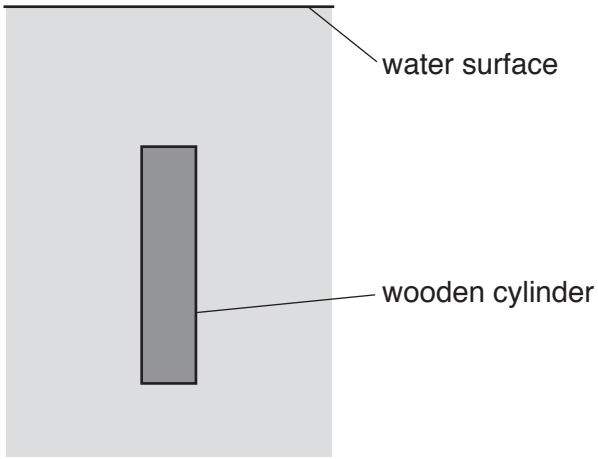

Fig. 18.2

(i) Add arrows to Fig. 18.2 to show the **three** forces acting on the wooden cylinder. Label the arrows. **[3]**

(ii) Describe and explain how the **resultant** force on the wooden cylinder varies from the moment the cylinder is fully submerged until it reaches its deepest point.

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..... **[3]**

(d) The graph of Fig. 18.3 shows the depth *d* reached for different initial drop height *h*.

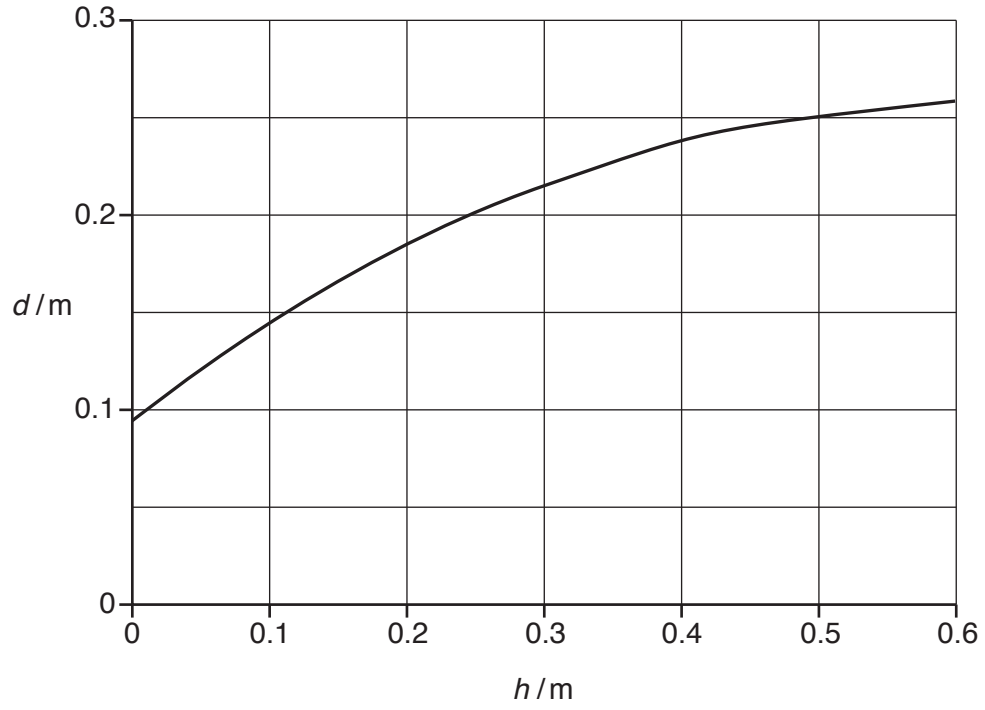

Fig. 18.3

The designer is required to double the height of a diving board for an existing swimming pool.
He suggests that the depth of the pool also needs to be doubled.
Use Fig. 18.3 to explain whether you agree with this suggestion.

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

19 This question is about a simple pendulum made from a length of string attached to a mass (bob).
For oscillations of small amplitude, the acceleration a of the pendulum bob is related to its displacement x by the expression

$$a = -\left(\frac{g}{L}\right)x$$

where g is the acceleration of free fall and L is the length of the pendulum.
The pendulum bob oscillates with simple harmonic motion.

(a) (i) Show that the period T of the oscillations is given by the expression

$$T^2 = \frac{4\pi^2}{g}L.$$

[3]

(ii) A student notices that the amplitude of each oscillation decreases over time.
Explain this observation and state what effect this may have on T.

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

(b)* Describe with the aid of a labelled diagram how an experiment can be conducted and how the data can be analysed to test the validity of the equation $T^2 = \frac{4\pi^2}{g}L$ for oscillations of small amplitude.

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..... **[6]**

(c) Another student conducts a similar experiment in the laboratory to investigate the small amplitude oscillations of a pendulum of a mechanical clock. Each 'tick' of the clock corresponds to **half** a period.

(i) Show that the length of the pendulum required for a tick of 1.0 s is about 1 m.

[2]

(ii) If the pendulum clock were to be used on the Moon, explain whether this clock would run on time compared with an identical clock on the Earth.

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

20 A plastic kettle is filled with 0.60 kg of water at a temperature of 20 °C.
A 2.2 kW electric heater is used to heat the water for a time of 4.0 minutes.

(a) Calculate the total energy supplied by the heater during the time of 4.0 minutes.

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

(b) The specific heat capacity of water is 4200 J kg^{-1} K^{-1} and the specific latent heat of vaporisation of water is 2.3 × 10^{6} J kg^{-1}. The boiling point of water is 100 °C.

Calculate the mass of water **remaining** in the kettle after 4.0 minutes.
Assume that all the thermal energy from the heater is transferred to the water.

mass of water remaining = ... kg **[4]**

21 **(a)** Fig. 21.1 shows some of the energy levels of electrons in hydrogen gas atoms. The energy levels are labelled **A**, **B**, **C** and **D**.

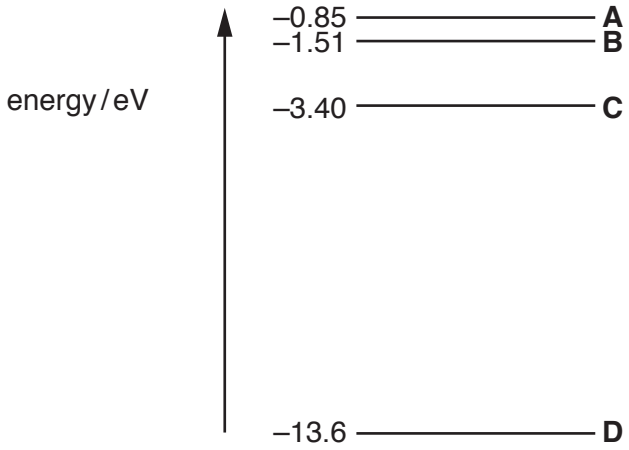

Fig. 21.1 (not to scale)

(i) Explain why the energy levels are negative.

.....

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

(ii) An electron makes a transition (jump) from level **C** to level **A**.

1 Calculate the energy gained by this electron.

energy = ... eV **[1]**

2 Calculate the wavelength in nm of the photon absorbed by this electron.

wavelength = ... nm **[3]**

(b) Light from a distant galaxy is passed through a diffraction grating. Fig. 21.2 shows the part of the spectrum of light that shows a strong hydrogen-alpha emission line.

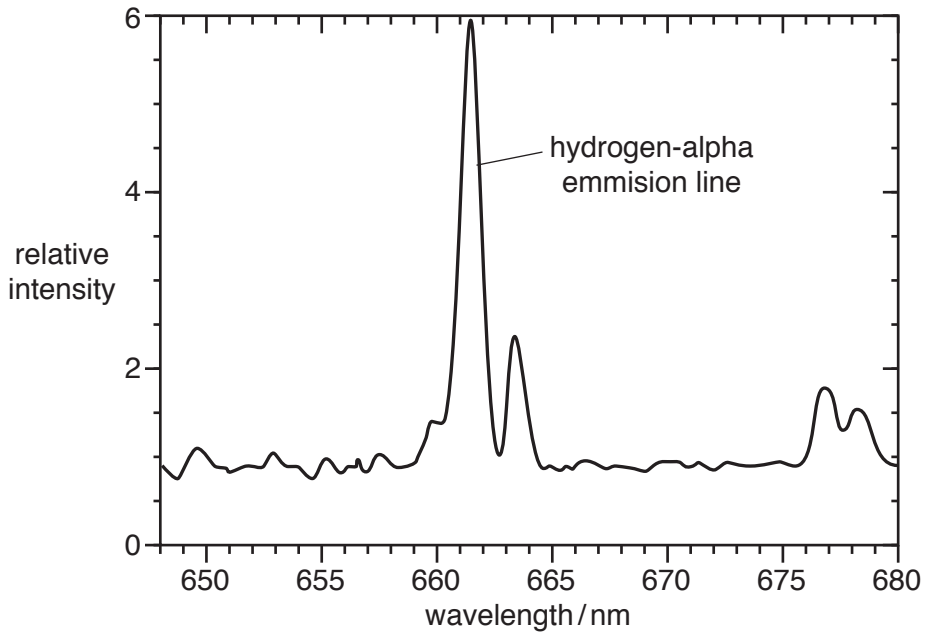

Fig. 21.2

(i) State how an emission line is produced.

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

(ii) State an adjustment that could be made to the experimental arrangement that would space the emission lines more widely.

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

(iii) In the laboratory, the wavelength of the hydrogen-alpha emission line is 656.3 nm. Use Fig. 21.2 to determine the recession velocity of the galaxy.

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

(iv) Suggest why hydrogen spectral lines play an important role in determining red shift of galaxies.

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

(c) Light from a similar star is viewed in a galaxy **further** away. The star is part of a pair of stars which orbit a common centre of mass.
Describe and explain how the equivalent spectrum might appear.

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..... **[3]**

22 **(a)** Define the *internal energy* of a substance.

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

(b) A block of paraffin wax is melting at a constant temperature of 52 °C. Use the behaviour of paraffin molecules to describe and explain the changes to the internal energy of the molecules of the paraffin wax as it melts.

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

23 **(a)** Write an expression for the gravitational potential V_g at the surface of a planet of mass M and radius r.

[1]

(b) The table below shows some data for Mercury and Pluto.

	Mass / kg	**Radius / m**	**Mean distance from Sun / m**
Mercury	3.30×10^{23}	2.44×10^{6}	57.9×10^{9}
Pluto	0.131×10^{23}	1.19×10^{6}	5910×10^{9}

(i) Show that the escape velocity v of a gas molecule on the surface of Pluto is given by the equation

$$v = \sqrt{\frac{2GM}{r}}$$

where M is the mass of Pluto and r is its radius.

[2]

(ii) Calculate the escape velocity v of gas molecules on the surface of Pluto.

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

(iii) Explain why Mercury has no atmosphere whilst Pluto still has a thin atmosphere. Use data from the table to support your explanation.

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..... **[3]**

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

A Level Physics A

H556/01 Modelling physics

Monday 4 June 2018 – Afternoon

Time allowed: 2 hours 15 minutes

You must have:
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First name									
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INFORMATION
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- This document consists of **32** pages.

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]**

4 The acceleration a of a simple harmonic oscillator is related to its displacement x by the equation

$$a = -25x.$$

What is the frequency of the oscillator?

A 0.80 Hz

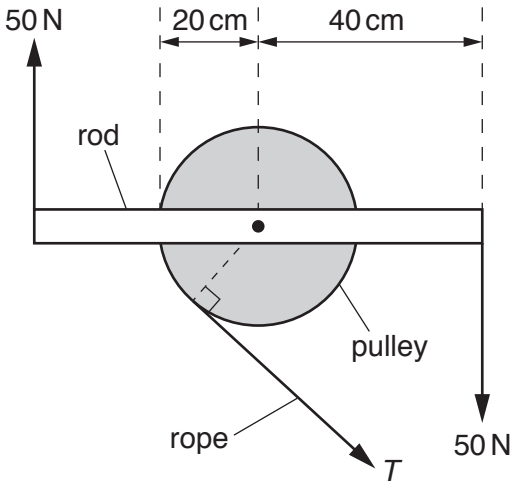
B 1.3 Hz

C 4.0 Hz

D 5.0 Hz

Your answer ☐ **[1]**

5 A rod is fixed to a pulley. Two 50 N forces are applied to the ends of the rod as shown. The tension in the rope attached to the pulley is T. The system is in equilibrium.



Not to scale

What is the moment of the tension T about the centre of the pulley?

A 10 N m

B 20 N m

C 30 N m

D 40 N m

Your answer ☐ **[1]**

6 The latent heat of vaporisation of a liquid is 2300 kJ kg^{-1} and it has a molar mass of 0.018 kg mol^{-1}.

What is the energy required to change 30 moles of the liquid to gas?

A 4.1×10^4 J

B 1.2×10^6 J

C 6.9×10^7 J

D 3.8×10^9 J

Your answer ☐ **[1]**

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

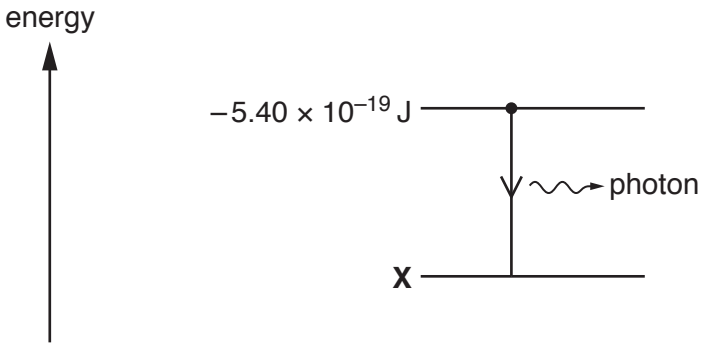
B $x = \frac{F}{E}$

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

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

Your answer ☐ **[1]**

8 An electron makes a transition between the two energy levels shown below.



This transition produces a photon of frequency 4.10×10^{14} Hz.

What is the value of the energy level **X**?

A -2.68×10^{-19} J

B -2.72×10^{-19} J

C -5.40×10^{-19} J

D -8.12×10^{-19} J

Your answer ☐ **[1]**

9 A pendulum is oscillating in air and experiences damping.

Which of the following statements is/are correct for the damping force acting on the pendulum?

1 It is always opposite in direction to acceleration.
2 It is always opposite in direction to velocity.
3 It is maximum when the displacement is zero.

A Only 1 and 2

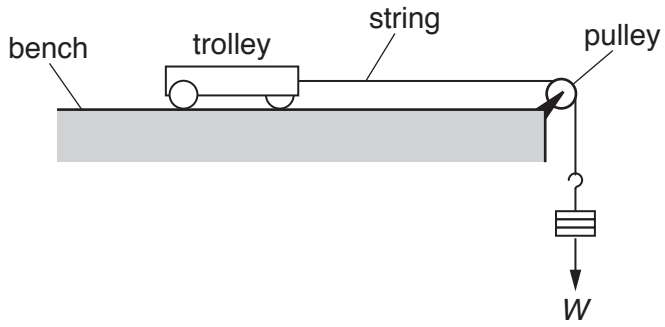
B Only 2 and 3

C Only 3

D 1, 2 and 3

Your answer ☐ **[1]**

10 A trolley of mass M is pulled along a horizontal table by a force W provided by a mass hanging from the end of a string as shown.



Frictional forces are negligible. The acceleration of free fall is g.

What is the correct equation for the acceleration a of the trolley?

A $a = \frac{W}{M}$

B $a = g$

C $a = \frac{W}{2M}$

D $a = \frac{W}{M + \frac{W}{g}}$

Your answer ☐ **[1]**

11 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

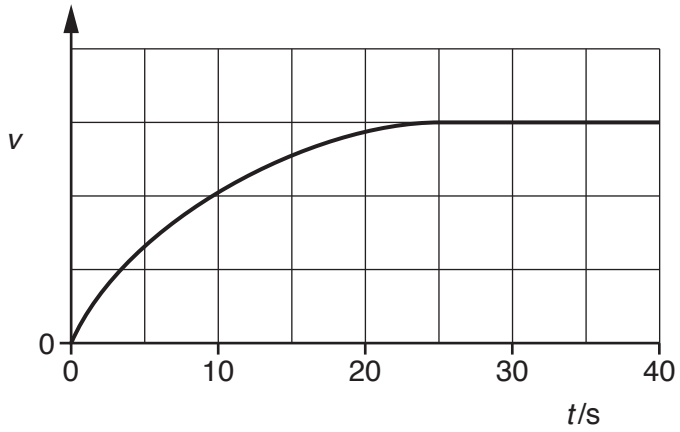
B 1.7

C 2.0

D 3.3

Your answer ☐ **[1]**

12 An object is dropped from rest at time $t = 0$. It falls vertically through the air. The variation of the velocity v with time t is shown below.



Which statement is correct about this object?

A It has constant acceleration.

B It experiences zero drag at $t = 30\,s$.

C It has an acceleration of $9.81\,m\,s^{-2}$ at $t = 0\,s$.

D It travels the same distance in every successive 10 s.

Your answer ☐ **[1]**

13 Earth has a mass of 6.0×10^{24} kg and a radius of 6400 km.
A satellite of mass 320 kg is lifted from the Earth's surface to an orbit 1200 km above its surface.

What is the change in the gravitational potential energy of the satellite?

A 9.1×10^{2} J

B 9.9×10^{6} J

C 3.2×10^{9} J

D 3.8×10^{9} J

Your answer ☐ **[1]**

14 The volume of one mole of an ideal gas is V. The gas exerts pressure p and has thermodynamic temperature T.

Which of the following has the units $\text{J mol}^{-1}\text{ K}^{-1}$?

A pV

B $\frac{p}{T}$

C $\frac{V}{T}$

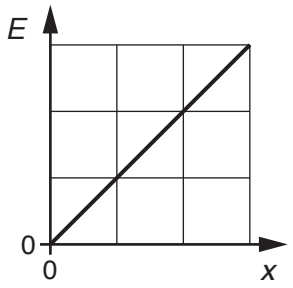
D $\frac{pV}{T}$

Your answer ☐ **[1]**

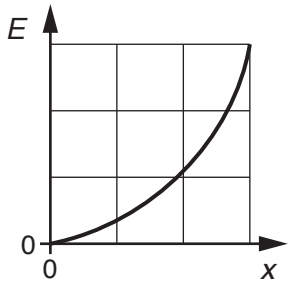
15 An object oscillates with simple harmonic motion.

Which graph **best** shows the variation of its potential energy E with distance x from the equilibrium position?

A



B



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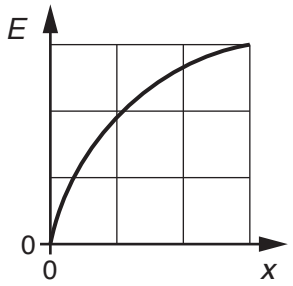
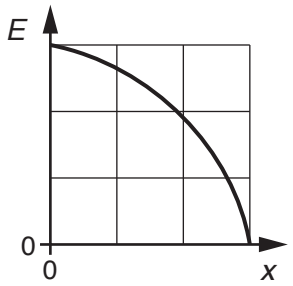


D



Your answer ☐ **[1]**

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SECTION B

Answer **all** the questions.

16 (a) A tennis ball is struck with a racket.
The initial velocity v of the ball leaving the racket is $30.0\,m\,s^{-1}$ and it makes an angle of 70° to the horizontal as shown in Fig. 16.
Air resistance is negligible

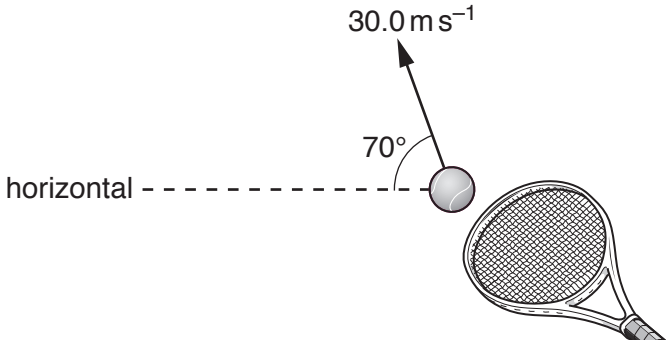

Fig. 16

(i) Calculate the vertical component of the initial velocity of the ball.

vertical component = ... $m\,s^{-1}$ **[1]**

(ii) Use your answer in **(i)** to show that the ball reaches a maximum height h of about 40 m.

h = ... m **[2]**

(iii) Explain why the kinetic energy of the ball is not zero at maximum height.

.....

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

(iv) The mass m of the ball is 57.0 g.
Calculate the kinetic energy E_k of the ball when it is at its **maximum** height.

E_k = ... J **[2]**

(b)* A metal ball is rolled off the edge of a horizontal laboratory bench. The initial horizontal velocity of the ball is v. The ball travels a horizontal distance x before it hits the level floor.

Use your knowledge of projectile motion to suggest the relationship between v and x. Describe how an experiment can be safely conducted to test this relationship and how the data can be analysed.

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[6]

17 (a) Phobos is one of the two moons orbiting Mars. Fig. 17.1 shows Phobos and Mars.

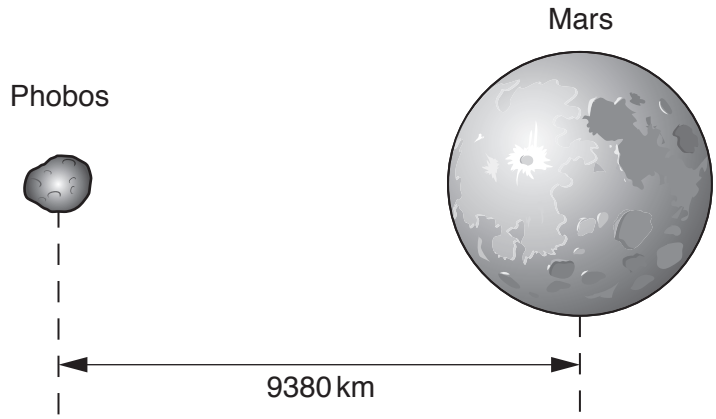

Fig. 17.1

The orbit of Phobos may be assumed to be a circle. The centre of Phobos is at a distance 9380 km from the centre of Mars and it has an orbital speed $2.14 \times 10^3\,m\,s^{-1}$.

(i) On Fig. 17.1, draw an arrow to show the direction of the force which keeps Phobos in its orbit. **[1]**

(ii) Calculate the orbital period T of Phobos.

T = ... s **[2]**

(iii) Calculate the mass M of Mars.

M = ... kg **[3]**

(b) The gravitational field strength at a distance r from the centre of Mars is g.

The table below shows some data on Mars.

g / N kg^{-1}	r / km	lg (g / N kg^{-1})	lg (r / km)
1.19	6000	0.076	3.78
0.87	7000		
0.67	8000	−0.174	3.90
0.53	9000	−0.276	3.95
0.43	10000	−0.367	4.00

(i) Complete the table by calculating the missing values. **[1]**

(ii) Fig. 17.2 shows the graph of lg (g / N kg^{-1}) against lg (r / km).

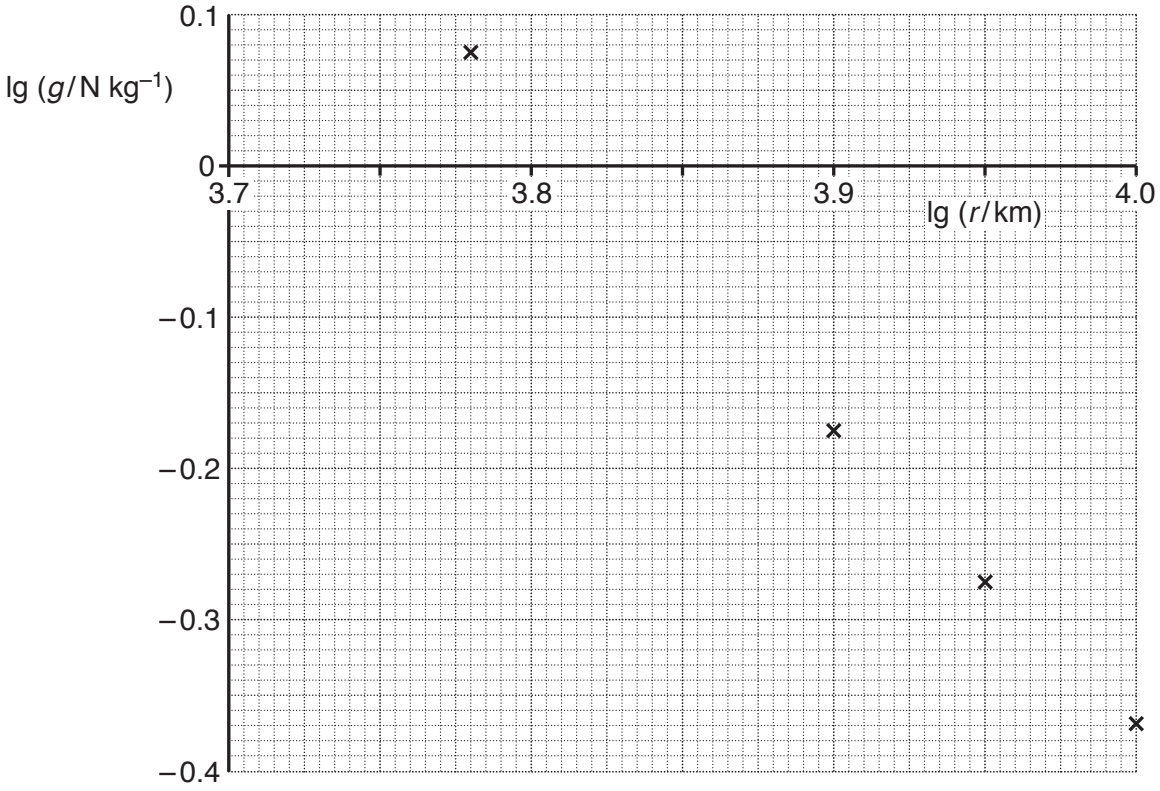

Fig. 17.2

1 Plot the missing data point on the graph and draw the straight line of best fit. **[2]**

2 Use Fig. 17.2 to show that the gradient of the straight line of best fit is −2.

[1]

3 Explain why the gradient of the straight line of best fit is −2.

[2]

(c) In July 2018, the closest distance between the centre of Mars and the centre of Earth will be 5.8×10^{10} m.
Fig. 17.3 shows the variation of the **resultant** gravitational field strength g between the two planets with distance r from the centre of the **Earth**.

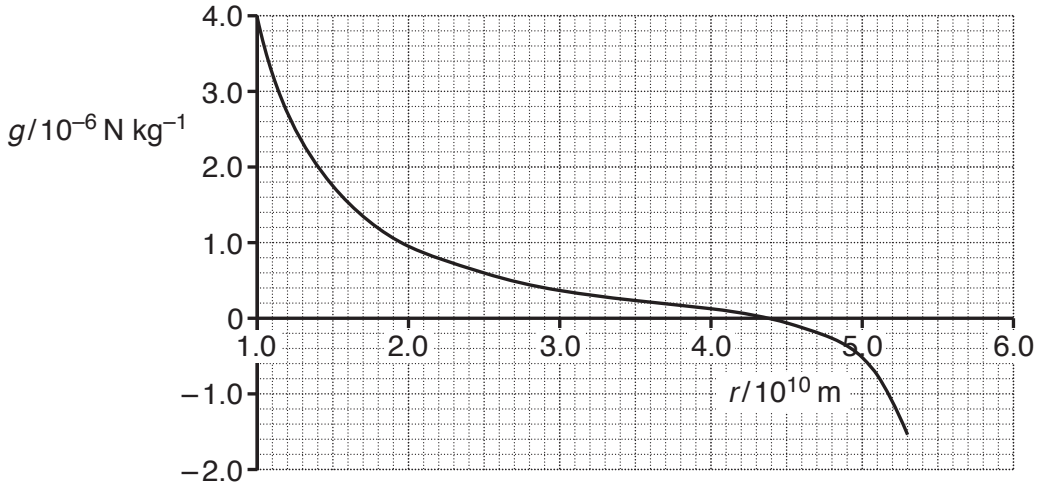

Fig. 17.3

(i) Explain briefly the overall shape of the graph in Fig. 17.3.

.....

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

(ii) Use the value of r when $g = 0$ from Fig. 17.3 to determine the ratio

$$\frac{\text{mass of Earth}}{\text{mass of Mars}}.$$

$$\frac{\text{mass of Earth}}{\text{mass of Mars}} = \text{.....} \quad \textbf{[2]}$$

18 Wind turbines convert the kinetic energy of the wind into electrical energy.
Fig. 18 shows a wind turbine.

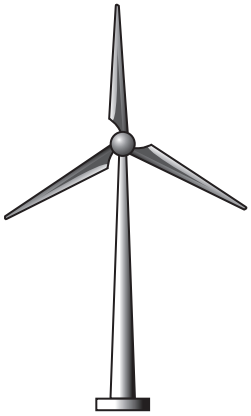

Fig. 18

(a) When the wind speed is $8.0\,m\,s^{-1}$, the kinetic energy of the air incident at the turbine per second is $1.2\,MJ\,s^{-1}$.
Calculate the mass of the air incident at the turbine per second.

mass per second = ... $kg\,s^{-1}$ **[2]**

(b) A group of engineers are investigating the design of wind turbines.
The maximum **input** power P from the wind is given by the equation

$$P = \frac{1}{2}\rho A v^3$$

where A is the area swept out by the rotating blades, ρ is the density of air and v is the speed of the wind.

(i) Show that the equation is homogeneous with both sides of the equation having the same base units.

[3]

(ii) The input power to the wind turbine is 1.2 MW when the wind speed is 8.0 m s^{-1}. The density of air is 1.3 kg m^{-3}.

Calculate the length *L* of the turbine blades.

L = ... m **[2]**

(iii) A wind farm is required to produce an output power of 50 MW when the average wind speed is 8.0 m s^{-1}. The efficiency of each wind turbine is 42%.

Calculate the minimum number *N* of wind turbines required to meet this demand.

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

19 Fig. 19 is an incomplete Hertzsprung-Russell (HR) diagram of stars in our galaxy.

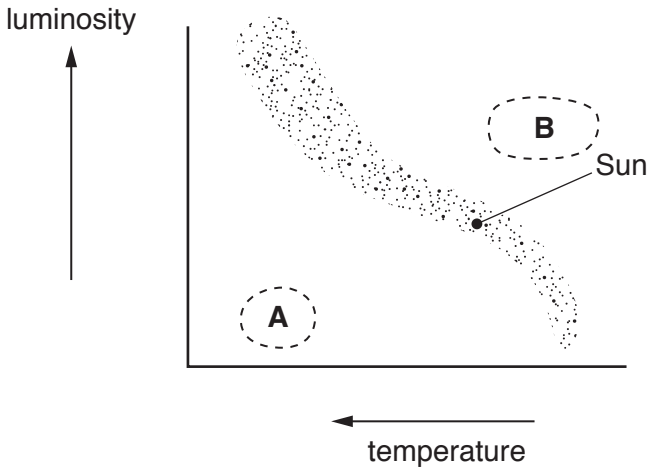

Fig. 19

The position of the Sun on the HR diagram is shown in Fig. 19.

(a) State the type of stars found in regions **A** and **B**.

A ..... **B** ..... **[1]**

(b) The Sun is a main sequence star. Its surface temperature is 5800 K. The wavelength of the emitted light at maximum intensity is 550 nm.

Beta Pictoris is also a main sequence star. The wavelength of the emitted light at maximum intensity from this star is 370 nm.

(i) Calculate the surface temperature of Beta Pictoris.

temperature = ... K **[2]**

(ii) On Fig. 19, mark the likely position of Beta Pictoris with a letter **P**. **[1]**

20 **(a)** Use the equations for momentum and kinetic energy to derive an expression for the kinetic energy E_k of a particle in terms of its momentum p and mass m.

[2]

(b) Fig. 20.1 shows an electric motor used to lift and lower a load.

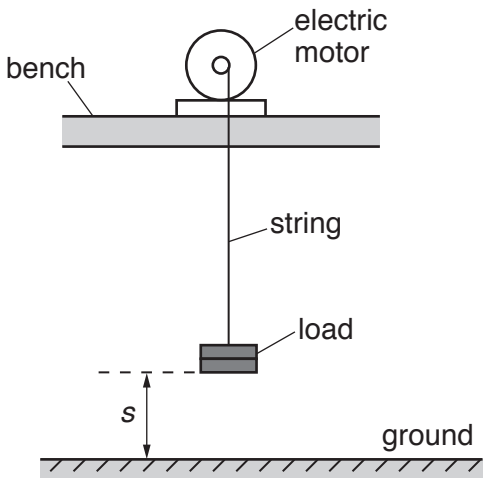

Fig. 20.1

At time $t = 0$ the load is on the ground with displacement $s = 0$.
Fig. 20.2 shows the variation of the displacement s of the load with time t.

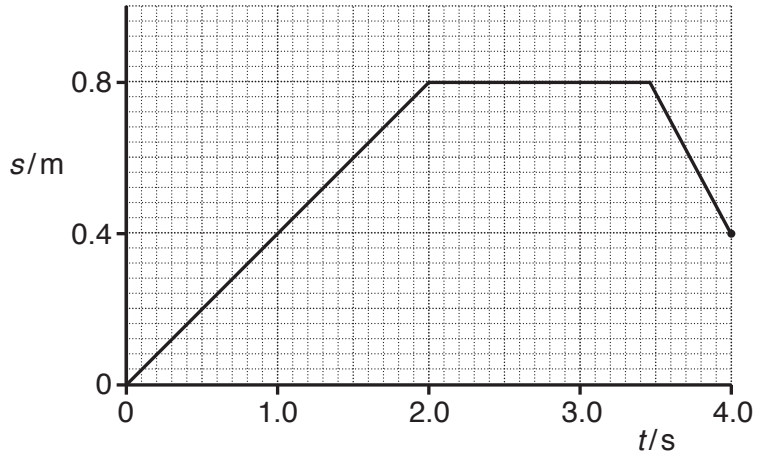

Fig. 20.2

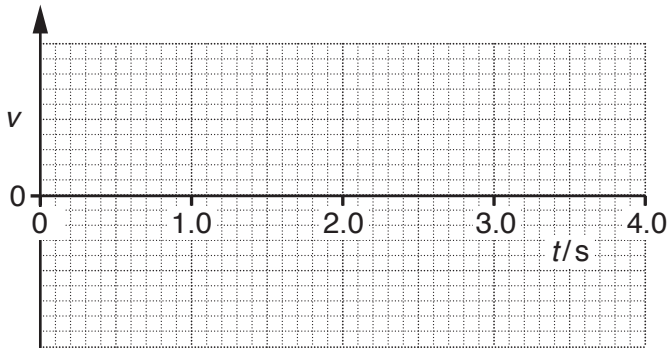

Fig. 20.3

(i) On Fig. 20.3, sketch a graph to show the variation of the velocity v of the load with time t. You do not need to insert a scale on the v axis. **[3]**

(ii) Describe how the kinetic energy and the gravitational potential energy of the load varies from $t = 0$ to $t = 2.0$ s.

.....

.....

.....

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

(iii) During the **downward** journey of the load, the string breaks at t = 4.0 s. It then falls vertically towards the ground. The mass of the load is 120 g.
Air resistance is negligible.

1 Calculate the velocity V of the load just before it hits the ground.

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

2 The load hits the ground and comes to **rest** in a time interval of 25 ms.

Calculate the average force F exerted by the ground on the load.

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

21 Fig. 21 shows the drum of a washing machine.

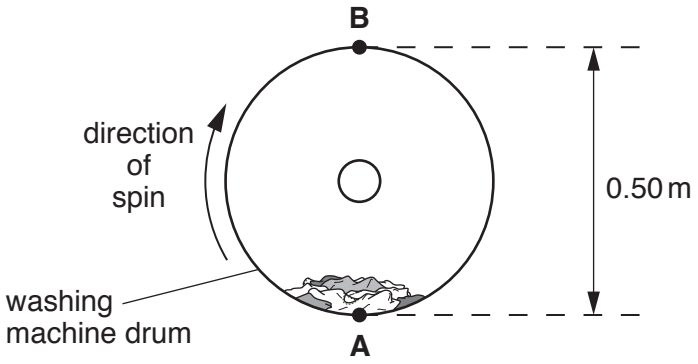

Fig. 21

The clothes inside the drum are spun in a **vertical** circular motion in a clockwise direction.

(a) When the drum is at rest, the weight of the clothes is equal to the normal contact force on the clothes at point **A**.

Explain why these two forces are not an example of Newton's Third Law of motion.

.....

.....

.....

.....

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

(b) The drum has diameter 0.50 m. The manufacturer of the washing machine claims that the drum spins at 1600 ± 100 revolutions per minute.

Calculate the speed of rotation of the drum and the absolute uncertainty in this value.

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

(c) The washing machine is switched off and the speed of the drum slowly decreases. The clothes at the top of the drum at point **B** start to drop off at a certain speed v.

At this speed v, the normal contact force on the clothes is zero.

Calculate the speed v.

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

22 **(a)** A helium atom **X** travelling at 610 m s^{-1} makes an elastic collision with a stationary helium atom **Y**. The magnitude of the velocity of **X** after the collision is 258 m s^{-1}. The directions of the velocities of **X** and **Y** are as shown in Fig. 22.

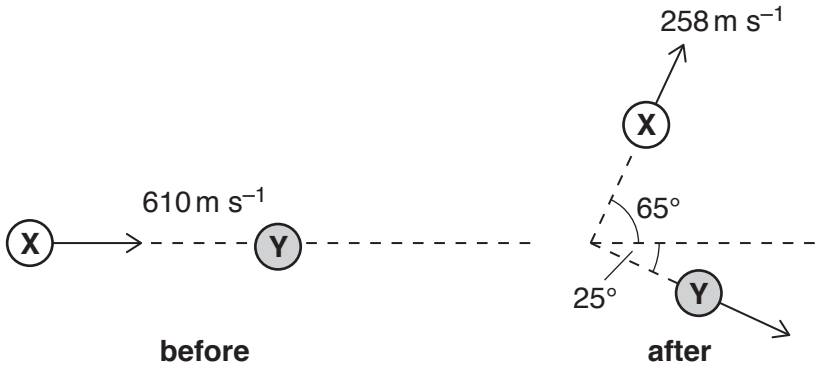

Fig. 22

(i) Explain what is meant by an *elastic collision*.

.....

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

(ii) The mass of a helium atom is 6.64 × 10^{-27} kg.
Calculate the magnitude of the momentum p of **Y** after the collision.

p = ... kg m s^{-1} **[3]**

(b)* There is a lot of helium in the Universe. This was also true of the Earth when it was formed billions of years ago. However, only small traces of helium are now found in the atmosphere of the Earth.

Use the kinetic theory of gases to explain why only small amounts of helium are found in the Earth's atmosphere. Use the information below to do suitable calculations to support your answer.

- typical atmospheric temperature = 10 °C
- mass of helium atom = 6.64 × 10^{-27} kg
- escape velocity from the Earth = 11 km s^{-1}

[6]

23 **(a)** According to the Cosmological principle, the Universe is isotropic, homogeneous and the laws of physics are universal.

State what is meant by the term *homogeneous*.

.....

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

(b) Astronomers often use absorption spectral lines to determine the relative velocity of distant galaxies. The wavelength of a specific absorption spectral line observed in the laboratory is 280 nm.

The galaxy RXJ1242-11 is 200 Mpc away from the Earth and it has a massive black hole at its centre.

(i) Calculate in nm the wavelength λ of the same spectral line from RXJ1242-11 when **observed** from the Earth. Assume the Hubble constant is 68 $km\,s^{-1}\,Mpc^{-1}$.

λ = ... nm **[3]**

(ii) State one of the characteristics of a black hole.

.....

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

(c) The Universe evolved from the Big Bang.

Describe the evolution of the Universe up to the formation of the first nuclei.

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

24 A group of students are conducting an experiment to determine the wavelength of monochromatic light from a laser.
Fig. 24.1 shows the laser beam incident normally at a diffraction grating.

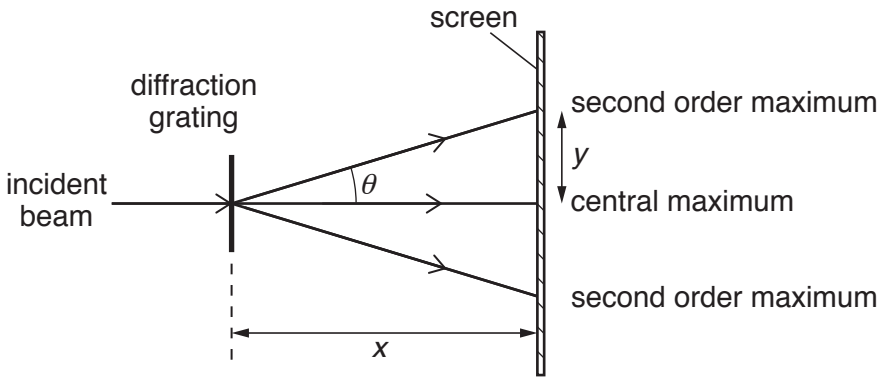


Fig. 24.1

The students use a diffraction grating with 600 lines mm^{-1}. They vary the distance x between the grating and the screen from 1.000 m to 2.000 m. They measure the distance y from the **central** maximum to the **second order** maximum.

(a) The students decide to plot a graph of y against $\sqrt{x^2 + y^2}$.

Show that the gradient of the graph is equal to sin θ, where θ is the angle between the central maximum and the **second** order maximum.

[1]

(b) Fig. 24.2 shows the graph plotted by the students.

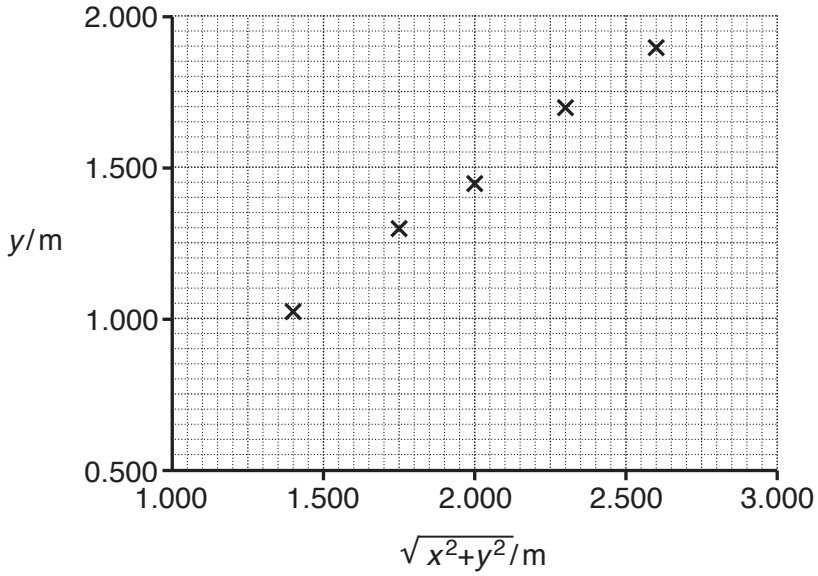


Fig. 24.2

(i) Use Fig. 24.2 to determine an accurate value of the wavelength λ of the light from the laser.

λ = ... m **[3]**

(ii) Suggest why there are no error bars shown in Fig. 24.2.

.....

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

(iii) Suggest how the precision of this experiment may be affected by using a protractor to measure the angle θ.

.....

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

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Monday 20 May 2019 – Afternoon

A Level Physics A

H556/01 Modelling physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formula and Relationships Booklet (sent with general stationery)

You may use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Answer **all** the questions.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **32** pages.

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

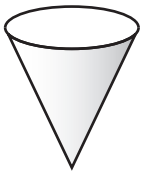
B milli, centi, micro, kilo

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}

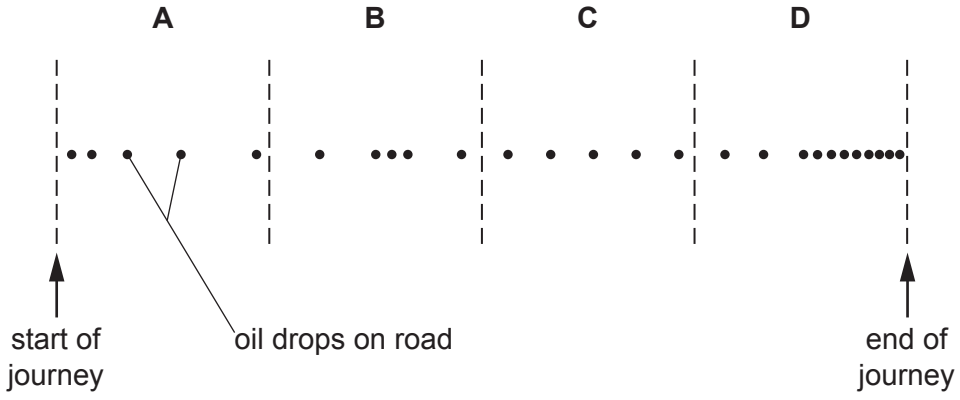
B 21 rad s^{-1}

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]**

6 The Earth is surrounded by a gravitational field.

Which of the following statements is/are correct about the gravitational field lines near the **surface** of the Earth.

1 They are parallel.
2 They show the direction of the force on a small mass.
3 They are equally spaced.

A Only 1

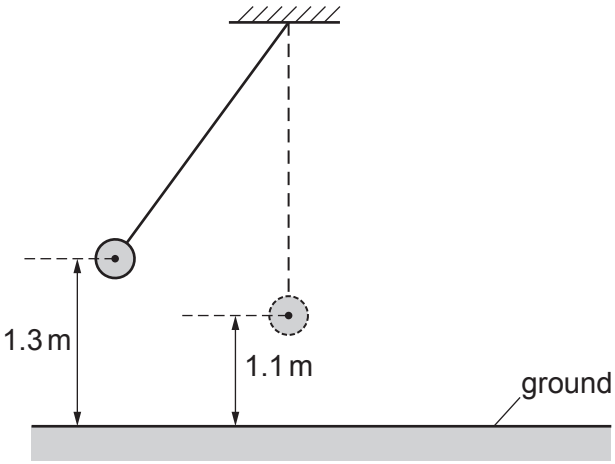
B Only 1 and 2

C Only 2 and 3

D 1, 2 and 3

Your answer ☐ **[1]**

7 A pendulum bob is oscillating in a vacuum.
The maximum height of the bob from the ground is 1.3 m and its minimum height is 1.1 m.



What is the maximum speed of the pendulum bob?

A $2.0\,m\,s^{-1}$

B $3.9\,m\,s^{-1}$

C $5.1\,m\,s^{-1}$

D $26\,m\,s^{-1}$

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]**

11 A student has collected some data on the Solar System.
The student plots a graph, but only two data points are shown below.

The distance from the centre of the Sun is *r*.

Which quantity *y* is represented on the vertical axis?

A Speed of a planet.

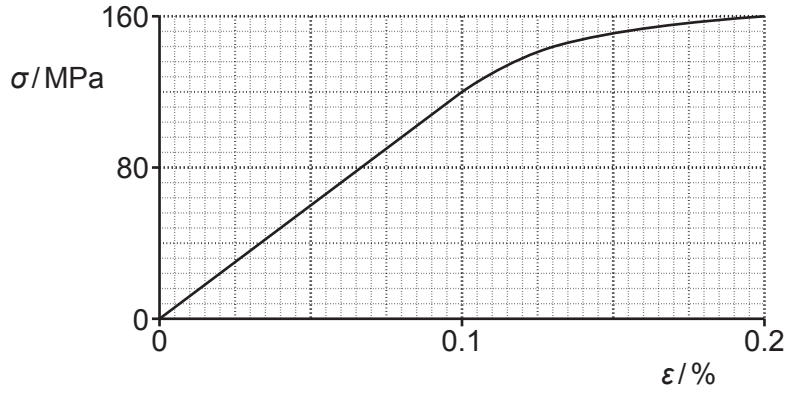
B Period of a planet.

C Gravitational potential of the Sun.

D Gravitational field strength of the Sun.

Your answer ☐ **[1]**

12 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]**

13 Which column **A**, **B**, **C** or **D**, shows the correct sequence for the evolution of the Universe between the Big Bang and the formation of stars?

A	**B**	**C**	**D**
Universe starts to expand ↓ quarks and leptons form ↓ hadrons form ↓ nuclei form ↓ atoms form	Universe starts to expand ↓ hadrons form ↓ quarks and leptons form ↓ nuclei form ↓ atoms form	quarks and leptons form ↓ nuclei form ↓ Universe starts to expand ↓ atoms form ↓ hadrons form	quarks and leptons form ↓ hadrons form ↓ Universe starts to expand ↓ nuclei form ↓ atoms form

Your answer ☐ **[1]**

14 Some stars will evolve into white dwarfs.
The mass of the Sun is 2.0×10^{30} kg.

Which of the following **cannot** be the mass of a white dwarf?

A 1.2×10^{30} kg

B 2.0×10^{30} kg

C 2.7×10^{30} kg

D 3.2×10^{30} kg

Your answer ☐ **[1]**

15 An astronomer analyses the light from a distant galaxy.
One of the spectral lines in the spectrum observed from the galaxy has wavelength 610 nm.
The same spectral line has a wavelength of 590 nm when measured in the laboratory.

What is the speed of this galaxy?

A $9.8 \times 10^{6}\,\text{m s}^{-1}$

B $1.0 \times 10^{7}\,\text{m s}^{-1}$

C $2.9 \times 10^{8}\,\text{m s}^{-1}$

D $3.0 \times 10^{8}\,\text{m s}^{-1}$

Your answer ☐ **[1]**

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Question 16 begins on page 10

SECTION B

Answer **all** the questions.

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

.....

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

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

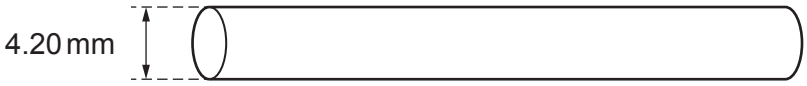

Fig. 16.1 (not to scale)

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

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

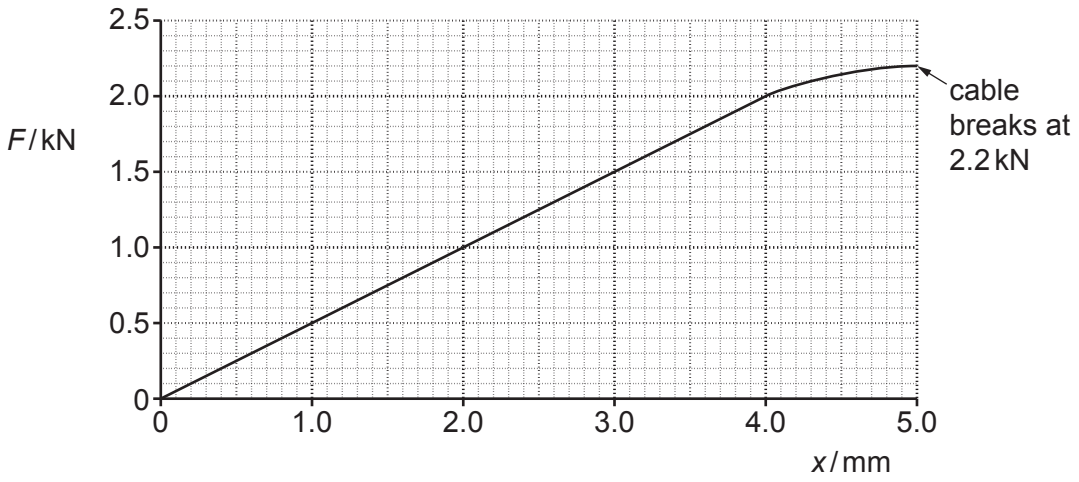

Fig. 16.2

The cable breaks when the force is 2.2 kN.

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

.....

.....

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

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

1. elastically

F = ... kN

2. plastically.

F = ... kN
[2]

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

k = ... $\mathrm{N\,m^{-1}}$ **[2]**

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

σ = ... Pa **[2]**

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

.....

.....

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

17 A student uses a motion-sensor connected to a laptop to investigate the motion of a hollow ball of mass 1.2×10^{-2} kg falling through air.

The ball is dropped from rest. It reaches terminal velocity before it reaches the ground.

The upthrust on the ball is negligible.

Fig. 17 shows the variation with time t of the velocity v of the ball as it falls towards the ground.

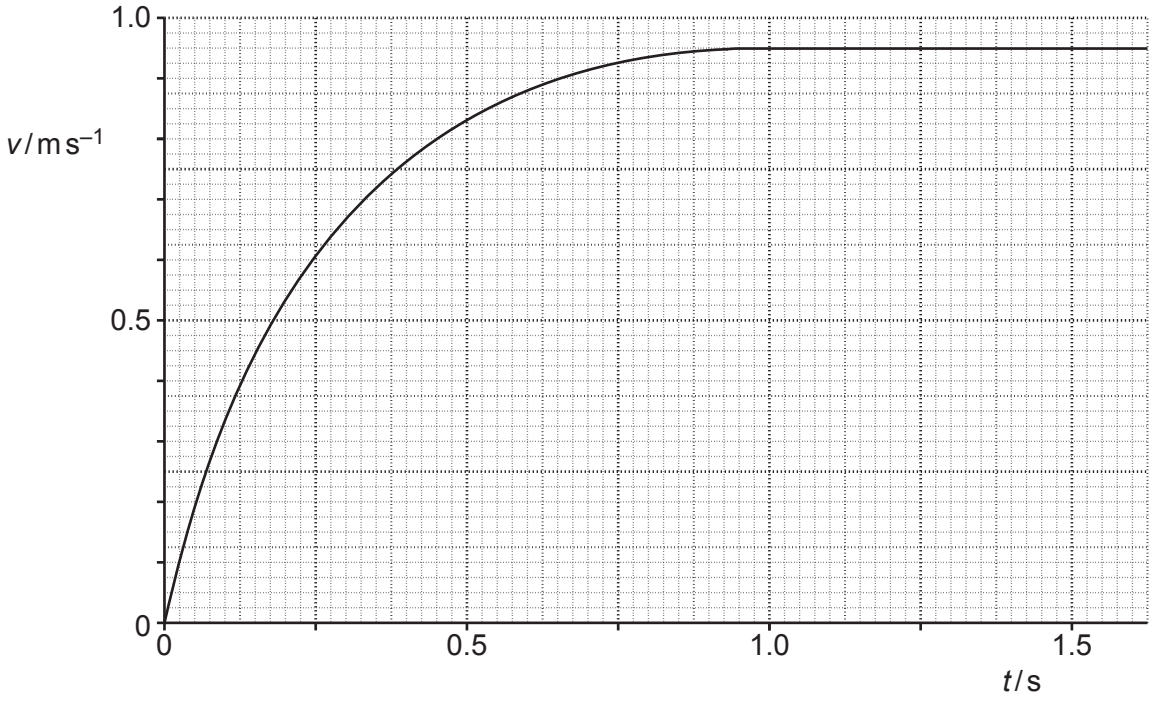

Fig. 17

(a) Draw a tangent to the curve at $t = 0.25$ s and determine the acceleration of the ball.

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

(b) Calculate the resultant force F acting on the ball at $t = 0.25\,\text{s}$.

$F =$ ..... N **[1]**

(c) Use your answer in **(b)** to calculate the drag on the ball at time $t = 0.25\,\text{s}$.

drag = ... N **[3]**

(d) The student now adds a small amount of sand inside the hollow ball.
As before, the ball is dropped from rest and it also reaches terminal velocity before it reaches the ground.

(i) Describe how the forces acting on the sand-filled ball at $v = 0.50\,\text{m s}^{-1}$ compare with the forces acting on the hollow ball at this speed.

.....

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

(ii) Explain why the terminal velocity of the sand-filled ball will be greater than the terminal velocity of the hollow ball.

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

18 A mass hanging from a vertical spring is pulled down.
It is then released from rest at time $t = 0$.
The mass oscillates vertically in a **vacuum** with simple harmonic motion about the equilibrium position. The spring is in tension at all times.

Fig. 18.1 shows the position of the mass at $t = 0$.

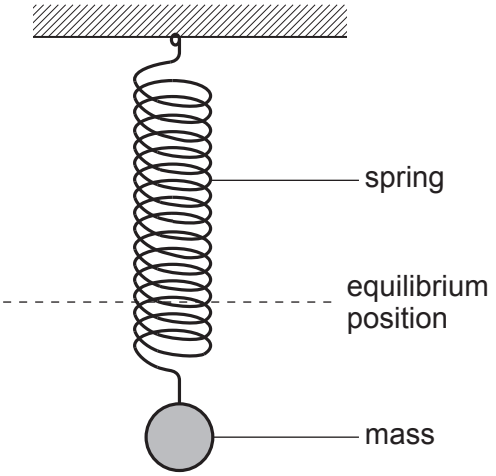

Fig. 18.1

At time $t = 6.5\,\text{s}$ the magnitude of the acceleration a of the mass is $3.6\,\text{m s}^{-2}$ and its displacement x is $4.6 \times 10^{-2}\,\text{m}$.

(a) (i) Use the defining equation for simple harmonic motion to show that the natural frequency f_0 of the mass-spring system is about 1.4 Hz.

[3]

(ii) Calculate the amplitude *A* of the oscillations.

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

(b) The mass-spring system shown in Fig. 18.1 is now made to oscillate in **air**.

Different types of energy are involved in the oscillations of this mass-spring system.

Describe the energy changes that will take place as the mass moves from the lowest point in its motion through the equilibrium position to the highest point in its motion.

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

Question 18 continues on page 16

(c) Fig. 18.2 shows the mass and spring now attached to a mechanical vibrator, which can oscillate with variable frequency.

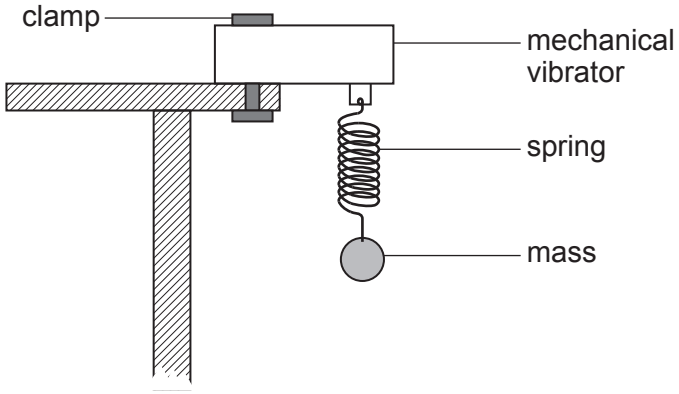

Fig. 18.2

The mass oscillates in air.

(i) The vibrator frequency is varied from 0 Hz to 2.5 Hz.
On Fig. 18.3, sketch a graph to show the variation with vibrator frequency of the amplitude of the mass. Label your graph **K**.

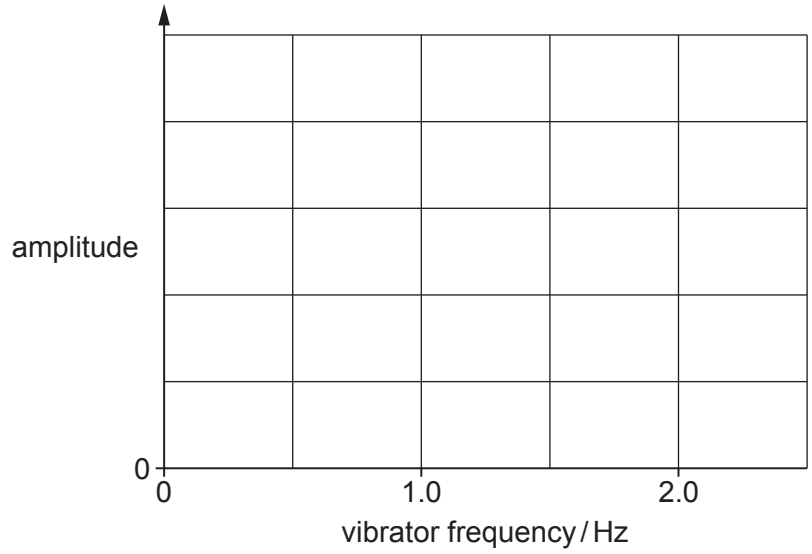

Fig. 18.3

[2]

(ii) A light disc is now attached to the mass to increase the damping.
The vibrator frequency is again varied from 0 Hz to 2.5 Hz.
Sketch a second graph on Fig. 18.3 to show the new variation of the amplitude.
Label this graph **D**. **[1]**

(iii) Explain why the phenomenon demonstrated in this experiment can cause problems for engineers when designing suspended footbridges.

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

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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20 A bicycle manufacturer carries out tests on the braking system of their new model.
A cyclist on this new bicycle travels at a constant initial speed U.
The cyclist applies the brakes at time $t = 0$ and the bicycle comes to a stop at time $t = 2.0\,s$.

Fig. 20.1 shows the variation of the braking force F on the bicycle with time t.

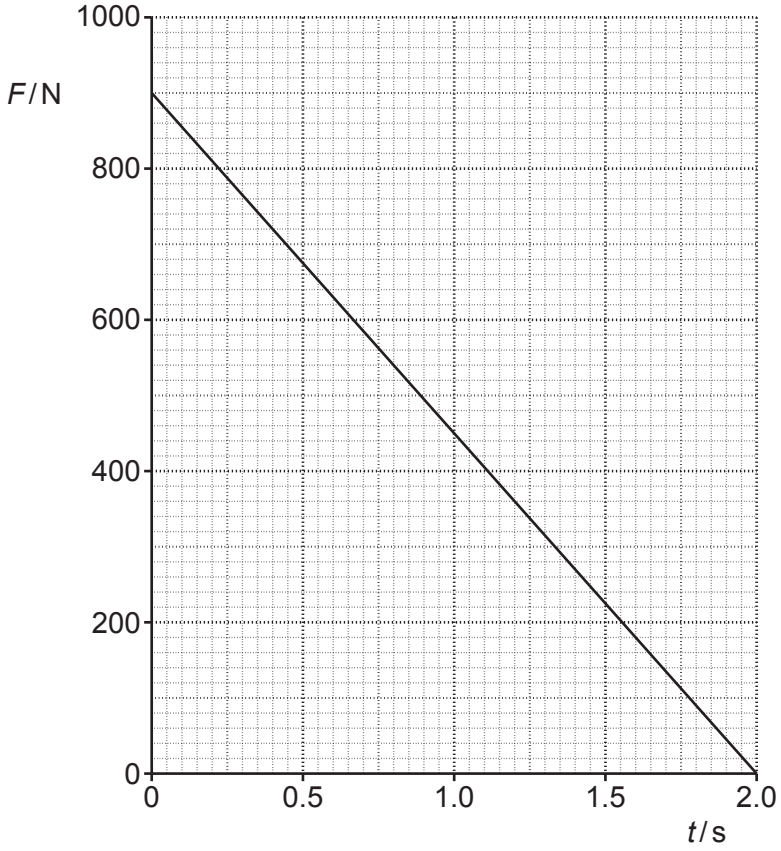

Fig. 20.1

(a) Use Newton's second law of motion to explain the physical quantity represented by the area under the graph shown in Fig. 20.1.

.....

.....

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

(b) The total mass of cyclist and bicycle is 71 kg.

Use Fig. 20.1 to calculate the initial speed U.

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

(c) Complete Fig. 20.2 to show the variation of the speed of the bicycle from $t = 0$ to $t = 2.0$ s.

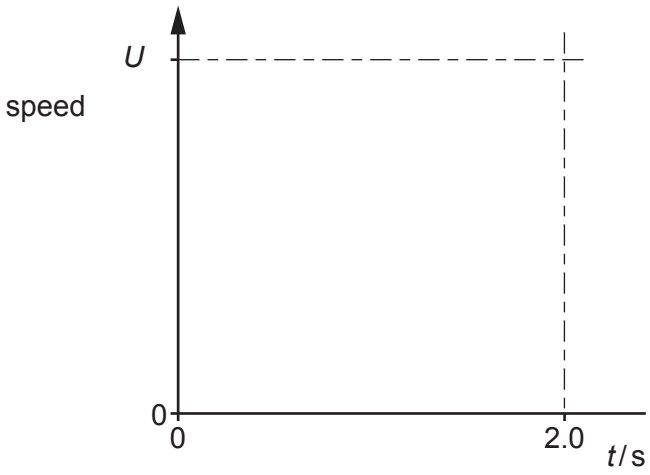

Fig. 20.2

[2]

21 A substance can exist as a crystalline solid, a liquid or a gas.
A solid sample of the substance is placed in a sealed container and heated at a constant rate until it changes into a gas.

Fig. 21 shows the variation with time t of the temperature θ for the substance.

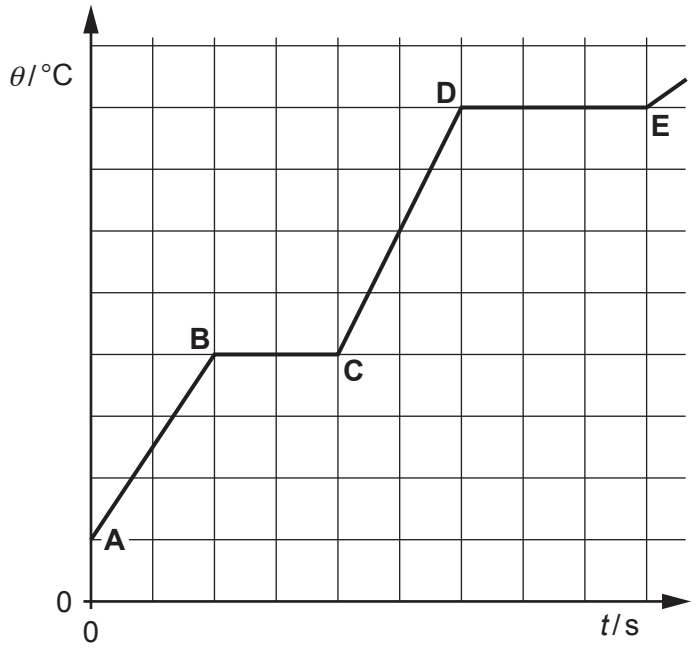

Fig. 21

(a) Use the kinetic theory of matter to describe the solid phase (section **AB**) and the liquid phase (section **CD**) in terms of the motion and arrangement of the molecules of the substance.

Section **AB**: .....

.....

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Section **CD**: .....

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[4]

(b) Use Fig. 21 to explain how the specific heat capacity of the liquid compares with the specific heat capacity of the solid.

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

(c) State what is meant by the **internal energy** of the substance.

.....

.....

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

(d) Beyond the point **E** in Fig. 21, the substance behaves as an ideal gas.

(i) The mass of a gas molecule is 4.8×10^{-26} kg.
Calculate the root mean square speed of the gas molecules at a temperature of 250 °C.

root mean square speed = ... $m\,s^{-1}$ **[3]**

(ii) Calculate the internal energy of 1.3 moles of the gas at 250 °C.

internal energy = ... J **[3]**

22 A screw is used to hang a wooden sign on a wall. It is screwed into the wall using a screwdriver.

(a) The width of the screwdriver blade is 5.0×10^{-3} m from end to end.
The ends of the blade exert equal and opposite forces on the screw.
The magnitude of each force is 350 N, as shown in Fig. 22.1.

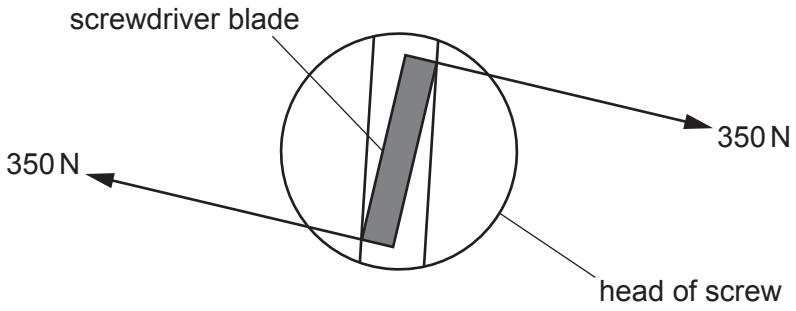

Fig. 22.1

Calculate the magnitude of the torque of the couple produced by the forces at each end of the screwdriver blade.

torque = ... N m **[1]**

(b) The wooden sign is then hung on the screw at point **A**.
The forces acting on the screw are shown in Fig. 22.2.

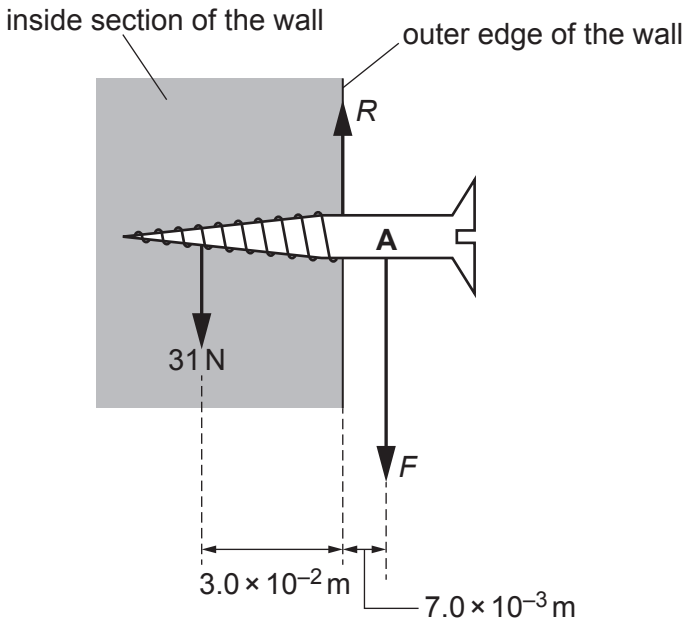

Fig. 22.2

The inside section of the wall exerts a maximum downwards force of 31 N at a distance of 3.0×10^{-2} m from the outer edge of the wall.
The hanging wooden sign exerts a force *F* at a distance 7.0×10^{-3} m from the outer edge of the wall.
There is a force *R* acting on the screw at the outer edge of the wall.
The mass of the screw is negligible.

Use the principle of moments to calculate the maximum mass of the wooden sign.

mass = ... kg **[3]**

23 (a)* In 2017, an ultra-cool star TRAPPIST-1 was discovered with at least five of its own orbiting planets. Astronomers are interested about the possibility of finding life on some of the planets orbiting TRAPPIST-1.

The table below shows some data.

	TRAPPIST-1	**Sun**
Luminosity *L* / W	2.0×10^{23}	3.8×10^{26}
Surface temperature *T* / K	2500	5800
Radius of star / m	*R*	7.0×10^{8}
Distance between Earth and Sun / m		1.5×10^{11}
Distance between planets and TRAPPIST-1 / m	1.6×10^{9} to 9.0×10^{9}	

The temperature *T* in kelvin of a planet, its distance *d* from the star and the luminosity *L* of the star are related by the expression

$\frac{T^4 d^2}{L}$ = constant.

- The average temperature of the Earth is about 290 K. Explain how life may be possible on some of the planets orbiting TRAPPIST-1.
- Use your knowledge of luminosity to show that the radius *R* of TRAPPIST-1 is smaller than the Sun.
- Support your answers by calculations. **[6]**

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Additional answer space if required.

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Question 23 continues on page 28

(b) Kepler's third law can be applied to a satellite in a geostationary orbit around the Earth.

(i) Complete the equation for Kepler's third law below.
You do not need to define any of the terms.

$$\text{.....} = \frac{4\pi^2}{GM} \text{.....}$$

[1]

(ii) The mass of Earth is 6.0×10^{24} kg.
Calculate the radius of the circular path of a satellite in a geostationary orbit around the Earth.

radius = ... m **[2]**

24 **(a)** Proxima Centauri is the closest star to Earth.
Fig. 24.1 shows the apparent positions of this star against the background of very distant stars as seen from the Earth over a period of exactly 6 months.

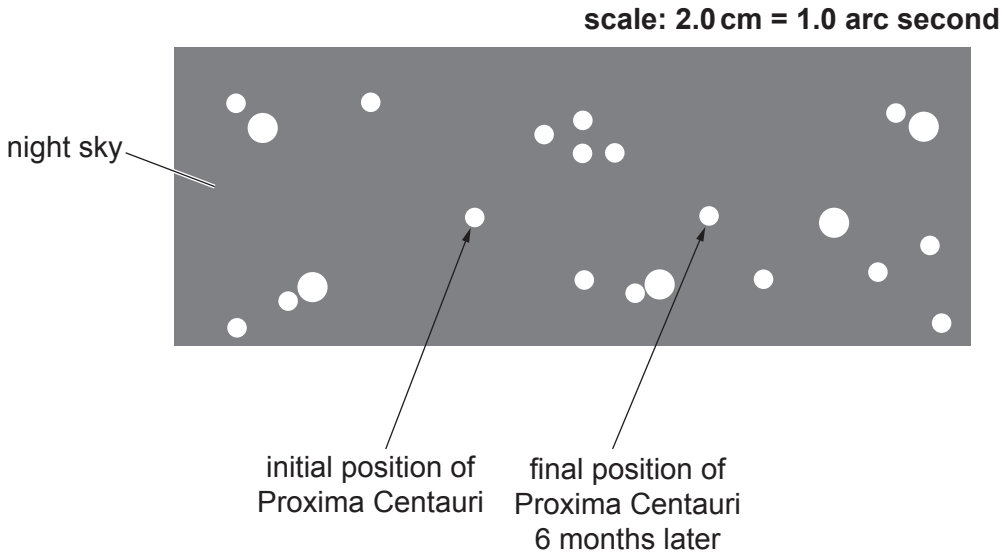


Fig. 24.1

The parallax angle for Proxima Centauri can be determined from Fig. 24.1 using the scale provided.

(i) Show that the parallax angle *p* for Proxima Centauri is about 0.8 arc second.

[2]

Question 24 continues on page 30

(ii) Use your answer in **(i)** to calculate the distance *d* of Proxima Centauri from the Earth in light-years (ly).

1 pc = 3.26 ly

d = ... ly **[2]**

(b) The galaxies in the Universe may be assumed to be distributed uniformly through space.

In this model, the separation between two neighbouring galaxies is 1.4×10^{23} m and each galaxy occupies a cube of space of volume 2.7×10^{69} m^3 as shown in Fig. 24.2.

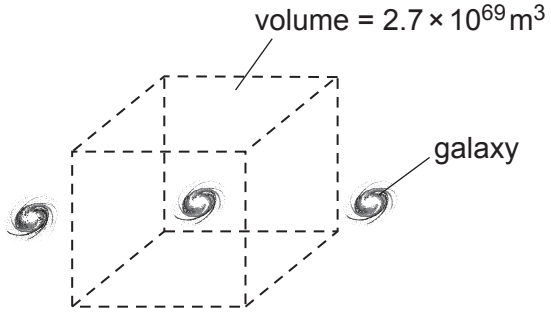


Fig. 24.2

There are on average 10^{11} stars in each galaxy and the mass of an average star is about 2.0×10^{30} kg.

(i) Estimate the gravitational force between two neighbouring galaxies.

force = ... N **[2]**

(ii) Show that the mean density of the Universe is about $7 \times 10^{-29}\,\text{kg}\,\text{m}^{-3}$.

[1]

(iii) Suggest why the actual mean density of the Universe is different from the value calculated in **(ii)**.

.....

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

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

OCR
Oxford Cambridge and RSA

Friday 09 October 2020 – Morning

A Level Physics A

H556/01 Modelling physics

Time allowed: 2 hours 15 minutes

You must have:
- the Data, Formulae and Relationships Booklet

You can use:
- a scientific or graphical calculator
- a ruler (cm/mm)

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

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.

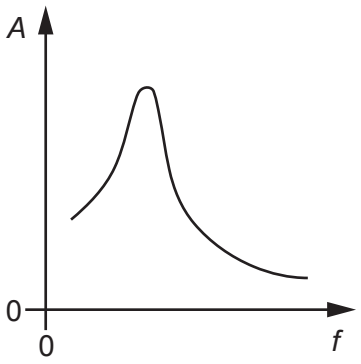
B The force acting on the ball is *F*.

C The ball experiences greatest drag.

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

Your answer ☐ **[1]**

4 An oscillator is forced to oscillate at different frequencies.
The graph of amplitude A against driving frequency f for this oscillator is shown.



The damping on the oscillator is now **decreased**.

Which of the following statements is/are correct?

1 The amplitude of the oscillations at any frequency decreases.
2 The maximum amplitude occurs at a lower frequency.
3 The peak on the graph becomes thinner.

A Only 1

B Only 2

C Only 3

D 1, 2 and 3

Your answer ☐ **[1]**

5 The gravitational force between two point-mass objects **X** and **Y** is F_1.

The mass of **X** increases and the distance between **X** and **Y** is halved.

Which statement about the new gravitational force F_2 between these two objects is correct?

A $0 < F_2 < 0.25F_1$

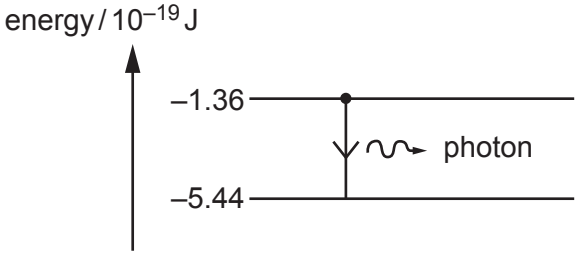
B $F_2 > 4F_1$

C $F_2 = F_1$

D $2F_1 < F_2 < 4F_1$

Your answer ☐ **[1]**

6 The diagram below shows two energy levels for the electron in the hydrogen atom.



The electron makes the transition shown by the arrow.

What is the wavelength of the photon emitted?

A 293 nm

B 366 nm

C 488 nm

D 1460 nm

Your answer ☐ **[1]**

7 Recent analysis of the data collected from the Hubble and Gaia telescopes gave the Hubble constant a value of 73.5 km s^{-1} Mpc^{-1}.

What is this value, written to 2 significant figures, in s^{-1}?

A $2.4 \times 10^{-21}\ s^{-1}$

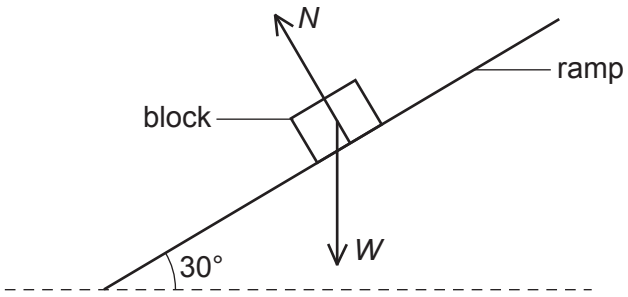
B $2.4 \times 10^{-18}\ s^{-1}$

C $2.4 \times 10^{-12}\ s^{-1}$

D $2.4 \times 10^{21}\ s^{-1}$

Your answer ☐ **[1]**

8 A wooden block is **stationary** on a ramp.

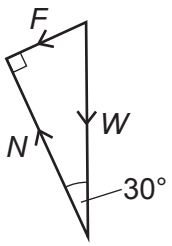


The diagram is **not** drawn to scale.

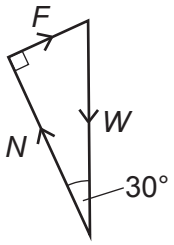
The block has weight *W*. The normal contact force on the block is *N*. The frictional force *F* on the block is not shown on the diagram.

Which triangle of forces diagram is correct?

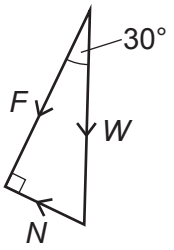
A



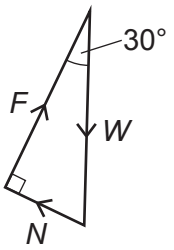
B



C



D



Your answer ☐ **[1]**

9 Laser light of wavelength of 640 nm is incident normally at a diffraction grating.
The separation between adjacent lines (slits) is 3.3×10^{-6} m.

What is the **total** number of bright spots that can be observed in the diffraction pattern?

A 5

B 6

C 10

D 11

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 In astronomy, distance can be measured in different units.

Which one of the following distances is the **largest**?

A 4.22×10^{16} m

B 1.91 pc

C 3.42 ly

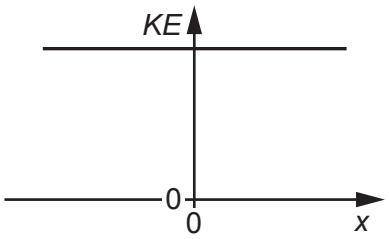
D 593 AU

Your answer ☐ **[1]**

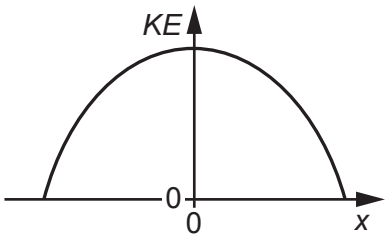
12 An oscillator is executing simple harmonic motion.

Which graph of kinetic energy *KE* against displacement *x* is correct for this oscillator?

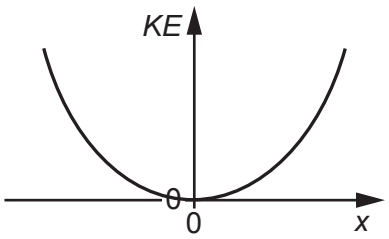
A



B



C



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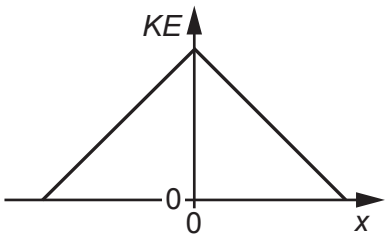


Your answer ☐ **[1]**

13 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 %

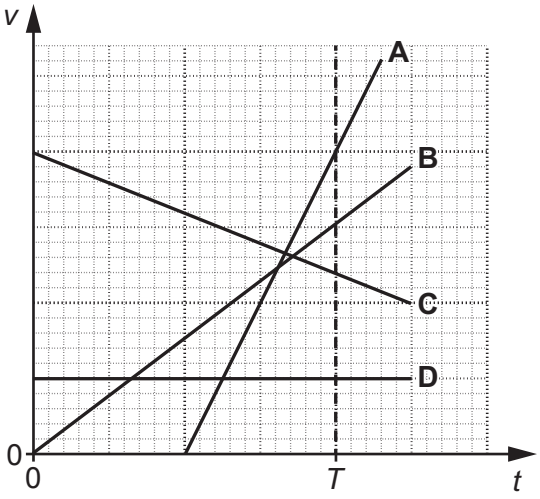
B 6.4 %

C 7.5 %

D 8.5 %

Your answer ☐ **[1]**

14 The velocity v against time t graphs for four objects **A**, **B**, **C** and **D** are shown below.



Which object travels the greatest distance between $t = 0$ and $t = T$?

Your answer ☐ **[1]**

15 The kinetic theory of matter is a model used to describe the behaviour of particles (atoms or molecules) in an ideal gas. There are a number of assumptions made in the kinetic model for an ideal gas.

Which one of the following assumptions is **not** correct?

A The collisions of particles with each other and the container walls are perfectly inelastic.

B The electrostatic forces between particles are negligible except during collisions.

C The particles occupy negligible volume compared to the volume of the gas.

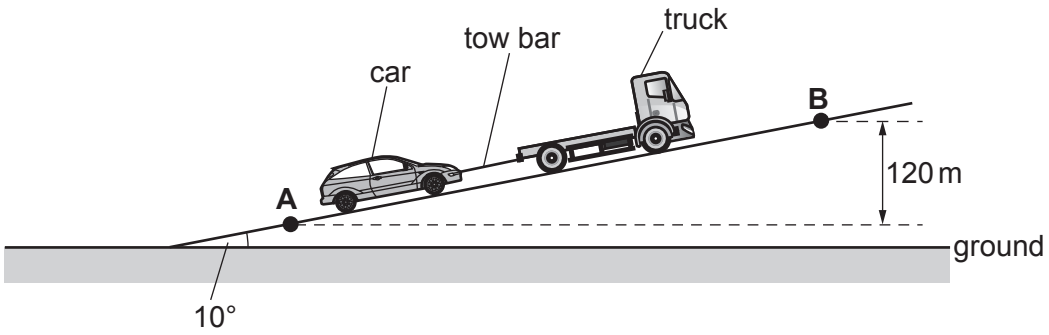
D There are a large number of particles in random motion.

Your answer ☐ **[1]**

SECTION B

Answer **all** the questions.

16 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.

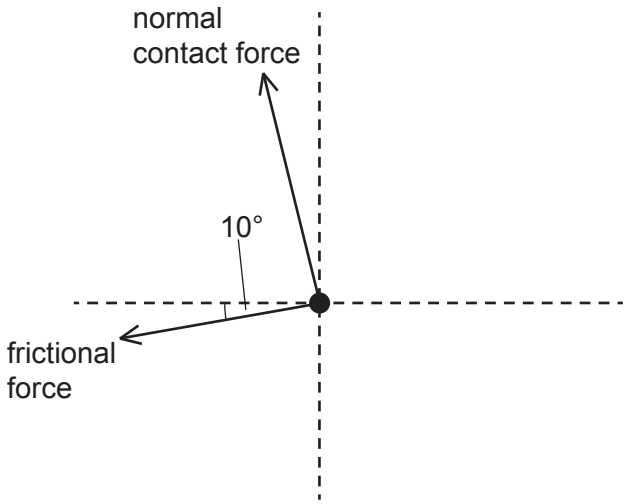


The diagram is **not** drawn to scale.

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.

(a) 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**.

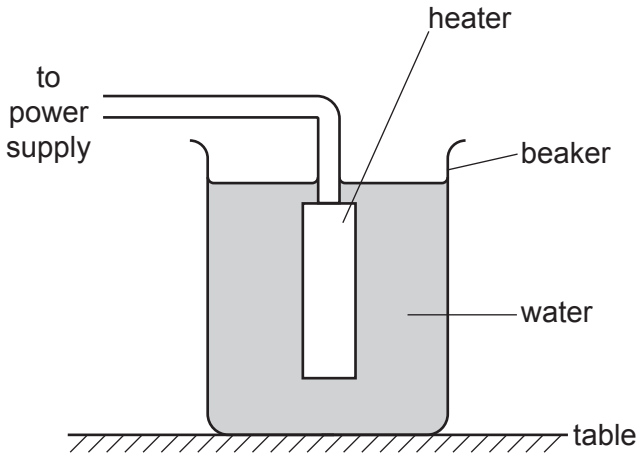
work done = ... J **[3]**

(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.

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

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

17 (a) A heater is used to heat water in a beaker.



(i) Before switching on, the metal heater and the water are both at room temperature.

Describe the motion of the atoms of the metal heater and of the water molecules.

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..... **[3]**

(ii) The heater is now switched on.
The power of the heater is 200 W.
The mass of the water in the beaker is 500 g.
It takes 10.0 minutes to increase the temperature of the water in the beaker from 20 °C to 60 °C.

Calculate the energy transferred from the water to the **beaker and the surroundings**.

- specific heat capacity of water = 4200 $J\,kg^{-1}\,K^{-1}$

energy transferred = ... J **[3]**

(b)* A student is carrying out an experiment to determine the specific latent heat of fusion L_f of ice. The student has two sets of apparatus next to each other on the laboratory bench, as shown in **Fig. 17.1** and **Fig. 17.2**.

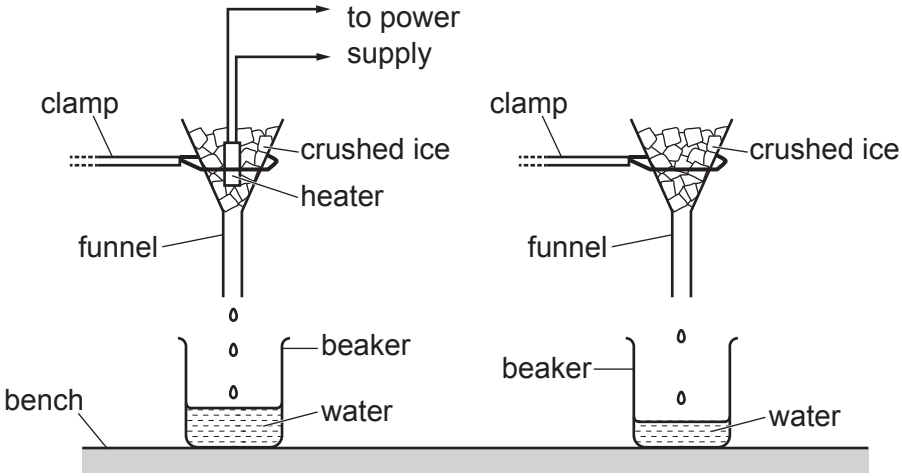

Fig. 17.1

Fig. 17.2

Both funnels are identical and have the same mass of crushed ice at 0 °C.

The current in the heater is 5.0 A and the potential difference across it is 12 V.

Fig. 17.3 shows the variation of mass of water m collected in each beaker with time t.

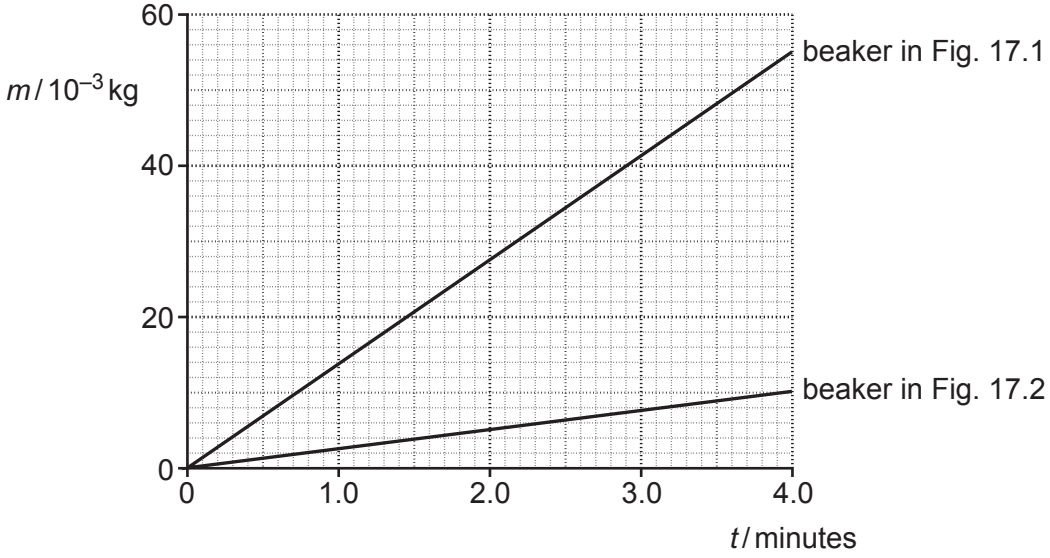

Fig. 17.3

Describe and explain the shape of the two graphs in **Fig. 17.3** and use them to determine the specific latent heat of fusion L_f of ice. **[6]**

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Additional answer space if required

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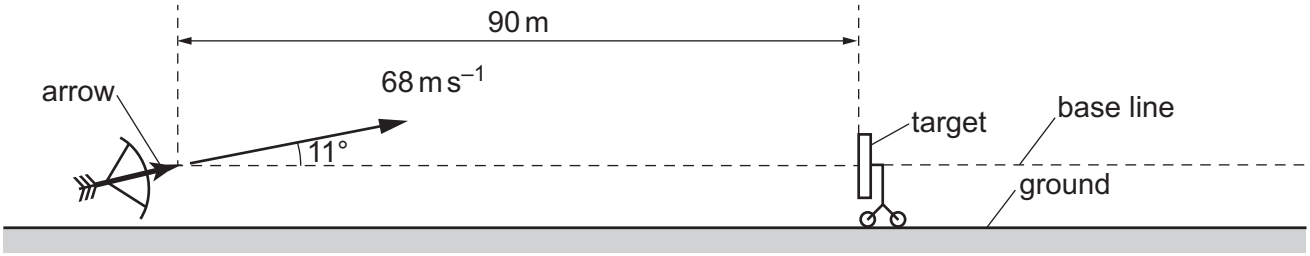
18 An archer fires an arrow towards a target as shown below.



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

The centre of the target is at the same height as the initial position of the arrow.
The target is a distance of 90 m from the arrow.
The arrow has an initial velocity of 68 m s^{-1} and is fired at an angle of 11° to the horizontal.

Air resistance has negligible effect on the motion of the arrow.

(a) Describe how the kinetic energy of the arrow changes during its journey from when it is fired until it reaches its maximum height.

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

(b) Show that the time taken for the arrow to reach its maximum height is about 1.3 s.

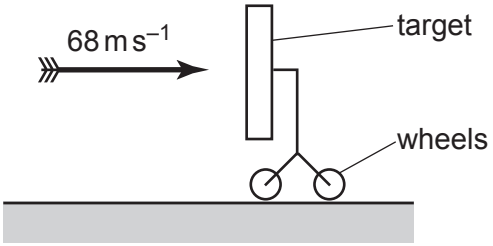
[2]

(c) The arrow misses the target.

Calculate the horizontal distance, measured along the base line, by which the arrow misses the target.

horizontal distance = ... m **[3]**

(d) The arrow is now fired horizontally at $68\,m\,s^{-1}$ into the target at very close range.



The arrow sticks into the target. The collision between the arrow and the target is inelastic.

(i) Explain what is meant by an **inelastic collision**.

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

(ii) The target is mounted on wheels. The target has a much larger mass than the mass of the arrow.

Using ideas of momentum, explain the velocity of the target immediately after the arrow sticks into the target.

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

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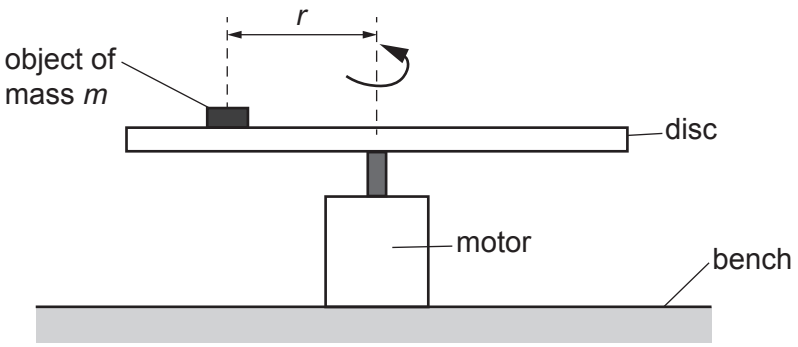
20 A small object of mass m is placed on a rotating horizontal metal disc at a distance r from the centre of the disc.



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

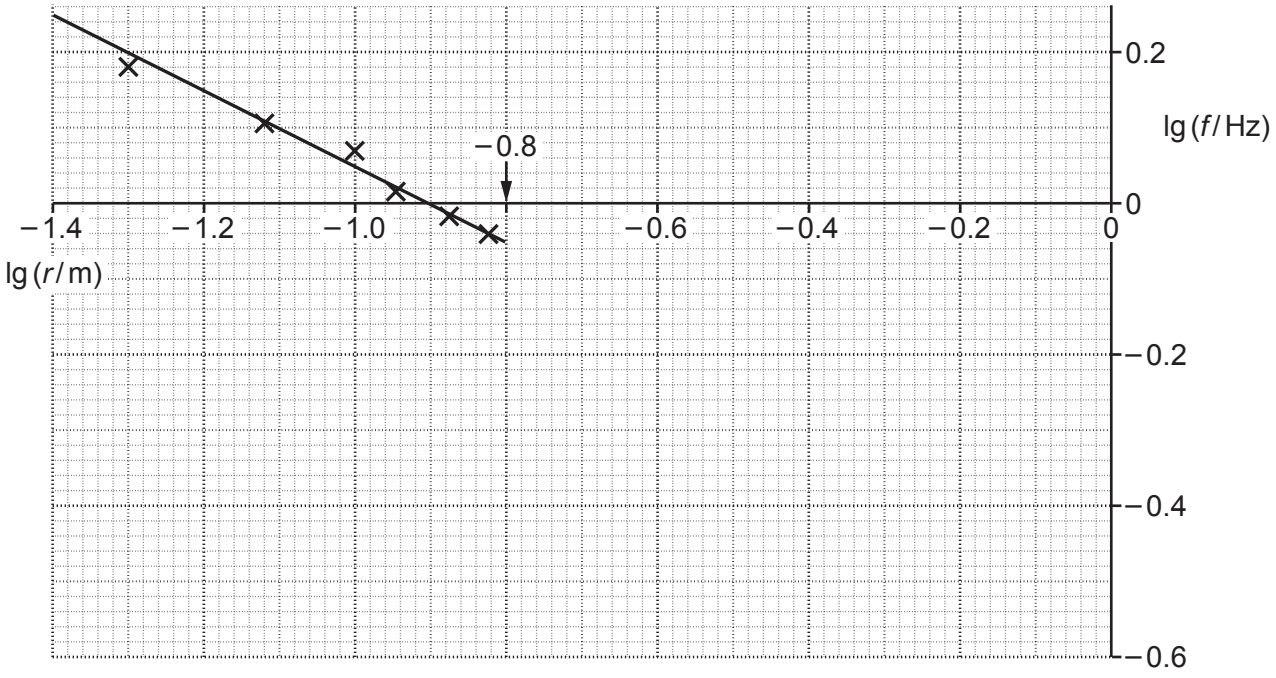
The frequency of rotation of the disc is slowly increased from zero, until the object slips off. At this point, the friction F acting on the object is equal to the centripetal force.

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).

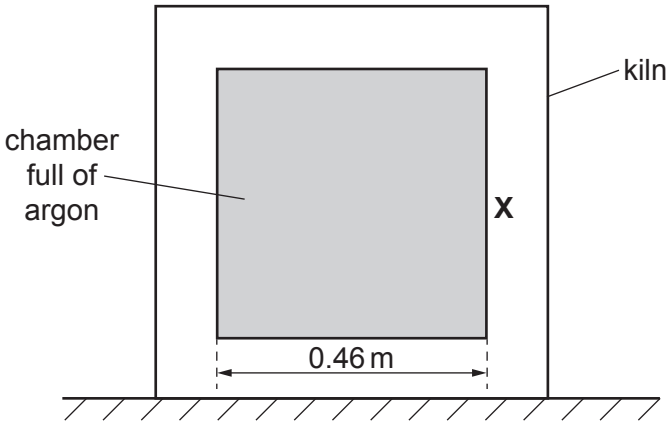


For this graph: *y*-intercept = $\frac{1}{2} \times \lg\left(\frac{gk}{4\pi^2}\right)$

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

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

21 A kiln used to harden ceramics is shown below.



The internal chamber is a cube. Each side of this cube has length 0.46 m.
The chamber is sealed and full of argon. Argon behaves as an ideal gas.

(a) The kiln is initially at 20 °C.
The argon in the kiln has an initial pressure of 100 kPa.

(i) Calculate the amount of argon *n* in the chamber in moles.

n = ... mol **[2]**

(ii) The temperature of the kiln is increased from 20 °C to 1300 °C.

Calculate the pressure in kPa at 1300 °C.

pressure = ... kPa **[2]**

(b) The temperature of the kiln is 1300 °C.
A single atom of argon is travelling horizontally towards the vertical side **X** of the chamber.
The initial speed of this atom is 990 m s^{-1}. After collision, it rebounds at the same speed.

(i) Calculate the change in momentum Δp of this atom.
- mass of argon atom = 6.6×10^{-26} kg

Δp = ... kg m s^{-1} **[2]**

(ii) Assume that this atom does not collide with any other argon atoms inside the chamber. Instead, it travels horizontally, making repeated collisions with the opposite vertical walls of the chamber.

1 Show that the atom makes about 1000 collisions with side **X** in a time interval of 1.0 s.

[1]

2 Calculate the average force F on side **X** made by the atom.

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

(iii) Without calculation, explain how your answer to **(ii)2** could be used to estimate the total pressure exerted by the atoms of the argon gas in the kiln.

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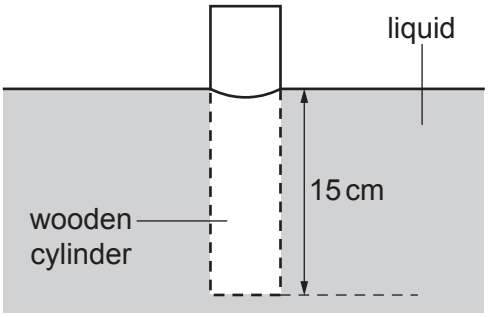
..... **[2]**

22 A long wooden cylinder is placed into a liquid and it floats as shown.



The length of the cylinder below the liquid level is 15 cm.

(a) (i) State **Archimedes' principle**.

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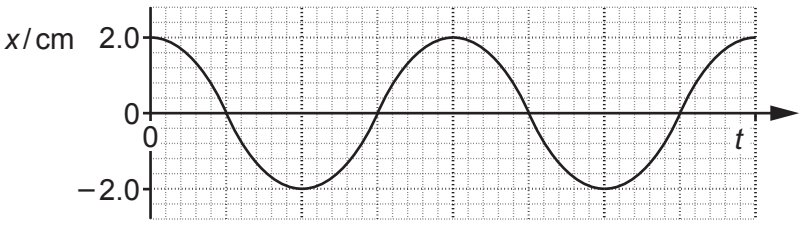
..... **[1]**

(ii) The pressure exerted by the liquid alone on the bottom of the cylinder is 1.9×10^3 Pa.

Calculate the density ρ of the liquid.

ρ = ... kg m^{-3} **[2]**

(b) The cylinder is pushed down into the liquid and then allowed to oscillate freely.
The graph of displacement x against time t is shown below.



The cylinder oscillates with simple harmonic motion with frequency of 1.4 Hz.

(i) Calculate the displacement, in cm, at time $t = 0.60\,s$.

displacement = ... cm **[3]**

(ii) Calculate the maximum speed of the oscillating cylinder.

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

(iii) The cylinder is now pushed down further into the liquid before being released.
As before, the cylinder oscillates with simple harmonic motion.

State the effect this has on

1 the amplitude

.....

2 the period.

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[2]

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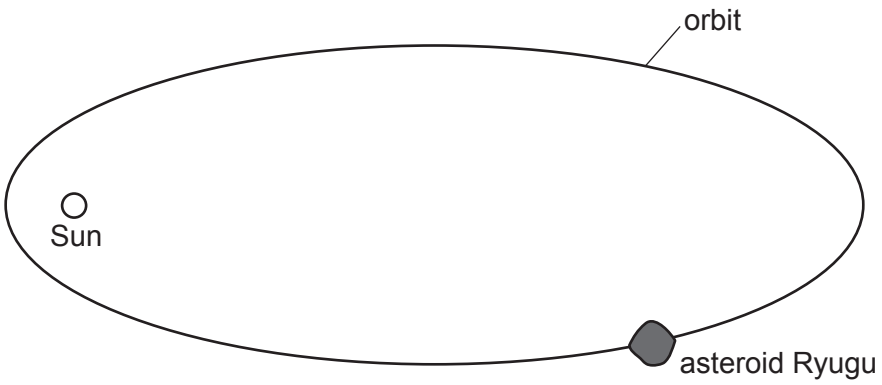
23 In June 2018, the spacecraft Hayabusa2 arrived at an asteroid called Ryugu.

(a) The asteroid orbits the Sun in an elliptical orbit as shown below.



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

(i) Indicate with a letter **X** on the orbit where the asteroid would be moving at maximum speed. **[1]**

(ii) Use Kepler's **second law** to explain your answer to **(a)(i)**.

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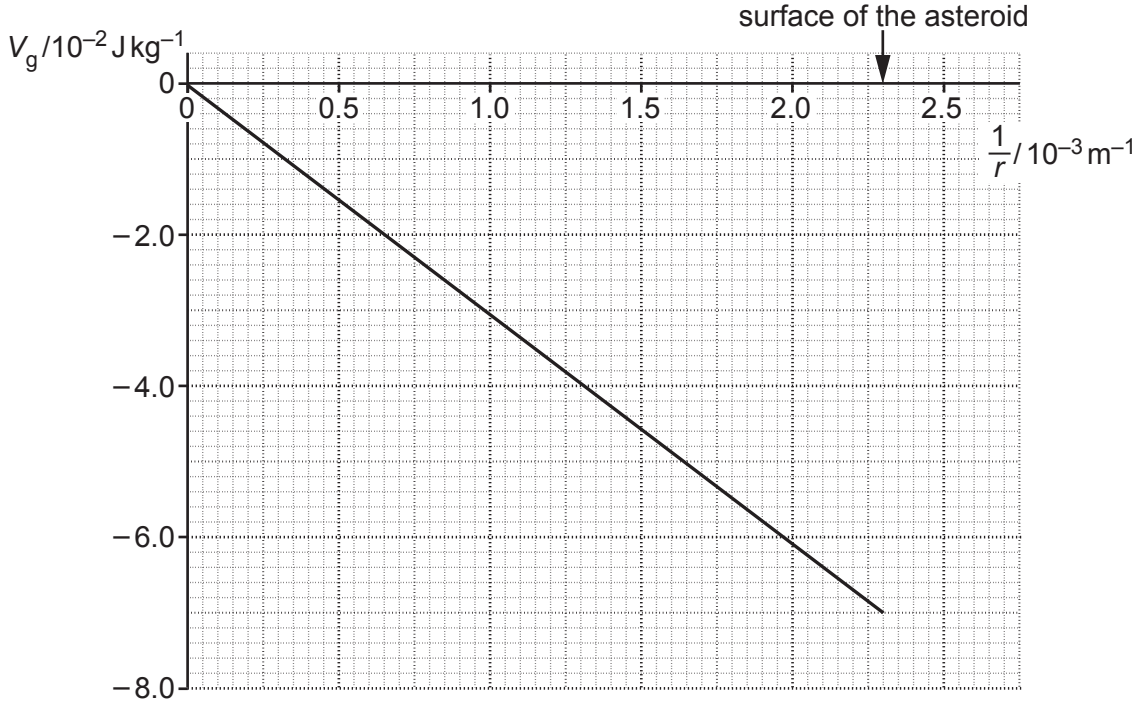
..... **[2]**

(b) The gravitational potential at a distance r from the centre of the asteroid Ryugu is V_g. The graph of V_g against $\frac{1}{r}$ for the asteroid is shown below.



(i) Define **gravitational potential**.

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

(ii) Show that the magnitude of the gradient of the graph is equal to GM, where M is the mass of the asteroid and G is the gravitational constant.

[1]

(iii) Use the gradient of the graph to show that the mass M of the asteroid is about 4.6×10^{11} kg.

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

(c) In October 2018, the probe Mobile Asteroid Surface Scout (MASCOT) was released from **rest** from the Hayabusa2 spacecraft from a distance of 600 m from the centre of the asteroid.

Assume that the spacecraft was stationary relative to the asteroid when MASCOT was dropped.

Use information from **(b)** to calculate the speed of the impact v when MASCOT landed on the surface of the asteroid.

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

Question 24 is on page 30

24 **(a)** Our Sun will eventually become a red giant.

Describe and explain the next stages of evolution of our Sun.

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

(b) Rigel is a blue giant star in the constellation of Orion.
The table below shows some data about Rigel and about our Sun.

	Rigel	**Sun**
Surface temperature / K		5.8×10^3
Luminosity / W	4.62×10^{31}	3.85×10^{26}
Wavelength of emitted light at peak intensity / nm	240	500

(i) Show that the surface temperature of Rigel is 12 000 K.

[2]

(ii) Calculate the radius of Rigel.

radius = ... m **[2]**

(c) An astronomer claims to have discovered a white dwarf with a mass twice that of our Sun.

Suggest why this claim must be incorrect.

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

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).