

Please write clearly in block capitals.

Centre number

Candidate number

Surname StemUp Model Solution

Forename(s) _____

Candidate signature _____

I declare this is my own work.

INTERNATIONAL AS PHYSICS

Unit 1 Mechanics, materials and atoms

Tuesday 5 January 2021

07:00 GMT

Time allowed: 2 hours

Materials

For this paper you must have:

- a Data and Formulae Booklet as a loose insert
- a ruler with millimetre measurements
- a scientific calculator, which you are expected to use where appropriate
- a protractor.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for questions are shown in brackets.
- The maximum mark for this paper is 80.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12–25	
TOTAL	



J A N 2 1 P H 0 1 0 1

Section A

Answer **all** questions in this section.

0 1

State **two** precautions for the safe use of a gamma source in a school laboratory.

[2 marks]

1 *Handle the source with long tongs, never directly with the hands.*2 *Store the source in a lead-lined box when not in use, and limit the time it is out (exposure time).*

2

0 2 . 1

State what is meant by the rest energy of a particle.

[1 mark]

The energy equivalent to the rest mass m_0 of the particle, given by $E = m_0 c^2$.

0 2 . 2

Calculate, in MeV, the rest energy of an electron.

[2 marks]

$$E = mc^2 = 9.11 \times 10^{-31} \times (3.00 \times 10^8)^2$$

$$E = 8.20 \times 10^{-14} \text{ J}$$

$$E = 8.20 \times 10^{-14} / 1.60 \times 10^{-13} = 0.511 \text{ MeV}$$

$$(\text{or } 5.49 \times 10^{-4} \text{ u} \times 931.5 \text{ MeV} = 0.511 \text{ MeV})$$

rest energy = 0.51 MeV

3

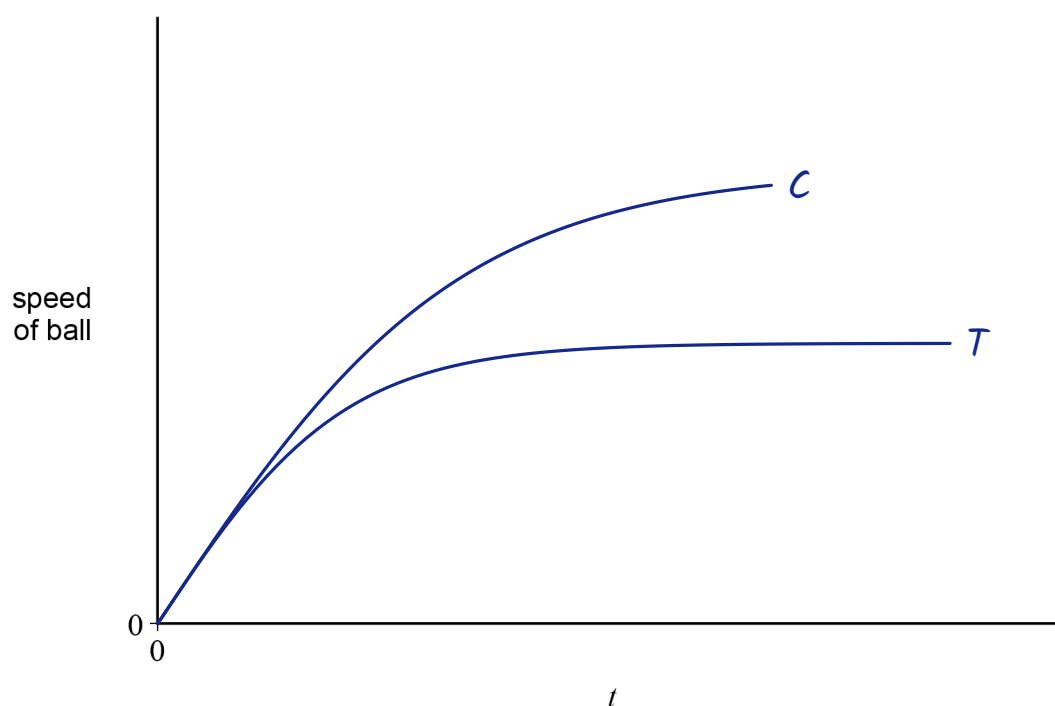


0 3

A tennis ball of mass 58 g has a rough surface.
A cricket ball of mass 160 g has a smooth surface.
Assume that the balls have the same diameter.
Both balls are dropped from the roof of a tall building at the same time and they fall through the air to the ground.

Sketch, on the axes below, graphs to show the variations with time t of the speed of each ball.

Label your graphs with a **T** for the tennis ball and a **C** for the cricket ball.
No calculations are required.

[3 marks]

*same initial gradient (g); T reaches a lower terminal speed sooner;
areas under both graphs are equal (same distance fallen)*

Turn over for the next question

3

Turn over ►



0 4 . 1

An object is made to rotate by a couple acting about an axis through its centre of mass.

State what is meant by a couple.

[2 marks]

A couple is a pair of forces that are equal in magnitude and act in opposite directions.

The two forces are coplanar but not colinear (their lines of action are parallel but do not coincide).

0 4 . 2

State how a single force applied to an object can cause the object to rotate.

[1 mark]

The line of action of the force does not pass through the centre of mass, so the force has a moment about the centre of mass.

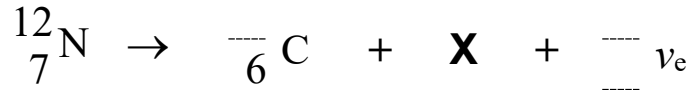
3



0 5

In the decay of a nucleus of nitrogen-12, an electron neutrino (ν_e) and another particle **X** are emitted from the nucleus.

The decay is shown in the equation below.



0 5 . 1

Identify **X**.

[1 mark]

X = positron (β^+)

0 5 . 2

State the nucleon number of the nucleus produced by this decay.

[1 mark]

nucleon number = 12

0 5 . 3

Complete below the missing data for the neutrino.

[1 mark]

0

 ν_e

0

0 5 . 4

Explain why the existence of the neutrino was suggested before the particle was observed.

[2 marks]

Beta particles from a particular decay were observed to have a range of

kinetic energies, up to a maximum value.

For energy to be conserved, another (undetected) particle had to be

emitted carrying the missing energy, so the neutrino was proposed.

Turn over ►



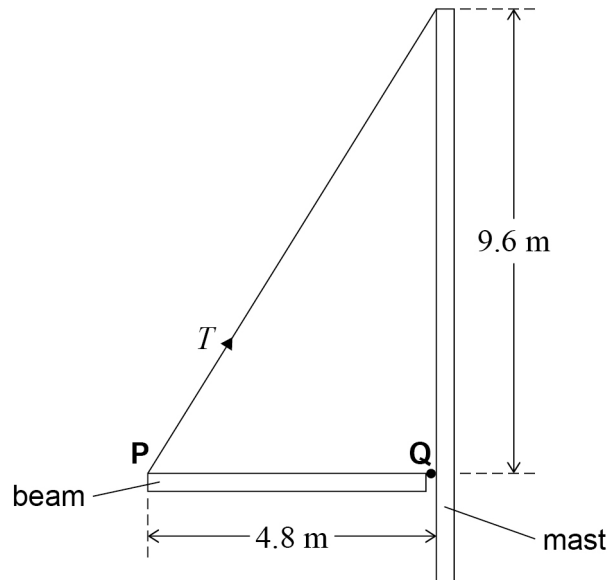
0 6

Figure 1 shows the mast of a sailing boat.

A uniform horizontal beam **PQ** is attached by a pivot to the mast at **Q**. The beam is supported by a light inextensible rope attached to the top of the mast and to the free end of the beam at **P**.

The tension in the rope is T .

Figure 1



0 6 . 1

The mass of the beam is 12 kg.

Calculate T by taking moments about **Q**.

[4 marks]

$$\text{angle between rope and beam: } \tan \theta = 9.6 / 4.8 = 2.0, \quad \theta = 63.4^\circ$$

$$\text{moments about Q: clockwise moment} = \text{anticlockwise moment}$$

$$T \times 4.8 \sin 63.4^\circ = 12 \times 9.81 \times 2.4$$

$$4.29 T = 282.5$$

$$T = 282.5 / 4.29 = 65.8 \text{ N}$$

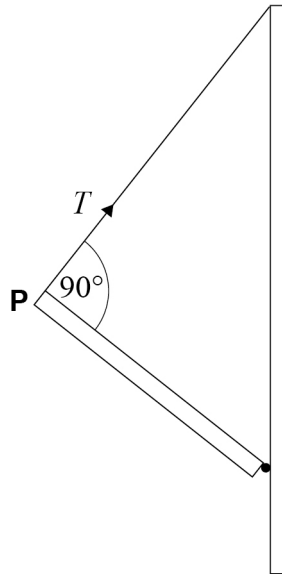
$$T = \underline{\quad 66 \quad} \text{ N}$$



0 6 . 2

The end **P** of the beam is now raised by shortening the rope until it makes an angle of 90° to the beam as shown in **Figure 2**.

Figure 2



The magnitude of T varies as **P** is raised.

Explain the variation in the magnitude of T .
Calculations are not required.

[2 marks]

T decreases as P is raised.

The centre of mass of the beam moves nearer to the mast, so the moment of the beam's weight about Q decreases.

Also, the perpendicular distance from Q to the line of action of T increases (up to 4.8 m when the rope is at 90° to the beam), so a smaller T gives the moment needed.

6

Turn over ►



0 7

In an experiment to determine the acceleration due to gravity, a steel ball is dropped from rest.

The time t taken for the ball to fall a distance h is measured for a range of values of h . All of the measurements are shown in **Table 1**.

Table 1

h / m	t / s
0.5	0.35
1.0	0.48
1.5	0.6
2.0	0.67

0 7 . 1

Describe **three** ways in which the procedure and the recording of results could be improved.

Refer to **Table 1** in your answer.

[3 marks]

1 *Record h to a greater (consistent) number of significant figures, e.g.*

0.500 m rather than 0.5 m, as h can be measured to the nearest

mm.

2 *Record all values of t to the same number of decimal places, e.g.*

0.60 s rather than 0.6 s.

3 *Take more sets of results within the range (only four values of h are*

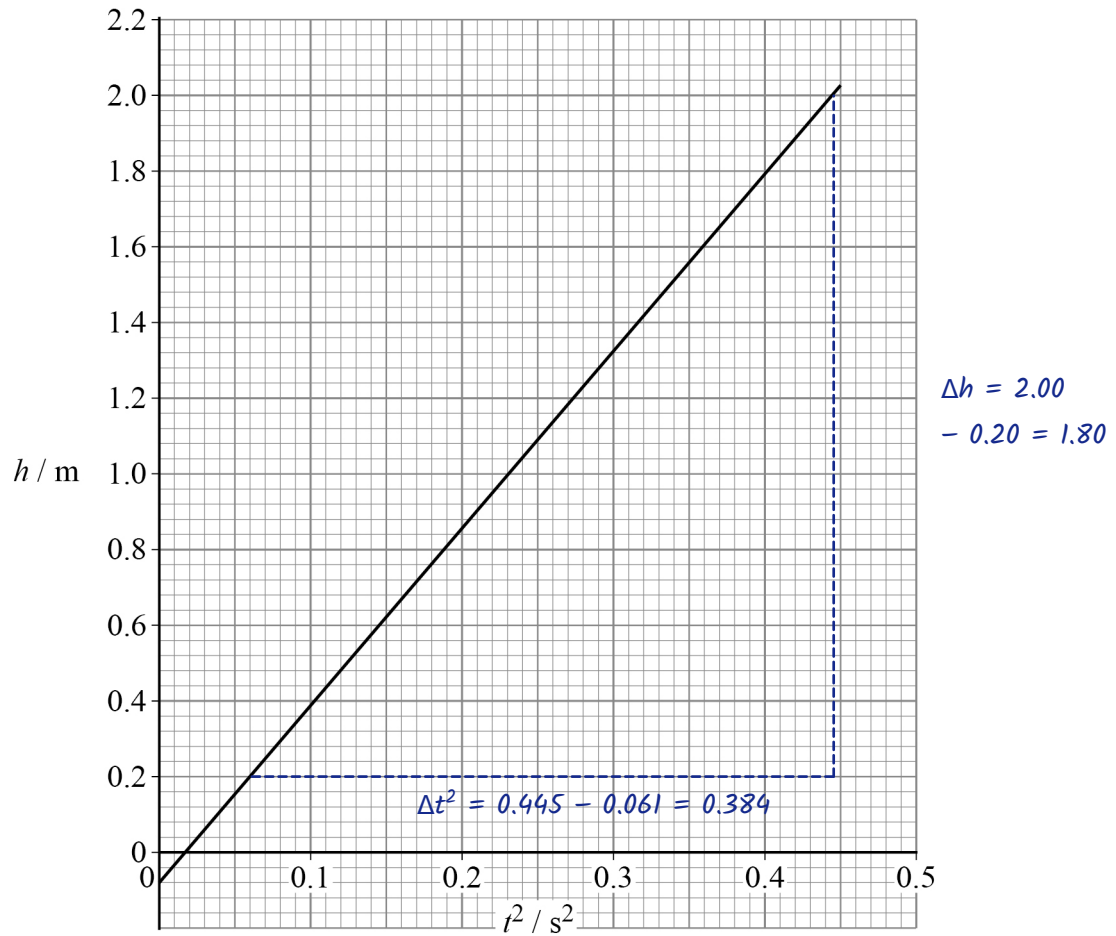
used), e.g. every 0.2 m, and repeat each reading and calculate a mean

t .



Figure 3 shows the best-fit line of a graph of h against t^2 for this experiment.

Figure 3



0 7 . 2

Determine, using **Figure 3**, a value for the acceleration due to gravity.

[3 marks]

$$h = \frac{1}{2}gt^2, \text{ so gradient of } h \text{ against } t^2 = g / 2$$

$$\text{gradient} = 1.80 / 0.384 = 4.69 \text{ m s}^{-2}$$

$$g = 2 \times \text{gradient} = 2 \times 4.69 = 9.38 \text{ m s}^{-2}$$

acceleration due to gravity = 9.4 m s⁻²

Question 7 continues on the next page

Turn over ►



07.3

The best-fit line in **Figure 3** does not go through the origin.

Suggest a systematic error that could account for this.

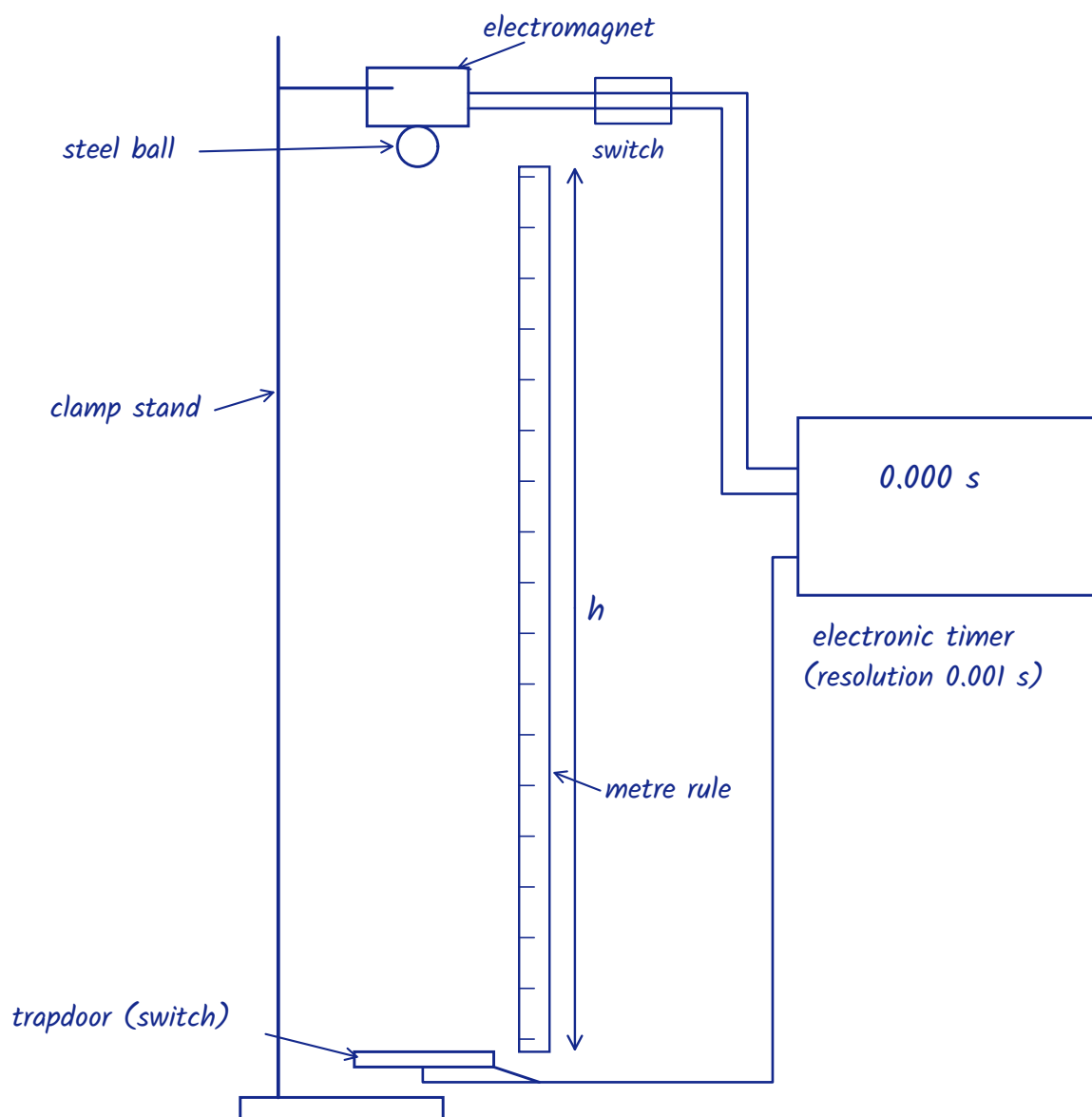
[1 mark]

A zero error in measuring h , e.g. h measured from the top of the ball instead of the bottom of the ball.

07.4

Draw a labelled diagram of the arrangement of apparatus you would use to measure t to an appropriate resolution.

[2 marks]

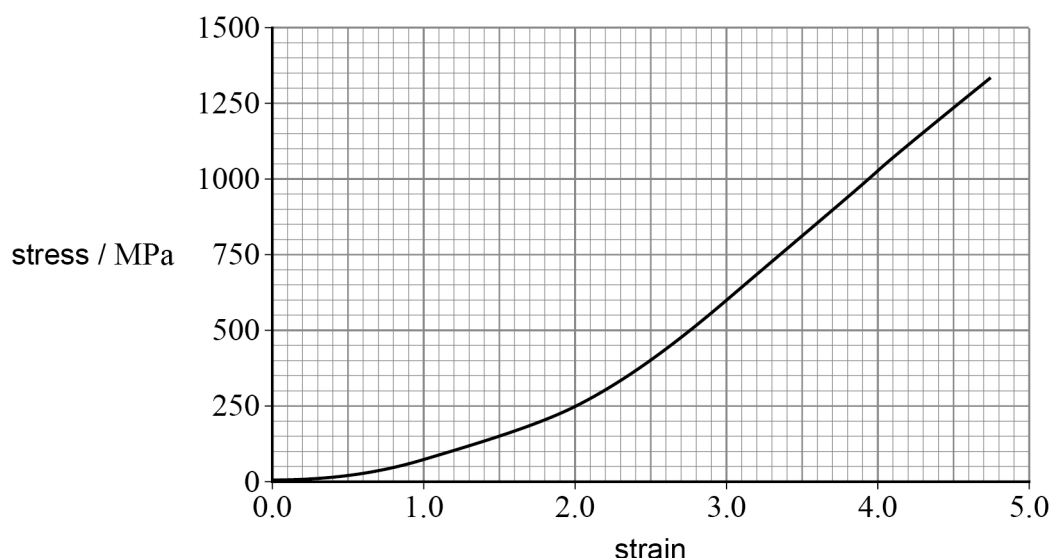


*switching off the electromagnet releases the ball and starts the timer;
the ball hitting the trapdoor stops the timer*



0 8

A strand of spider web silk is tested by increasing the tension in it until it breaks. **Figure 4** shows a stress–strain graph for the strand.

Figure 4

0 8 . 1

Explain whether or not the graph in **Figure 4** shows that the strand is elastic.

[2 marks]

Elastic means the strand returns to its original length when the stress (force) is removed.

It is not possible to tell from the graph, as it only shows the stress increasing: the stress is never removed (no unloading curve).

0 8 . 2

The original length of this strand is 1.8 cm.

Show that the length of the strand just before it breaks is approximately 10 cm.

[2 marks]

breaking strain from Figure 4 = 4.75

extension = strain $\times$ original length = $4.75 \times 1.8 = 8.55$ cm

length = $1.8 + 8.55 = 10.35$ cm $\approx$ 10 cm

Question 8 continues on the next page

Turn over ►



08.3

The work done per unit volume in stretching the strand is equivalent to the area under a stress–strain curve.

The volume of the strand remains constant as it stretches.

The initial diameter of the strand is $8.0 \times 10^{-6} \text{ m}$.

Determine the energy needed to break the strand.

[4 marks]

area under graph ≈ 18 large squares

$$1 \text{ square} = 0.5 \times 250 \times 10^6 = 1.25 \times 10^8 \text{ J m}^{-3}$$

$$\text{energy per unit volume} = 18 \times 1.25 \times 10^8 = 2.25 \times 10^9 \text{ J m}^{-3}$$

$$\text{volume} = \pi r^2 L = \pi \times (4.0 \times 10^{-6})^2 \times 0.018 = 9.05 \times 10^{-13} \text{ m}^3$$

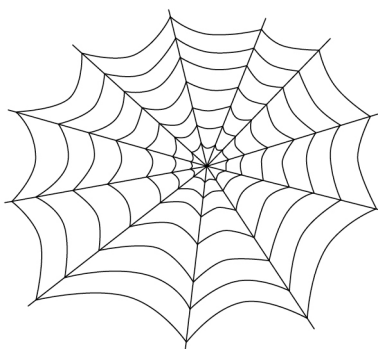
$$\text{energy} = 2.25 \times 10^9 \times 9.05 \times 10^{-13} = 2.0 \times 10^{-3} \text{ J}$$

$$\text{energy} = \underline{2.0 \times 10^{-3}} \text{ J}$$

08.4

Figure 5 shows the spider's web.

Figure 5



An insect flies into the web. The kinetic energy of the insect is much greater than the value of energy calculated in Question **08.3**.

Suggest why the web is unlikely to break.

[1 mark]

The energy (force) is shared out between many strands of the web, so no single strand breaks.



0 9

A rock is ejected from point **O** on the side of a volcano and hits the sea at **P**.

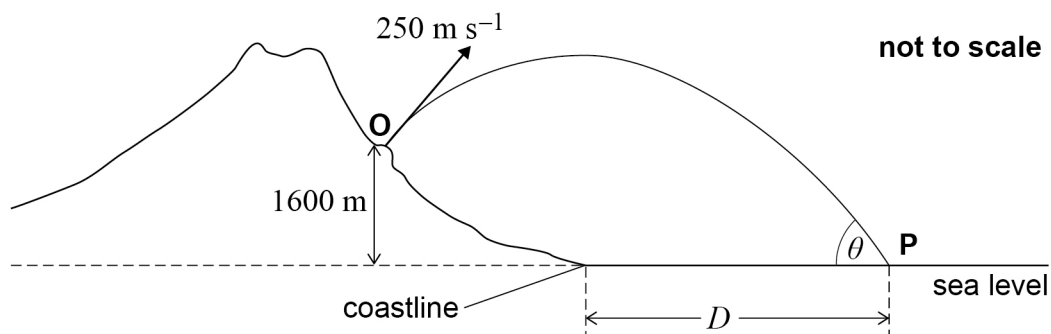
Figure 6 shows the trajectory of the rock.

The mass of the rock is 3.70 kg and its initial speed is 250 m s^{-1} .

O is 1600 m above sea level.

Assume that air resistance is negligible.

Figure 6



0 9 . 1

Show that the kinetic energy of the rock as it enters the sea at **P** is approximately $1.7 \times 10^5 \text{ J}$.

[3 marks]

$$\text{initial } E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 3.70 \times 250^2 = 1.156 \times 10^5 \text{ J}$$

$$\text{loss of } E_p = mgh = 3.70 \times 9.81 \times 1600 = 5.81 \times 10^4 \text{ J}$$

$$E_k \text{ at } P = 1.156 \times 10^5 + 5.81 \times 10^4$$

$$= 1.737 \times 10^5 \text{ J} \approx 1.7 \times 10^5 \text{ J}$$

0 9 . 2

Show that the speed of the rock at **P** is approximately 300 m s^{-1} .

[1 mark]

$$\frac{1}{2}mv^2 = 1.737 \times 10^5$$

$$v = \sqrt{(2 \times 1.737 \times 10^5 / 3.70)} = 306 \text{ m s}^{-1} \approx 300 \text{ m s}^{-1}$$

Question 9 continues on the next page

Turn over ►



The horizontal component of velocity of the rock at **O** is 167 m s^{-1} .

0 9 . 3

Show that the vertical component of the velocity of the rock at **P** is approximately 260 m s^{-1} .

[2 marks]

horizontal component stays 167 m s^{-1} (no air resistance)

$$v_v = \sqrt{v^2 - v_h^2} = \sqrt{306.4^2 - 167^2}$$

$$v_v = 257 \text{ m s}^{-1} \approx 260 \text{ m s}^{-1}$$

0 9 . 4

The rock enters the sea at **P** at an angle of θ to the horizontal.

Calculate θ .

[1 mark]

$$\tan \theta = 257 / 167, \quad \theta = 57.0^\circ$$

$$\theta = \underline{\hspace{2cm} 57 \hspace{2cm}}^\circ$$

0 9 . 5

The rock reaches its maximum height when it is exactly above the coastline.

Calculate D , the distance of **P** from the coastline.

[3 marks]

from the top (above the coastline) to P, vertical $u = 0$:

$$v = u + at: \quad 257 = 0 + 9.81t, \quad t = 26.2 \text{ s}$$

$$D = \text{horizontal velocity} \times \text{time} = 167 \times 26.2$$

$$D = 4375 \text{ m} \approx 4380 \text{ m}$$

$$D = \underline{\hspace{2cm} 4380 \hspace{2cm}} \text{ m}$$

END OF SECTION A

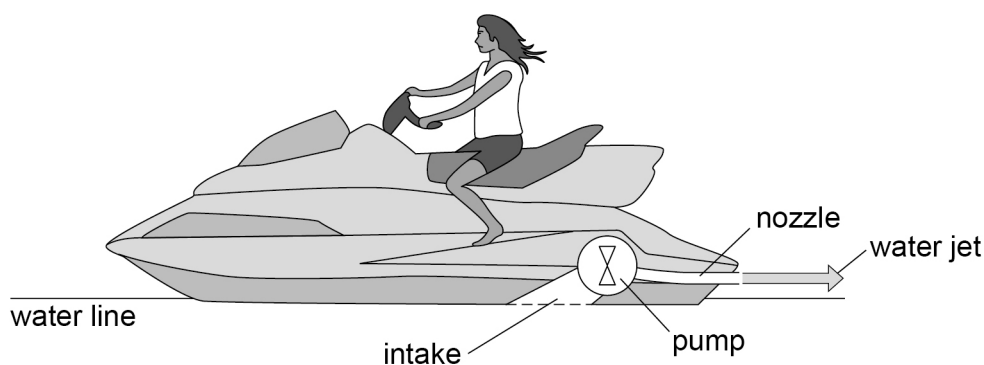


Section BAnswer **all** questions in this section.**1 0****Figure 7** shows a jet ski moving horizontally in a straight line.

The jet ski takes in water through an intake below the water line.

A pump ejects the water horizontally at high speed through a nozzle at the back of the jet ski.

The jet ski and rider have a combined mass of 521 kg.

Figure 7**1 0 . 1**The rider accelerates the jet ski uniformly from rest to its top speed of 27 m s^{-1} in a distance of 63 m.

Show that the resultant force accelerating the jet ski is approximately 3.0 kN.

[3 marks]

$$v^2 = u^2 + 2as: 27^2 = 0 + 2 \times a \times 63$$

$$a = 729 / 126 = 5.79 \text{ m s}^{-2}$$

$$F = ma = 521 \times 5.79$$

$$F = 3014 \text{ N} = 3.01 \text{ kN} \approx 3.0 \text{ kN}$$

Question 10 continues on the next page

Turn over ►



1 0 . 2

Explain, in terms of momentum, how the jet ski is propelled forwards.

[2 marks]

The pump pushes water backwards out of the nozzle, giving the water momentum backwards.

Momentum is conserved (rate of change of momentum is equal and opposite), so the jet ski gains an equal magnitude of momentum forwards.

1 0 . 3

During the acceleration, the jet ski ejects 78 kg of water per second through the nozzle.

Calculate the speed at which the water is ejected from the nozzle.

[2 marks]

$$\text{force} = \text{rate of change of momentum} = (\Delta m / \Delta t) \times v$$

$$3014 = 78 \times v$$

$$v = 3014 / 78 = 38.6 \text{ m s}^{-1}$$

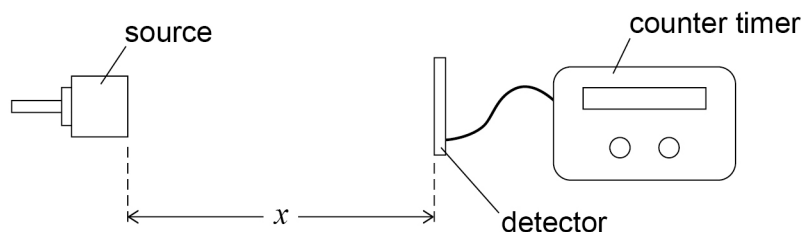
speed = 39 m s⁻¹

7



1 1

Figure 8 shows the apparatus used to verify the inverse-square law for gamma rays. The distance x between the source and a detector is measured. The detector is connected to a counter timer and the count rate C is measured for different values of x .

Figure 8

A student suggests that C is given by $C = \frac{k}{x^2}$ where k is a constant.

1 1

. 1

The count rate was measured three times for $x = 0.520$ m.

Table 2 shows the data recorded.

Table 2

Elapsed time / minute	5.00	5.00	10.00
Total count	2246	2263	4458

Calculate the mean count rate in counts per minute.

[1 mark]

$$\text{total count} = 2246 + 2263 + 4458 = 8967$$

$$\text{total time} = 5.00 + 5.00 + 10.00 = 20.00 \text{ minutes}$$

$$\text{mean count rate} = 8967 / 20.00 = 448 \text{ counts per minute}$$

mean count rate = 448 counts per minute

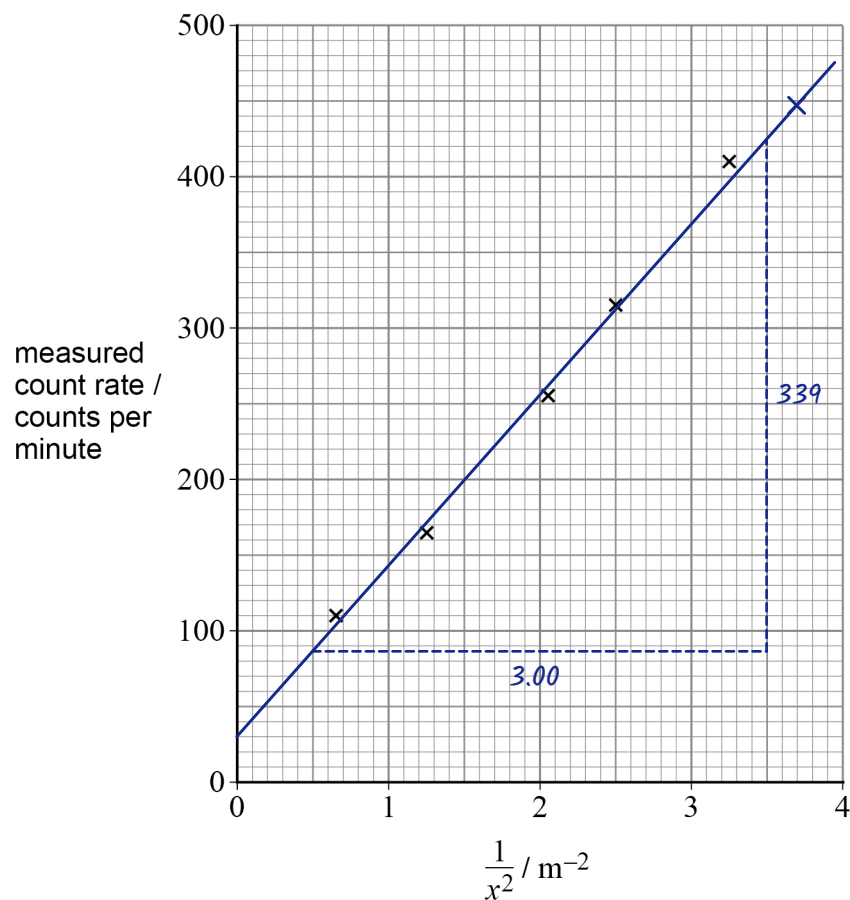
Question 11 continues on the next page

Turn over ►



Figure 9 shows a plot of C against $\frac{1}{x^2}$ for all of the other measured values of C and x .

Figure 9



1 1 . 2 Plot, on **Figure 9**, your answer to Question 11.1.

[1 mark]

1 1 . 3 Draw a line of best fit on **Figure 9**.

[1 mark]



1 1 . 4

Determine the gradient of your best-fit line on **Figure 9**.**[3 marks]***using a large triangle on the best-fit line:**from (0.50, 86.5) to (3.50, 425.5)*

$$\text{gradient} = (425.5 - 86.5) / (3.50 - 0.50)$$

$$\text{gradient} = 339 / 3.00 = 113$$

$$\text{gradient} = \underline{\quad 113 \quad} \text{ counts min}^{-1} \text{ m}^2$$

1 1 . 5

Explain whether or not **Figure 9** supports the student's suggestion that $C = \frac{k}{x^2}$.**[1 mark]***No: proportionality requires a straight line through the origin; the line is straight but does not pass through the origin.*

1 1 . 6

State the physical quantity represented by the intercept on the y -axis.**[1 mark]***The background count rate.*

1 1 . 7

Determine the value of the intercept on the y -axis.**[1 mark]**

$$c = y - mx = 425.5 - (113 \times 3.50) = 30 \text{ (line meets the } C \text{ axis at 30)}$$

$$\text{value of the intercept} = \underline{\quad 30 \quad} \text{ counts per minute}$$

END OF SECTION B**Turn over ►**

Section C

Each of the questions in this section is followed by four responses, **A**, **B**, **C** and **D**.

For each question select the best response.

Only **one** answer per question is allowed.

For each question, completely fill in the circle alongside the appropriate answer.

CORRECT METHOD



WRONG METHODS



If you want to change your answer you must cross out your original answer as shown. 

If you wish to return to an answer previously crossed out, ring the answer you now wish to select as shown. 

You may do your working in the blank space around each question but this will not be marked.
Do **not** use additional pages for this working.

1 2

A 3 N force and a 4 N force act on an object at right angles to each other. A third force of 8 N also acts on the object.
All of the forces are coplanar.

What is a possible resultant force on the object?

[1 mark]

A 1 N



B 10 N



C 14 N



D 15 N



1 3

What is **not** a possible unit for kinetic energy?

[1 mark]

A μJ



B kg m s^{-2}



C eV

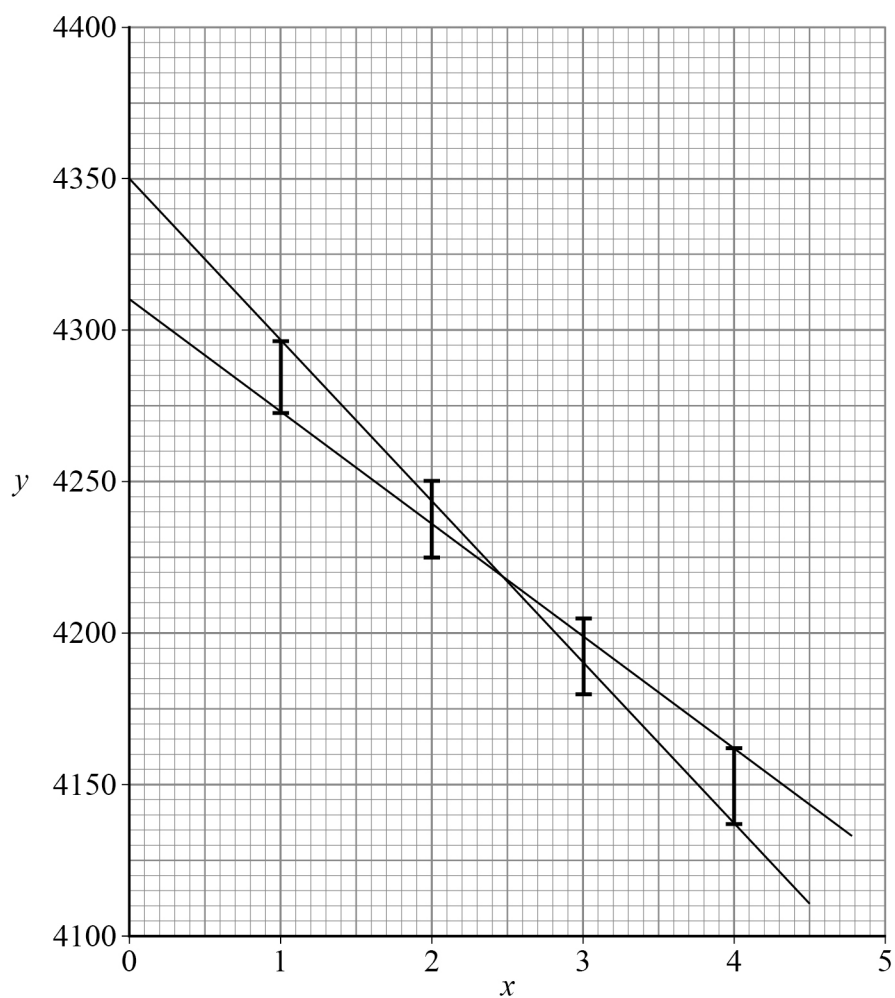


D Ws



1 4

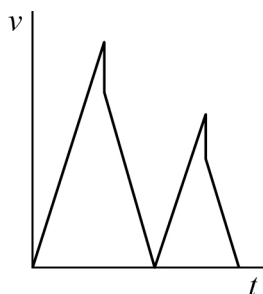
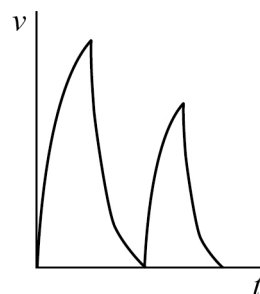
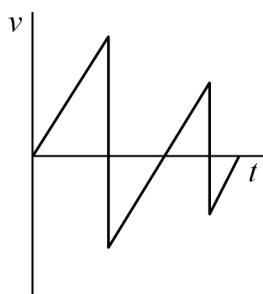
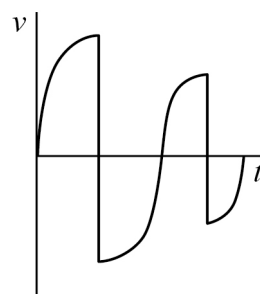
What is the percentage uncertainty in the value of the y -intercept that can be deduced from this graph?

[1 mark]**A** 0.5%**B** 0.9%**C** 5%**D** 9%**Turn over ►**

1 5

A ball is dropped onto a horizontal floor.
The ball bounces twice. The ball loses some energy each time it bounces.
Ignore the effect of air resistance and the time that the ball is in contact with the floor.

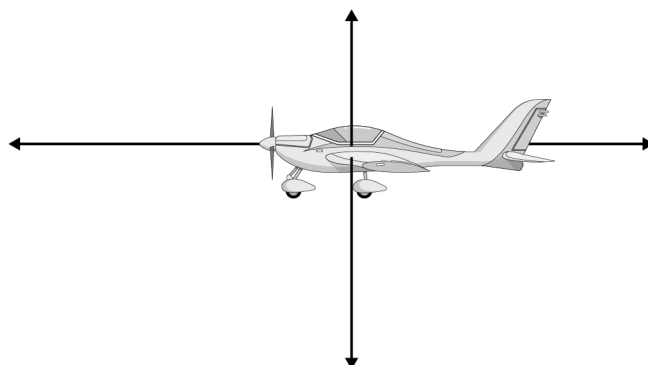
Which graph shows the variation of velocity v of the ball with time t ?

[1 mark]**A****B****C****D****A****B****C****D**

1 6

The diagram shows an aircraft and the forces acting on it.

The lengths of the arrows indicate the magnitude of the forces.



Which row describes the horizontal and vertical components of velocity of the aircraft?

[1 mark]

	Horizontal component of velocity	Vertical component of velocity	
A	constant to the left	constant downwards	☐
B	constant to the left	increasing downwards	☐
C	increasing to the left	constant downwards	☐
D	increasing to the left	increasing downwards	☒

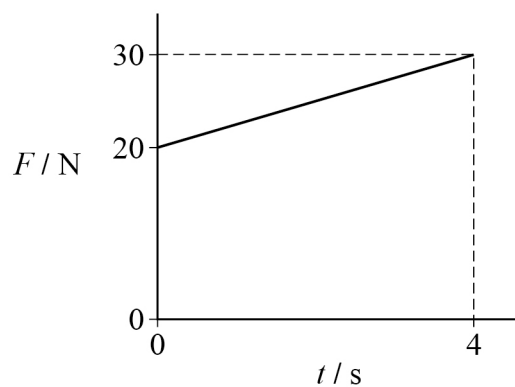
Turn over for the next question

Turn over ►



1 7

A force F acts on an object.
The graph shows the variation of F with time t .

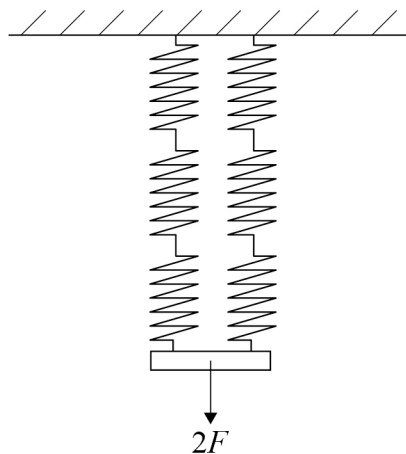


What is the impulse received by the object during the time shown by the graph?

[1 mark]**A** 2.5 kg m s^{-1} ☐**B** 10 kg m s^{-1} ☐**C** 30 kg m s^{-1} ☐**D** 100 kg m s^{-1} ☒

1 8

When a single spring of stiffness k is stretched by a force F , the extension is Δl . The diagram shows a network of six single springs of stiffness k being stretched by a force $2F$.



What is the total extension of the network of springs?

[1 mark]

A $\frac{4}{3} \Delta l$

☐

B $\frac{3}{2} \Delta l$

☐

C $3 \Delta l$

☒

D $6 \Delta l$

☐

Turn over for the next question

Turn over ►



1 9

When an elevator of mass 400 kg raises a load of mass 900 kg the efficiency is 60%.
The useful work done by the elevator is the work done in lifting the load.
When moving through a height h , the total energy input to the elevator is 3.4×10^5 J.

What is h ?

[1 mark]

A 16 m

☐

B 23 m

☒

C 44 m

☐

D 64 m

☐
2 0

The table shows observations and deductions from the Rutherford scattering experiment when carried out with copper-63 and gold-197 atoms.

Which row has a correct observation and a deduction that may be made from that observation?

[1 mark]

	Observation	Deduction
A	a small number of alpha particles are deviated through angles of more than 90°	atomic nuclei are very small
B	many alpha particles are deviated through angles of more than 90°	atomic nuclei carry a positive charge
C	copper foil deflects particles through greater angles than gold foil	a copper nucleus contains more nucleons than a gold nucleus
D	a minority of alpha particles pass through the foil without deviation	atomic nuclei are small and positively charged

☒
☐
☐
☐


2 1

Which pair of particles has the same magnitude of specific charge?

[1 mark]**A** ${}^3_2\text{He}$ nucleus and ${}^3_1\text{H}$ nucleus☐**B** ${}^2_1\text{H}$ nucleus and ${}^1_1\text{H}$ nucleus☐**C** proton and positron☐**D** beta particle and positron☒**2 2**

Which row shows two particles that can mutually annihilate and the energy produced in their annihilation?

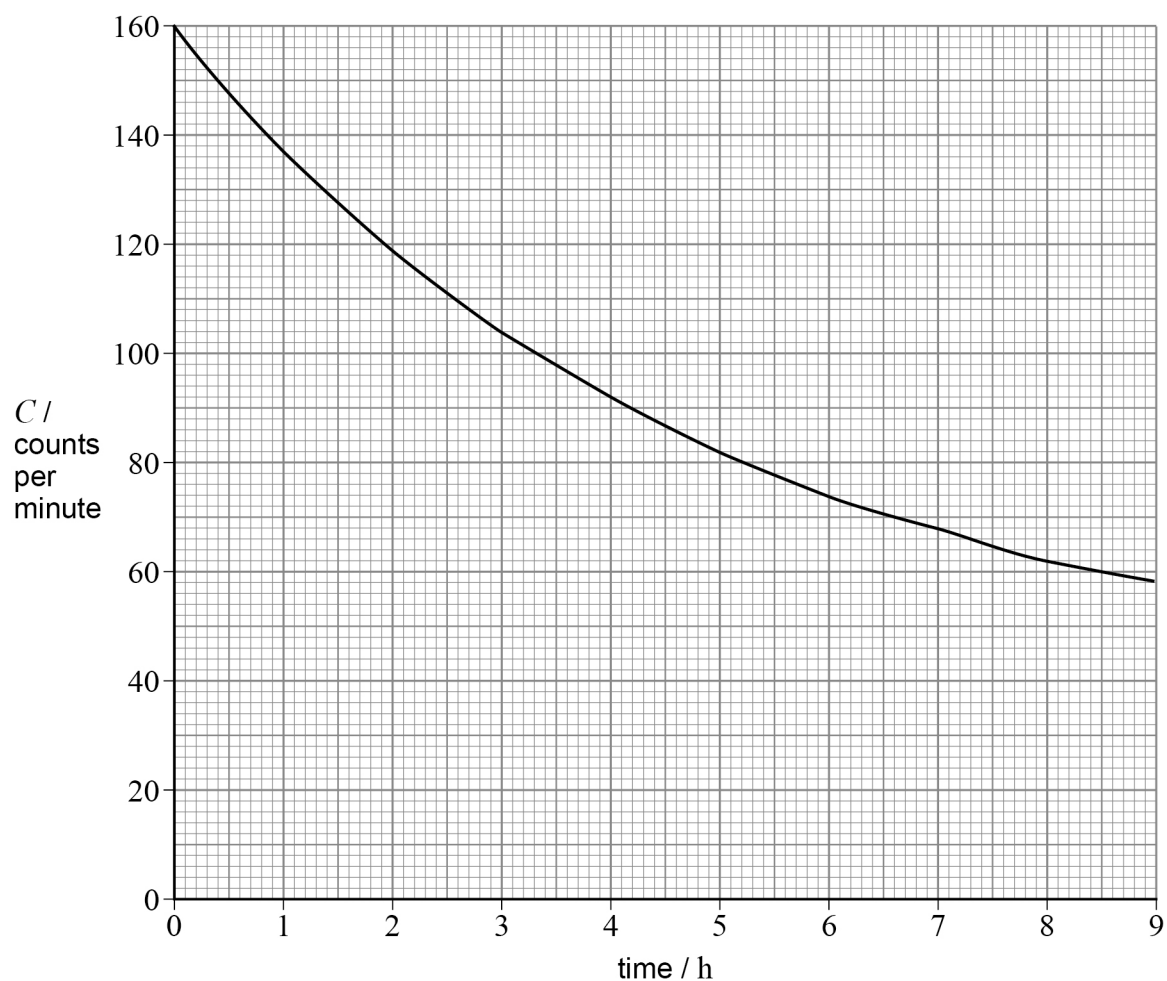
[1 mark]

	1st particle	2nd particle	Energy produced / MeV	
A	proton	proton	1860	☐
B	proton	proton	930	☐
C	proton	antiproton	1860	☒
D	proton	antiproton	930	☐

Turn over for the next question**Turn over ►**

2 3

A detector is placed near a source of radiation.
The total count rate C is plotted against time.
The background count rate is 40 counts per minute.



What is the half-life of the source?

[1 mark]

A 1.9 h

☐

B 3.3 h

☒

C 5.2 h

☐

D 8.8 h

☐


2 4

A detector is placed near to a radioactive source **S**.
Absorbers are placed between **S** and the detector.
The table shows the corrected count rate for radiation from **S** with and without absorbers present.

Absorber	Corrected count rate / counts s ⁻¹
none	480
one sheet of thin card	340
4 mm of aluminium	340

What is emitted from **S**?

[1 mark]

A α radiation only

☐

B α and β radiations only

☐

C α and γ radiations only

☒

D α , β and γ radiations

☐
2 5

Which statement concerning background radiation is correct?

[1 mark]

A Background radiation is made up of alpha, beta and gamma radiation only.

☐

B All background radiation comes from naturally occurring sources.

☐

C Some background radiation comes from sources not on the Earth.

☒

D All background radiation can be absorbed by a lead screen.

☐

14

END OF QUESTIONS



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



[illegible]

Copyright © 2021 Oxford International AQA Examinations and its licensors. All rights reserved.

