

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

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	
11–24	
TOTAL	



Section A

Answer **all** questions in this section.

0 1 . 1

State what is meant by background radiation.

[1 mark]

Radiation that is present all the time from the surroundings (the environment), not coming from the source being investigated.

0 1 . 2

Describe **one** origin of **artificial** background radiation.

[1 mark]

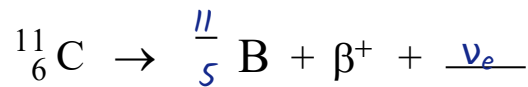
Radioactive waste or leaked material from nuclear power stations (or radioisotopes used in medicine).

2

0 2

Complete the equation for the beta-plus (β^+) decay of a carbon-11 nucleus.

[2 marks]



2

0 3

A photon of electromagnetic radiation can be converted into an electron and a second particle in a pair-production event.

0 3 . 1

Identify the second particle that is created in this pair-production event.

[1 mark]

A positron (antielectron, e^+)

0 3 . 2

Explain why the photon energy must be greater than a minimum value for the pair-production event to happen.

[2 marks]

The photon energy must be at least equal to the total rest energy (rest mass energy) of the particles created.

It must provide the rest energy of both the electron and the positron (particle and antiparticle), $2 \times 0.511 \text{ MeV} = 1.02 \text{ MeV}$, so there is a minimum photon energy.

3



0 4 . 1

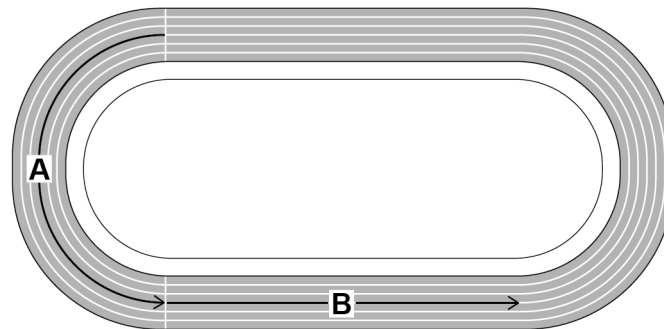
State what is meant by a vector quantity.

[1 mark]

A quantity that has both magnitude and direction.

Figure 1 shows an athletics track.

Figure 1



0 4 . 2

An athlete runs at constant speed through sections **A** and **B** of the track.

State and explain whether the athlete is accelerating in sections **A** and **B**.

[3 marks]

A *Accelerating. The direction of motion is changing on the bend, so the velocity changes (velocity is a vector), even though the speed is constant.*

B *Not accelerating. The track is straight, so the direction of the velocity is not changing, and the speed is constant, so velocity is constant.*

4

Turn over ►



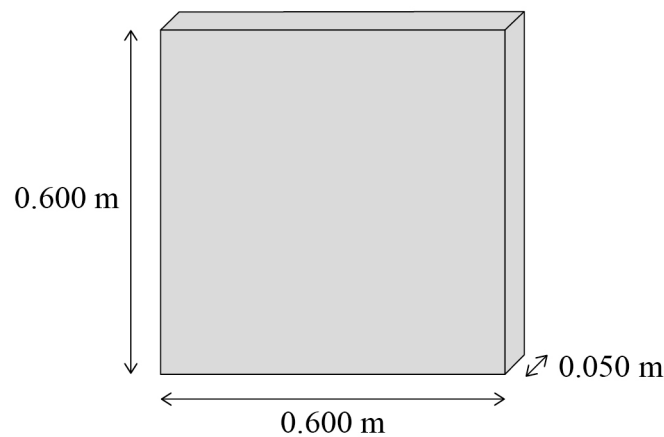
0 5 . 1

State what is meant by the centre of mass of an object.

[1 mark]

The point at which all of the mass of the object can be considered to be concentrated (the point where the weight acts).

A uniform concrete block has the dimensions shown in **Figure 2**.

Figure 2

The weight of the concrete block is 343 N.

0 5 . 2

Calculate the density of the concrete.

[2 marks]

$$W = mg \text{ so } m = W / g = 343 / 9.81 = 34.96 \text{ kg}$$

$$\text{volume } V = 0.600 \times 0.600 \times 0.050 = 0.0180 \text{ m}^3$$

$$\text{density } \rho = m / V = 34.96 / 0.0180$$

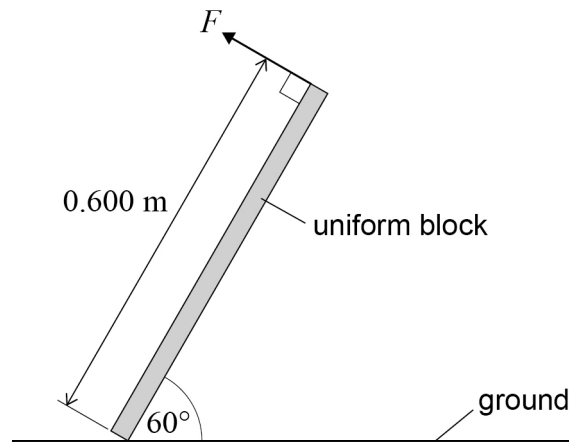
$$\rho = 1942 \text{ kg m}^{-3}$$

$$\text{density} = \underline{1940} \text{ kg m}^{-3}$$



0 5 . 3

Figure 3 shows the uniform block held in equilibrium by a force F that is acting at 90° to the block.

Figure 3

Calculate the magnitude of force F .

[3 marks]

take moments about the bottom corner of the block (pivot):

weight acts at the centre, 0.300 m along the block

perpendicular distance of W from pivot = $0.300 \cos 60^\circ = 0.150$ m

F acts at 90° to the block, 0.600 m from the pivot

clockwise moment = anticlockwise moment

$$343 \times 0.300 \cos 60^\circ = F \times 0.600$$

$$51.45 = 0.600 F$$

$$F = 51.45 / 0.600 = 85.75 \text{ N}$$

$$F = \underline{85.8} \text{ N}$$

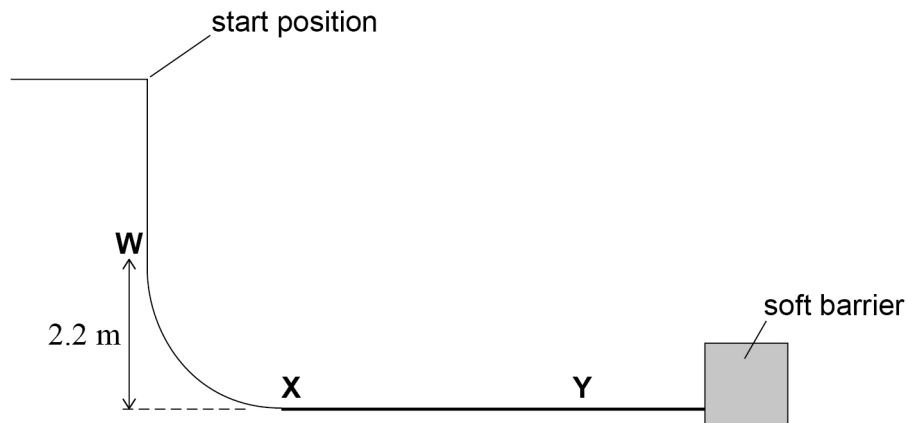
6

Turn over ►

0 6

Figure 4 shows a drop slide in a theme park.

Figure 4



W is the start of the curved section. **X** is the start of the horizontal section.

A child travels along the horizontal section of the slide before coming to rest at **Y**.

There is a soft barrier as a safety precaution.

Figures 5a, 5b and 5c represent the motion of the child on the vertical section, the curved section and the horizontal section of the drop slide.

Figure 5a

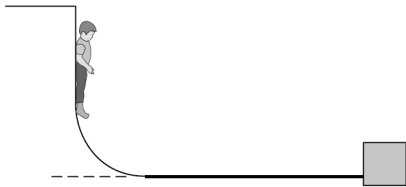


Figure 5b

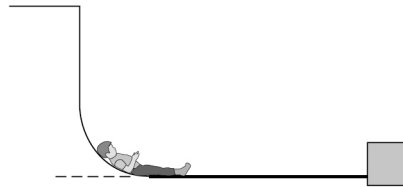
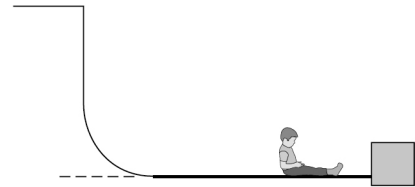


Figure 5c



0 6 . 1

A child of mass 40 kg using the drop slide has a speed of 7.5 m s^{-1} at **W**.

Show that the kinetic energy of the child at **X** is approximately 2 kJ.
Ignore friction between **W** and **X**.

[3 marks]

$$KE \text{ at } W = \frac{1}{2}mv^2 = \frac{1}{2} \times 40 \times 7.5^2 = 1125 \text{ J}$$

$$GPE \text{ lost from } W \text{ to } X = mg\Delta h = 40 \times 9.81 \times 2.2 = 863.3 \text{ J}$$

$$\text{no friction, so } KE \text{ at } X = KE \text{ at } W + GPE \text{ lost}$$

$$KE \text{ at } X = 1125 + 863.3 = 1988 \text{ J}$$

$$\approx 2.0 \times 10^3 \text{ J} = 2 \text{ kJ}$$



0 6 . 2

The average frictional force that acts on the moving child between **X** and **Y** is 250 N.

Calculate the distance **XY**.

[2 marks]

all the KE is transferred by work done against friction:

$$W = Fd \text{ so } d = W / F = 2000 / 250 = 8.00 \text{ m}$$

XY = 8.00 m

0 6 . 3

A man of mass 90 kg uses the slide. His speed as he hits the soft barrier is 3.2 m s^{-1} . The horizontal section is 12.5 m in length. He loses 90% of his kinetic energy along the horizontal section.

Calculate the average frictional force that acts on the man along the horizontal section.

[3 marks]

$$KE \text{ at barrier} = \frac{1}{2}mv^2 = \frac{1}{2} \times 90 \times 3.2^2 = 460.8 \text{ J}$$

$$\text{this is the 10\% left, so } KE \text{ at start of flat} = 460.8 \times 10 = 4608 \text{ J}$$

$$\text{work done against friction} = 4608 - 460.8 = 4147 \text{ J}$$

$$\text{work} = F \times d \text{ so } F = 4147 / 12.5$$

$$F = 332 \text{ N}$$

average frictional force = 332 N

0 6 . 4

Explain why a soft barrier is used to reduce the risk of injury rather than a rigid barrier.

[4 marks]

The man hits the barrier with the same velocity, so his change in momentum (impulse) when he is stopped is the same for both barriers.

The soft barrier deforms, so the time taken to stop him is greater.

So the rate of change of momentum is less, and since force = rate of change of momentum, the force on the man is smaller (less risk of injury).



07

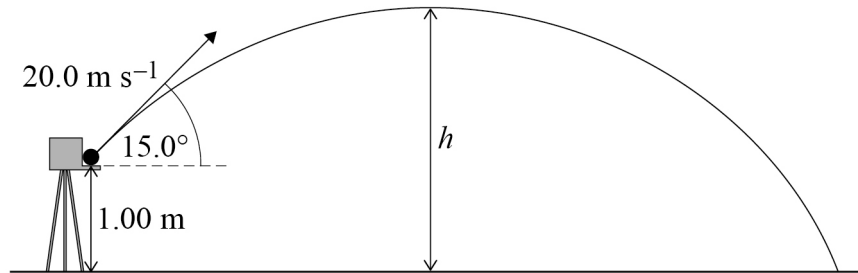
Figure 6 shows a machine that projects a tennis ball with an initial velocity of 20 m s^{-1} at an angle of 15.0° to the horizontal.

h is the maximum height that the ball reaches above the ground.

Ignore air resistance in all of your calculations.

Figure 6

not to scale



07.1

Calculate the vertical component of the initial velocity of the ball.

[1 mark]

$$\text{vertical component} = 20 \sin 15.0^\circ = 5.18 \text{ m s}^{-1}$$

$$\text{vertical component} = \underline{5.18} \text{ m s}^{-1}$$

07.2

Show that h is approximately 2.4 m.

[3 marks]

at the maximum height the vertical velocity is zero

$$v^2 = u^2 + 2as \text{ with } v = 0, u = 5.18 \text{ m s}^{-1}, a = -9.81 \text{ m s}^{-2}$$

$$0 = 5.18^2 - 2 \times 9.81 \times s$$

$$s = 5.18^2 / (2 \times 9.81) = 26.8 / 19.62 = 1.37 \text{ m}$$

ball starts 1.00 m above the ground, so

$$h = 1.37 + 1.00 = 2.37 \text{ m} \approx 2.4 \text{ m}$$



0 7 . 3

Calculate the horizontal distance the ball travels before it lands.

[3 marks]*time to reach max height: $v = u + at$*

$$t_1 = 5.18 / 9.81 = 0.528 \text{ s}$$

time to fall 2.37 m from max height ($u = 0$): $s = \frac{1}{2}at^2$

$$t_2 = \sqrt{(2 \times 2.37 / 9.81)} = 0.695 \text{ s}$$

$$\text{total time of flight} = 0.528 + 0.695 = 1.22 \text{ s}$$

$$\text{horizontal velocity} = 20 \cos 15.0^\circ = 19.3 \text{ m s}^{-1} \text{ (constant)}$$

$$\text{distance} = 19.3 \times 1.22 = 23.6 \text{ m}$$

$$\text{distance} = \underline{23.6} \text{ m}$$

0 7 . 4

The machine now projects a ball of mass 58 g vertically upwards.

The machine uses a compressed spring to do this.

The spring obeys Hooke's Law and is compressed through a distance of 0.050 m in order to project the ball.

The spring constant of the spring is 9.3 kN m^{-1} .

Calculate the maximum height above the point of release that the ball can reach.

[3 marks]

$$\text{elastic energy stored} = \frac{1}{2}kx^2 = \frac{1}{2} \times 9.3 \times 10^3 \times 0.050^2$$

$$= 11.6 \text{ J (11.625 J)}$$

$$\text{all transferred to GPE at max height: } \frac{1}{2}kx^2 = mgh$$

$$h = 11.625 / (0.058 \times 9.81)$$

$$h = 20.4 \text{ m}$$

$$\text{maximum height} = \underline{20.4} \text{ m}$$

Question 7 continues on the next page**Turn over ►**

07.5

The ball does not reach this maximum height.

Explain why.

[2 marks]

In the spring: not all of the elastic energy stored in the spring is transferred to the kinetic energy of the ball (some is wasted as heat and sound, and as kinetic energy of the spring itself).

In the air: work is done against air resistance as the ball rises, so the ball has less kinetic energy to convert to gravitational potential energy and reaches a lower height.

12



08.1

Calculate the specific charge of a nucleus of gold-197 ($^{197}_{79}\text{Au}$).

State an appropriate unit for your answer.

[3 marks]

$$\text{specific charge} = \text{charge} / \text{mass}$$

$$\text{charge} = 79 \times 1.60 \times 10^{-19} = 1.26 \times 10^{-17} \text{ C}$$

$$\text{mass} = 197 \times 1.67 \times 10^{-27} = 3.29 \times 10^{-25} \text{ kg}$$

$$\text{specific charge} = 1.26 \times 10^{-17} / 3.29 \times 10^{-25}$$

$$= 3.84 \times 10^7 \text{ C kg}^{-1}$$

specific charge = 3.84×10^7 unit C kg^{-1}

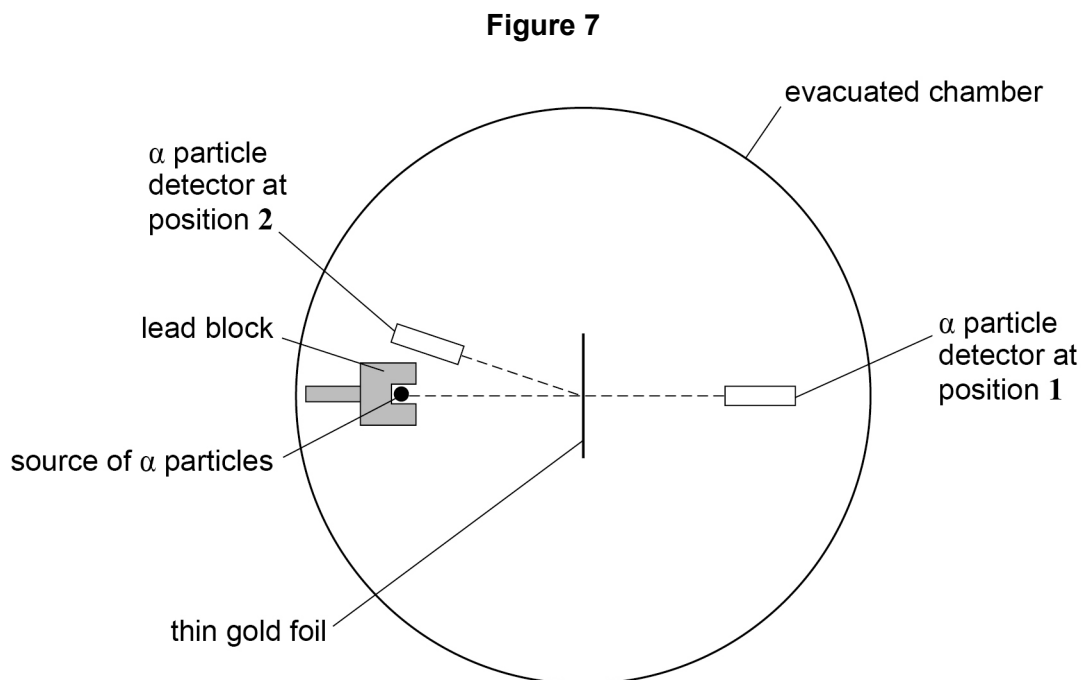
Question 8 continues on the next page

Turn over ►



Figure 7 shows a Rutherford scattering experiment in which alpha (α) particles are directed at a thin gold foil.

A detector counts the number of alpha particles scattered by the thin gold foil per second.



0 8 . 2 **Figure 7** shows two positions of the detector in the evacuated chamber.

Compare the numbers of alpha particles per second detected at position 1 and position 2.

[1 mark]

The count rate is much lower at position 2 than at position 1 (very few alpha particles are scattered through large angles).

0 8 . 3 State **two** conclusions from the Rutherford scattering experiment about the structure of the atom.

[2 marks]

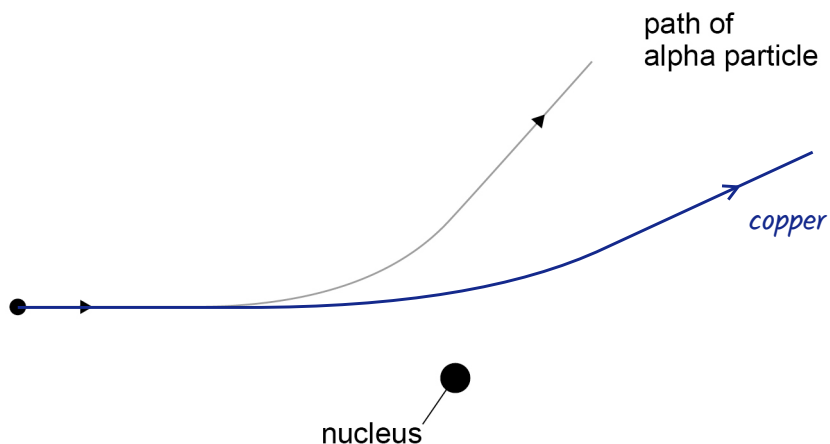
1 *The nucleus is very small compared with the atom (most of the atom is empty space).*

2 *The nucleus is very dense and positively charged; most of the mass of the atom is concentrated in the nucleus.*



Figure 8 shows the path of an alpha particle moving close to a gold nucleus.

Figure 8



The experiment is repeated with thin copper-63 (${}^{63}_{29}\text{Cu}$) foil instead of gold.

08.4

Sketch, on **Figure 8**, a line showing the path taken by an alpha particle with the same energy and starting from the same initial position.

[1 mark]

08.5

Explain your answer to Question 08.4.

[2 marks]

Copper has fewer protons in the nucleus (29 compared with 79), so the nucleus has less positive charge.

So the electrostatic (Coulomb) force of repulsion on the alpha particle is weaker at the same distance, so it is deflected (scattered) through a smaller angle.

END OF SECTION A

Turn over ►



Section B

Answer **all** questions in this section.

0 9

Technetium-99m is a radioactive isotope used in hospitals.

0 9 . 1

Identify the type of radiation that is emitted when a technetium-99m nucleus de-excites.

[1 mark]

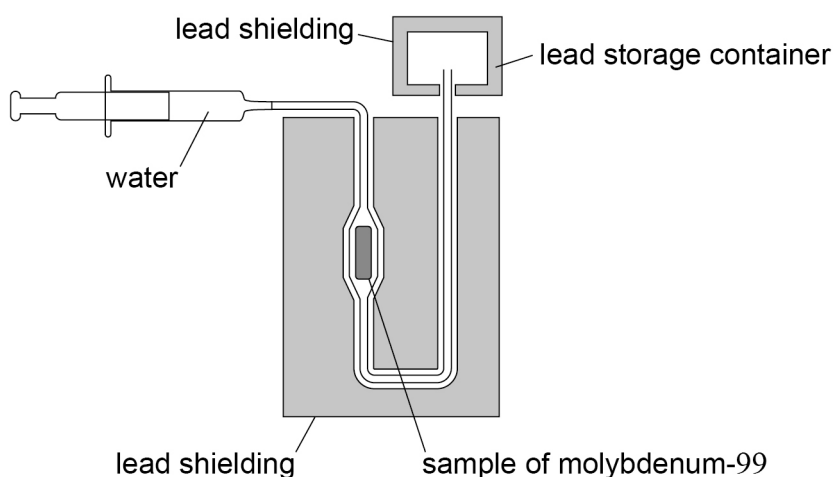
Gamma (γ) radiation

0 9 . 2

Samples of technetium-99m are prepared at a hospital from a source of the radioactive isotope molybdenum-99 that is stored at the hospital.

Figure 9 shows the generator that is used to prepare the sample of technetium-99m.

Figure 9



Water from a syringe passes through the molybdenum-99 sample. The technetium-99m that forms from the decay of the molybdenum-99 dissolves in the water. The water containing technetium-99m is collected in a lead storage container.

Explain how the apparatus in **Figure 9** allows safe handling of the collected sample.

[2 marks]

The generator and the storage container are surrounded by lead shielding, which absorbs most of the gamma radiation.

The technetium is collected directly into the lead container without being handled, so the dose the user is exposed to is reduced to a safe level.

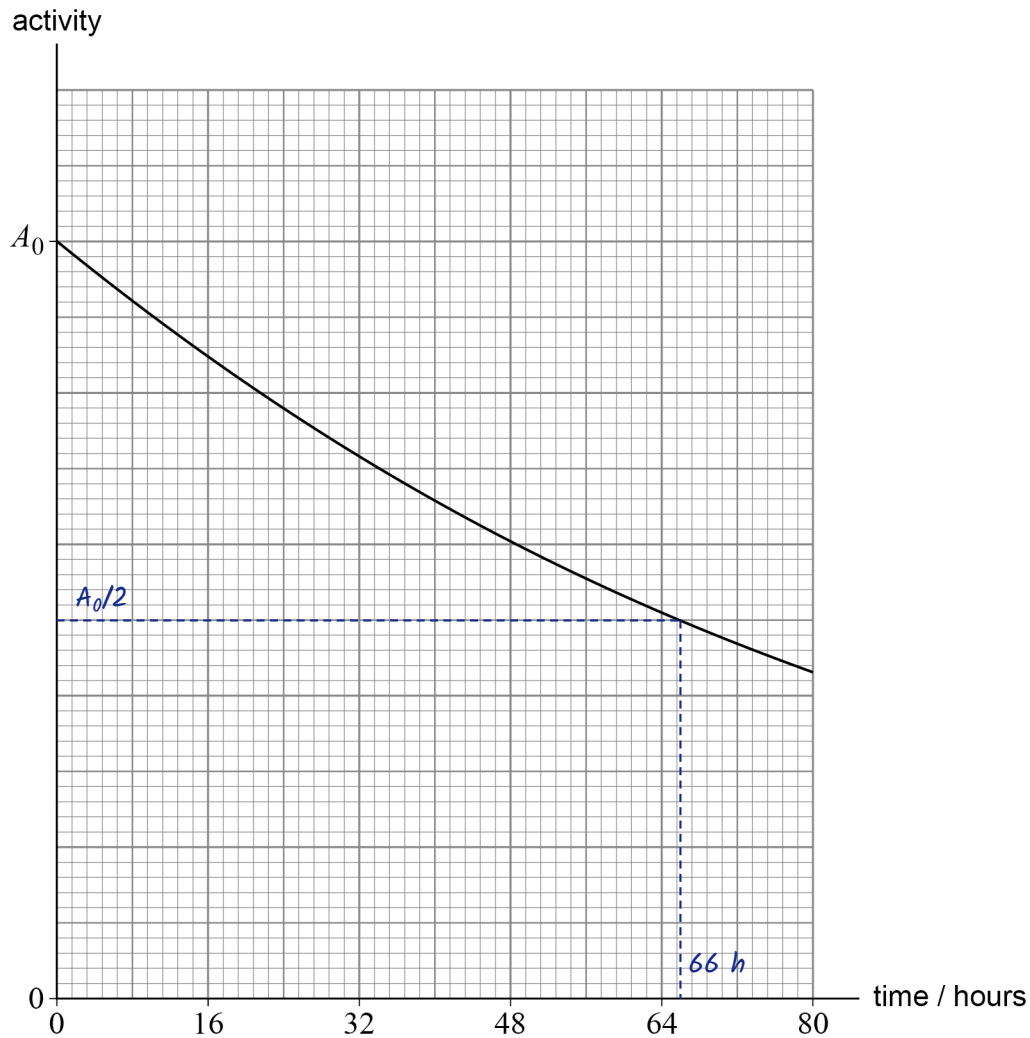


0 9 . 3

Figure 10 shows the variation of the activity of molybdenum-99 in the generator over an 80-hour period.

A_0 is the initial activity of the molybdenum-99 in the generator.

Figure 10



Estimate the half-life of molybdenum-99.

[1 mark]

activity falls to $A_0/2$ after 66 hours (read from graph)

half-life = 66 hours

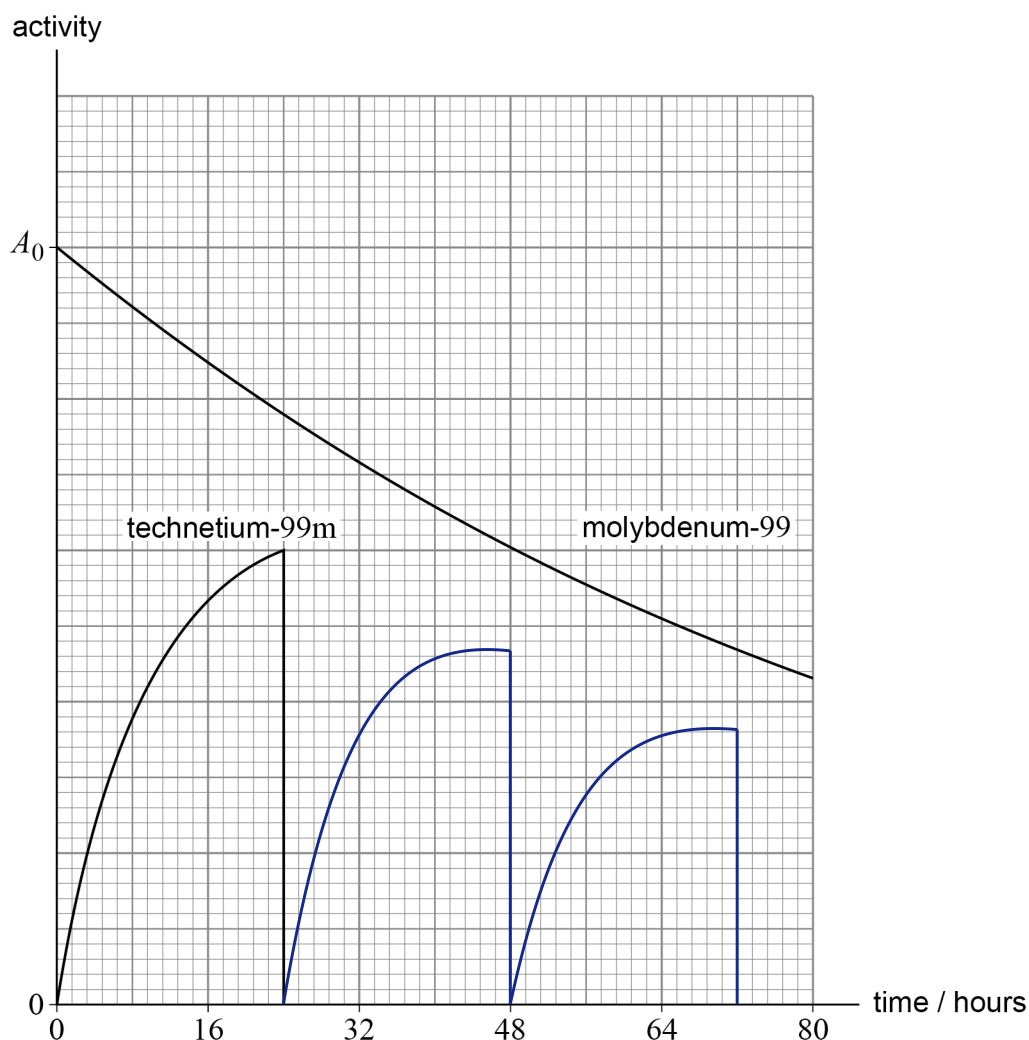
Question 9 continues on the next page

Turn over ►



0 9 . 4

Figure 11 shows the activity of the molybdenum-99 over an 80-hour period and the activity of the technetium-99m that is formed in the generator over the first 24 hours of the same period.

Figure 11

A sample of technetium-99m is collected from the generator every 24 hours causing the activity of the technetium-99m in the generator to fall to zero.

Sketch, on **Figure 11**, the activity of the **technetium-99m** between 24 and 72 hours.

[2 marks]



09.5

Explain why a sample of technetium-99m is collected every 24 hours and not more frequently.

[2 marks]

The technetium-99m activity in the generator rises and reaches its maximum (it levels off) after about 24 hours, when it is decaying as fast as it is formed.

Collecting at (near) maximum activity gives the largest activity sample; collecting more often would give samples of lower activity.

8

Turn over for the next question

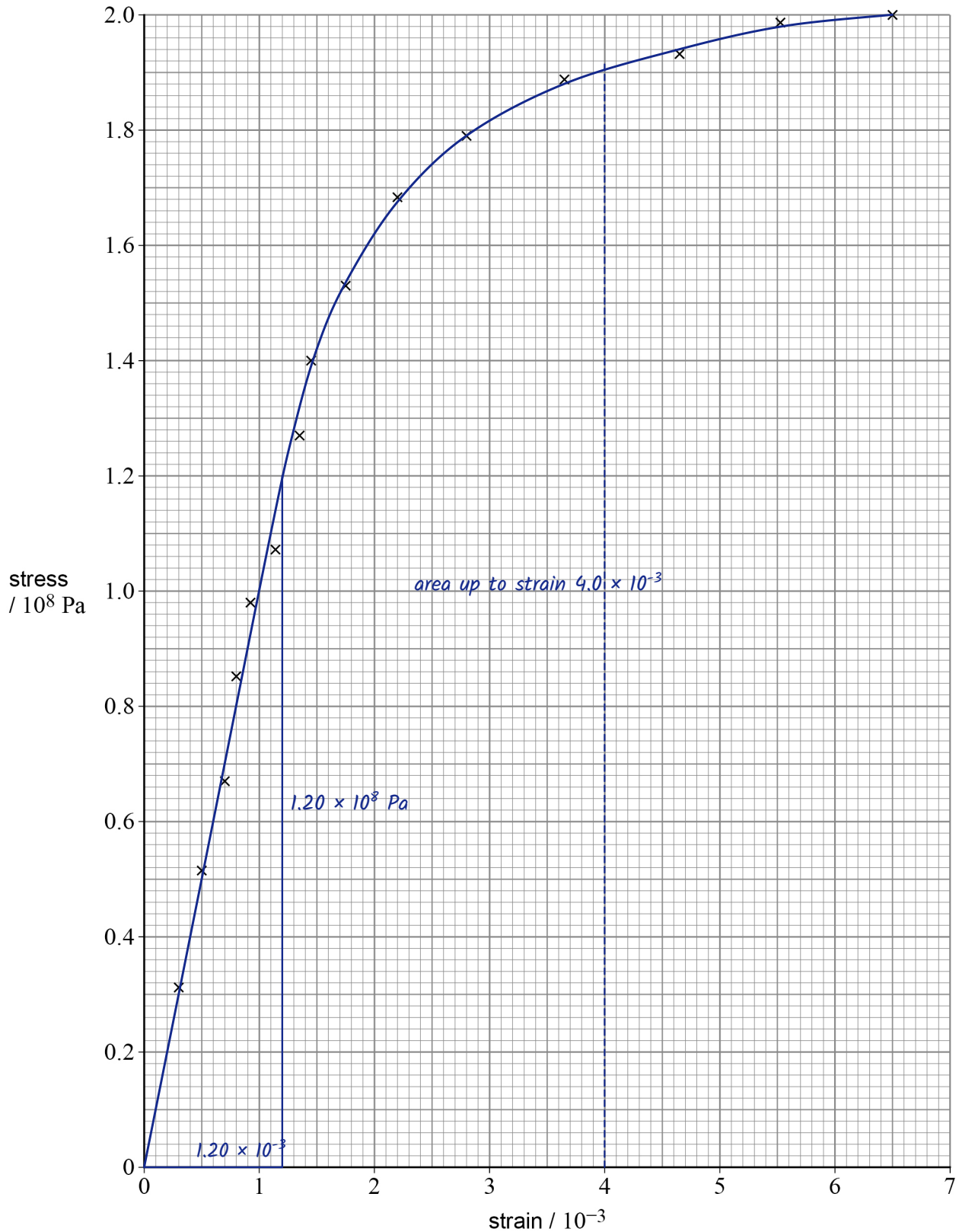
Turn over ►

1 0

Figure 12 shows the data from an experiment in which a copper wire was stretched by applying a known tensile force.

The total extension of the wire was recorded for each value of applied force.

Figure 12



1 0 . 1

Draw a line of best fit on **Figure 12**.

[1 mark]

1 0 . 2

Determine, using **Figure 12**, a value for the Young modulus for copper.

[2 marks]

$$E = \text{gradient of the initial straight line part}$$

$$E = \Delta \text{stress} / \Delta \text{strain} = 1.20 \times 10^8 / 1.20 \times 10^{-3}$$

$$E = 1.0 \times 10^{11} \text{ Pa}$$

Young modulus for copper = 1.0 × 10¹¹ Pa

1 0 . 3

Describe how the uncertainty in your value for the Young modulus could be estimated from the graph.

[1 mark]

Draw the steepest and the least steep straight lines that are still

consistent with the points on the linear part; the uncertainty is half

the difference between their gradients.

1 0 . 4

The area under a stress–strain graph represents the mechanical work done per unit volume on the material as it is deformed.

The original length of the wire used in this experiment is 1.50 m and its cross-sectional area is 0.397 mm².

Determine the work done on the wire as its original length is increased by 6.0 mm.

[4 marks]

$$\text{strain} = \Delta L / L = 6.0 \times 10^{-3} / 1.50 = 4.0 \times 10^{-3}$$

$$\text{area under graph up to strain } 4.0 \times 10^{-3} \approx 110 \text{ (1 cm) squares}$$

$$1 \text{ square} = 0.5 \times 10^{-3} \times 0.1 \times 10^8 = 5.0 \times 10^3 \text{ J m}^{-3}$$

$$\text{work per unit volume} = 110 \times 5.0 \times 10^3 = 5.5 \times 10^5 \text{ J m}^{-3}$$

$$\text{volume} = AL = 0.397 \times 10^{-6} \times 1.50 = 5.96 \times 10^{-7} \text{ m}^3$$

$$\text{work done} = 5.5 \times 10^5 \times 5.96 \times 10^{-7} = 0.33 \text{ J}$$

work done = 0.33 J

8

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 1 What is the unit of energy in SI (fundamental) base units?

[1 mark]

A N m

☐

B kg m s⁻¹

☐

C kg m² s⁻²

☒

D N m s⁻¹

☐

1 2 Which row shows a scalar quantity and a vector quantity?

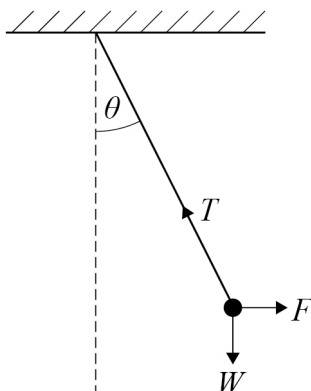
[1 mark]

	Scalar	Vector
A	displacement	acceleration
B	kinetic energy	displacement
C	weight	speed
D	distance	temperature

☐
☒
☐
☐


1 3

The bob of a pendulum is held in equilibrium as shown in the diagram.



Which expression is correct?

[1 mark]

A $F = T \times \cos \theta$

☐

B $F = T \times \sin \theta$

☒

C $\frac{\sin \theta}{F} = T$

☐

D $\frac{F}{\cos \theta} = T + W$

☐

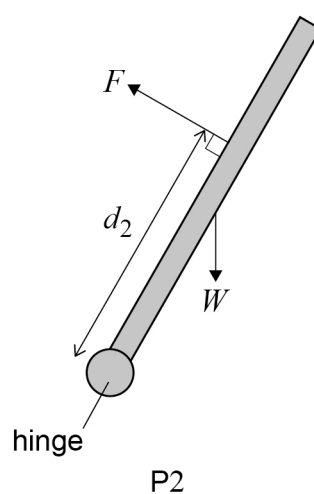
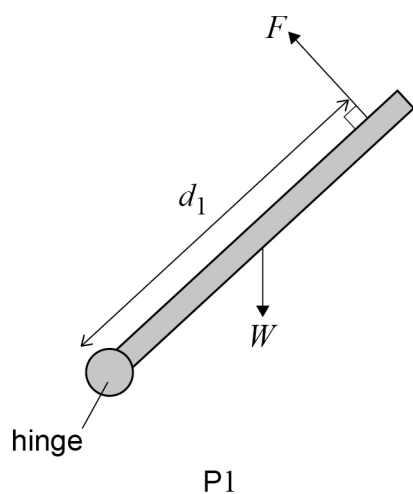
Turn over for the next question

Turn over ►



1 4

A hinged pole of weight W is in equilibrium at positions P1 and P2. Force F has the same magnitude in both positions. F is applied at right angles to the pole at different distances d_1 and d_2 from the hinge.



Which row is correct?

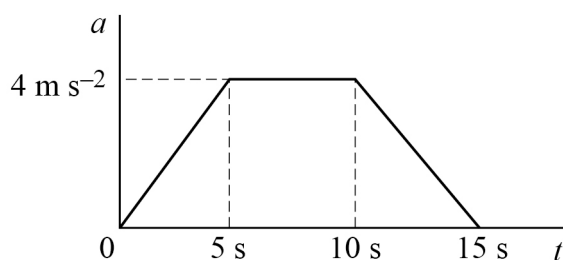
[1 mark]

	Clockwise moment about the hinge	Anticlockwise moment about the hinge	
A	larger in P1 than in P2	smaller in P1 than in P2	☐
B	larger in P1 than in P2	larger in P1 than in P2	☒
C	smaller in P1 than in P2	smaller in P1 than in P2	☐
D	smaller in P1 than in P2	larger in P1 than in P2	☐



1 5

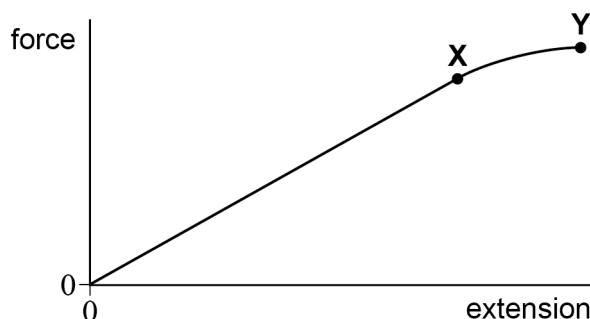
The graph shows the variation of acceleration a with time t for an object.



What is the change in velocity of the object due to this acceleration?

[1 mark]**A** 0
☐
B 30 m s^{-1}
☐
C 40 m s^{-1}
☒
D 60 m s^{-1}
☐
1 6

A force is applied to a metal wire and causes it to extend. The force is gradually increased from zero and then reduced back to zero. The force–extension curve is the same during loading and unloading.



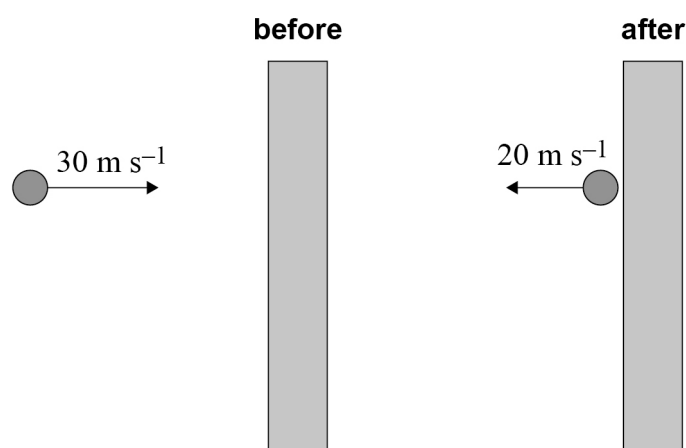
What is the behaviour of the wire between 0 and **X** and between **X** and **Y**?

[1 mark]

	0X	XY	
A	elastic	plastic	☐
B	elastic	elastic	☒
C	plastic	plastic	☐
D	plastic	elastic	☐

Turn over ►

- 1 7** A ball of mass 0.1 kg hits a wall and rebounds.



What is the magnitude of the impulse that acts on the ball?

[1 mark]

- A** 1 N s ☐
- B** 2 N s ☐
- C** 3 N s ☐
- D** 5 N s ☒

- 1 8** A box is pushed a distance x with a force F in a time t . The rate of energy transfer is P .

The same box is pushed a distance $2x$ with a force $5F$ in a time $\frac{t}{2}$.

What is the new rate of energy transfer?

[1 mark]

- A** $2P$ ☐
- B** $5P$ ☐
- C** $10P$ ☐
- D** $20P$ ☒

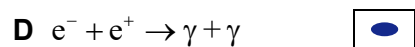
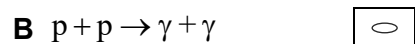


1 9

Which pair of nuclei has the same number of neutrons?

[1 mark]**2 0**

Which is a possible annihilation event?

[1 mark]**2 1**

Alpha particles

[1 mark]

A can be deflected by a strong magnetic field. ☒

B are less ionising than beta particles. ☐

C have a greater specific charge than beta particles. ☐

D obey the inverse-square law in air. ☐

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

2 2

A radioactive source has a half-life of 3 days.

Initially a detector at a fixed distance from the source records an average count rate of 180 counts per minute.

The average background count rate is 20 counts per minute.

What is the average count rate recorded by the detector 6 days later?

[1 mark]

A 40 counts per minute

☐

B 45 counts per minute

☐

C 60 counts per minute

☒

D 65 counts per minute

☐**2 3**

A detector is placed 30 cm from a gamma source and records an average count rate of 290 counts per minute.

A second identical detector is placed a distance of 90 cm from the source.

The average background count rate is 20 counts per minute.

What is the average count rate measured by the second detector?

[1 mark]

A 30 counts per minute

☐

B 32 counts per minute

☐

C 50 counts per minute

☒

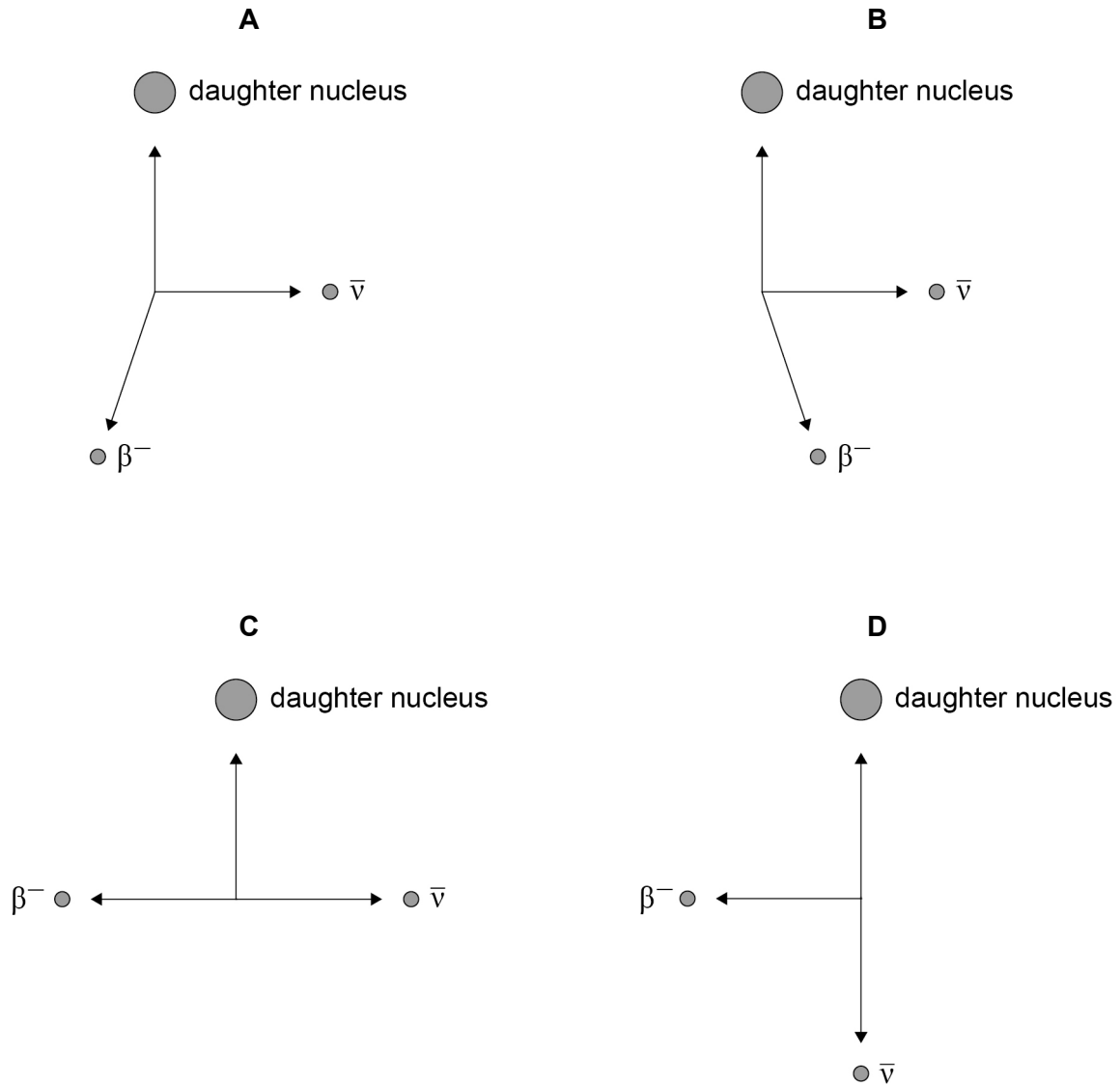
D 97 counts per minute

☐

2 4

Which diagram represents the beta-minus (β^-) decay of a stationary nucleus with the emission of an antineutrino ($\bar{\nu}$)?

The arrows show the direction of movement of the products of the decay.

[1 mark]

- A** ☐
- B** ☐
- C** ☐
- D** ☐

END OF QUESTIONS

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3 2



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