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Examiners' report

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259

For first teaching in 2016

J259/03 Summer 2024 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. A selection of candidate answers is also provided. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

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Paper 3 series overview

J259/03 Breadth in Physics is one of the two examination papers aimed at Higher tier candidates studying the GCSE (9-1) Twenty First Century Science suite.

The ten questions of this 90-mark paper assess knowledge and understanding from all six chapters of the syllabus plus Practical skills and Ideas about science. Questions 1 to 3 are overlap questions which appear in identical form on the Foundation tier paper. In common with previous qualifications, approximately 50% of the marks are awarded for demonstrating knowledge and understanding of scientific ideas, techniques and procedures, 30% for applying knowledge to solve problems and 20% for analysing information, drawing conclusions and improving experimental procedures. Approximately 39% of the marks on this paper are for simple and developed calculations. A very small number of questions worth 3 marks on this paper were synoptic. This means that candidates were required to piece together ideas from the different topic sections of the syllabus in order to answer them.

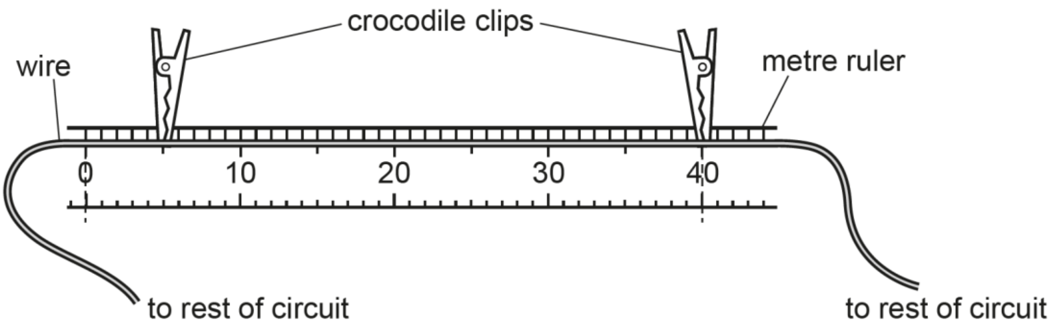
Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• selected appropriate formulae, rearranged when necessary and substituted numbers into them, with their working shown clearly • recognised when units such as kW needed to be converted into watts and mm to m for example, so avoided power-of-ten errors • made good use of data (for example, diameters of planets and their moons, turns ratios and voltage ratios in transformers, halogen vs LED lamps) to make different calculations and draw appropriate conclusions • used data in different formats to support conclusions, for example, nuclear equations to show mass conservation • suggested experimental techniques appropriate to the context of the question • gave precise descriptions of measurement techniques including the instrument being used and the quantity being measured • demonstrated knowledge and understanding of electrical circuits, space, forces, energy transfer, waves, acceleration, momentum and impulse, transformers and radioactivity.	• did not select equations from the equation sheet • did not make use of all the data provided and were not guided by the number of marks available for the question, for example, when comparing halogen and LED lamps (3 marks) stating only that LEDs last 20 000 hours more • did not consider whether calculated values were dimensionally correct, for example, multiplying force (N) by height (mm) to produce an incorrect value for compression (mm) • made limited comparisons, for example, when discussing elastic versus plastic deformation • did not follow the rubric instructions, for example, explaining how brakes work by describing energy transfers rather than using ideas about forces • used ideas about particles that were more relevant to describing changes of state rather than tension and compression.

Question 1 (a)

1 A student wants to find the resistance of a piece of wire.

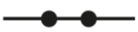
They clip the wire into a circuit with an **ammeter**, **voltmeter** and **variable power supply**.

The diagram shows how they clip the wire into the circuit.



(a) Draw a circuit diagram to show the full circuit they use.

Use:

- this symbol for the wire 
- this symbol for the variable power supply 

[3]

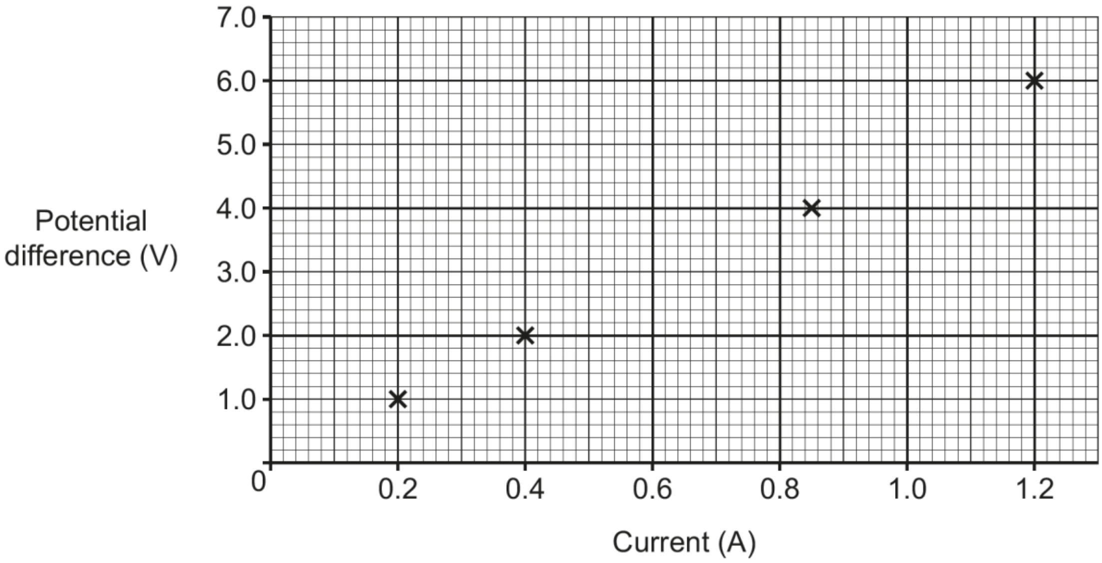
Most candidates drew correct circuits. The most common error was to place the voltmeter in series or place the voltmeter across the ammeter. Some candidates included several resistance wires and other additional circuit components which often prevented them gaining full marks.

Question 1 (b) (i)

(b) The student records the data shown in the table and plots a graph.

Current (A)	**Potential difference (V)**
0.20	1.0
0.40	2.0
0.65	**3.2**
0.85	4.0
0.98	**4.8**
1.20	6.0

(i) Plot the **two** missing points on the graph.



[1]

Most candidates plotted these points with precision and using small dots or crosses. The most common error was to plot 0.65 A at 0.70 A.

Question 1 (b) (ii)

(ii) Draw a line of best fit on the graph. **[1]**

Most candidates drew an accurate line of best fit and used a ruler to ensure that the line was straight. Candidates at this level also appeared to recognise that it was appropriate to extend their line to the origin (0,0).

Question 1 (b) (iii)

(iii) Calculate the gradient of the line.

Gradient = ... **[2]**

Most candidates extracted appropriate y and x values from the graph or they may also have used a single plotted point, for example, (1.2, 6.0) and (0,0).

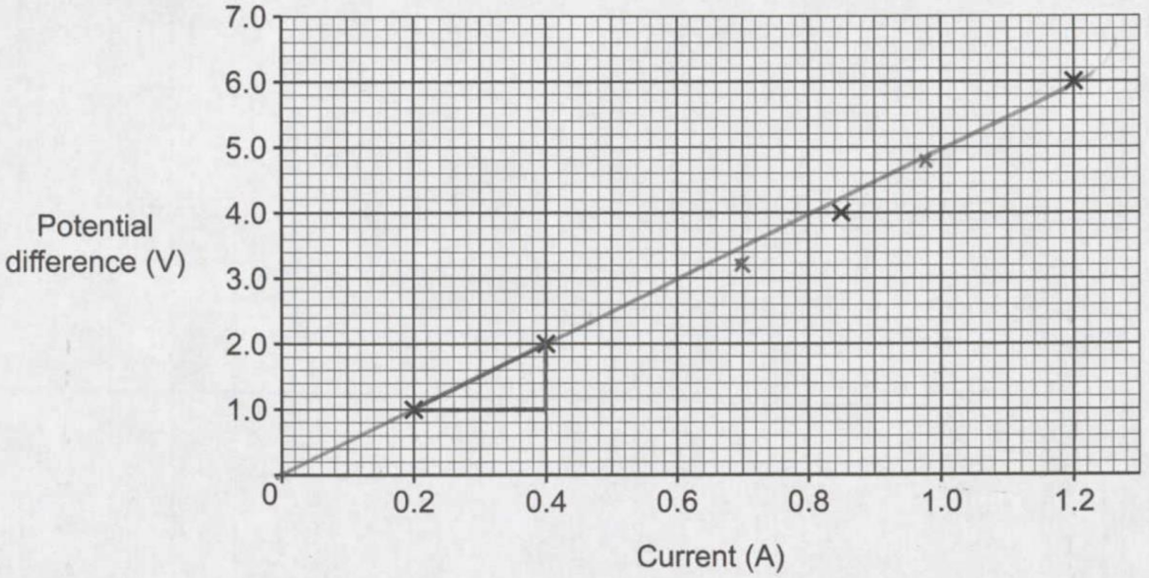
Some candidates did struggle with Question 1 part (b) (i) to 1 (b) (iv) however. A common error was Δx ÷ Δy. Other errors were in technique. Exemplar 1 shows a common error in the plotting of x = 0.65 A. The line of best fit at this point is also out of tolerance – a small clockwise rotation of the line would be an improvement. The candidate is awarded 1 mark for the equation but there is another common error in the substitution of x = 2 instead of x = 0.2.

Exemplar 1

(iii) Calculate the gradient of the line.

$$\frac{\text{change in y}}{\text{change in x}} = \frac{1}{2}$$

Gradient = $\frac{1}{2}$ **[2]**



Question 1 (b) (iv)

(iv) Find the resistance of the wire.

Resistance = ... Ω **[1]**

Most candidates extracted appropriate voltage and current values from either the table or their graph to calculate the resistance of the wire. Some candidates recognised that their gradient value was also dimensionally equal to the resistance of the wire and, if they did not gain a mark in (iii), picked up an 'error carried forward' (ECF) mark here.

Question 1 (c)

(c) The student clips a new piece of the same wire in the circuit and repeats their method to find the resistance.
The new piece of wire is double the length.

Describe how the resistance of the new length of wire is different to the resistance of the original length of wire.

....

....

....

.... **[2]**

Most candidates recognised that longer wires have higher resistance. Some candidates understood that if the length doubles, then the resistance also doubles. A few candidates seemed to have the misconception that the longer wire had less resistance because it has more electrons to allow a greater current.

Question 2 (a)

2 The table shows information about some objects in the solar system.

Name	**Pluto**	**Charon**	**Earth**	**The Moon**
Type of object	dwarf planet	moon	planet	moon
Orbits around	The Sun	Pluto	The Sun	Earth
Diameter (km)	2370	1210	12700	3480
Mass (kg)	1.3×10^{22}	1.6×10^{21}	6.0×10^{24}	7.4×10^{22}
Radius of orbit (km)	5.9×10^{9}	2.0×10^{4}	1.5×10^{8}	3.9×10^{5}
Gravitational force between the two objects (N)	5.0×10^{16}	3.5×10^{18}	3.5×10^{22}	1.9×10^{20}

(a) Name another **type** of object in the solar system that is **not** listed in the table.

.... **[1]**

Most candidates named a type of object such as a star or an asteroid.

Question 2 (b)

(b) A student looked at the data and said:
'A moon is always approximately half the diameter of the object it orbits.'

Show that the student is **incorrect**.

Use data from the table.

....

....

....

....

.... **[2]**

Most candidates understood that the command phrase 'use data' means more than simply quote data. Consequently, there were a few different approaches that candidates took to show that the student was incorrect. Most candidates halved Earth's diameter and showed that it was more than 3480. Some showed that the Moon was 27% of Earth's diameter or that Earth was 3.6 × larger (not double). A few candidates used the wrong data (radius of orbit) or simply claimed that the Earth was much bigger and therefore ignored the command phrase 'show that'.

Question 2 (c)

(c) Explain the difference in the time taken for Pluto and Earth to orbit the Sun.

Use data from the table.

....

....

....

....

.... **[2]**

Most candidates knew that Pluto is further away from the Sun than Earth without reference to the data, but followed the command to 'use data' and compared either orbital radius or gravitational force. A few candidates simply quoted the data without stating the comparison (bigger/smaller) or using the data to make a conclusion about the time taken.

Question 2 (d)

(d) The photo shows the formation of a star from a cloud of dust and gas.

Complete the sentences to explain the formation of the solar system and the birth of the Sun.

Use words from the list.

chemical	**combustion**	**friction**	**fusion**	**gravity**	**magnetism**

The objects in the solar system were formed over long periods of time from clouds of dust and gas drawn together by the force of ....

Particles at the centre collapsed together forcefully and increased the pressure and temperature until .... reactions began, forming the Sun. **[2]**

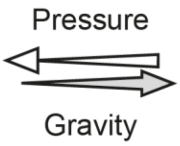
Most candidates knew that gravity causes the nebula to collapse, although a small number stated 'magnetism'. A common error was to state that chemical reactions occur due to the increase in temperature and pressure.

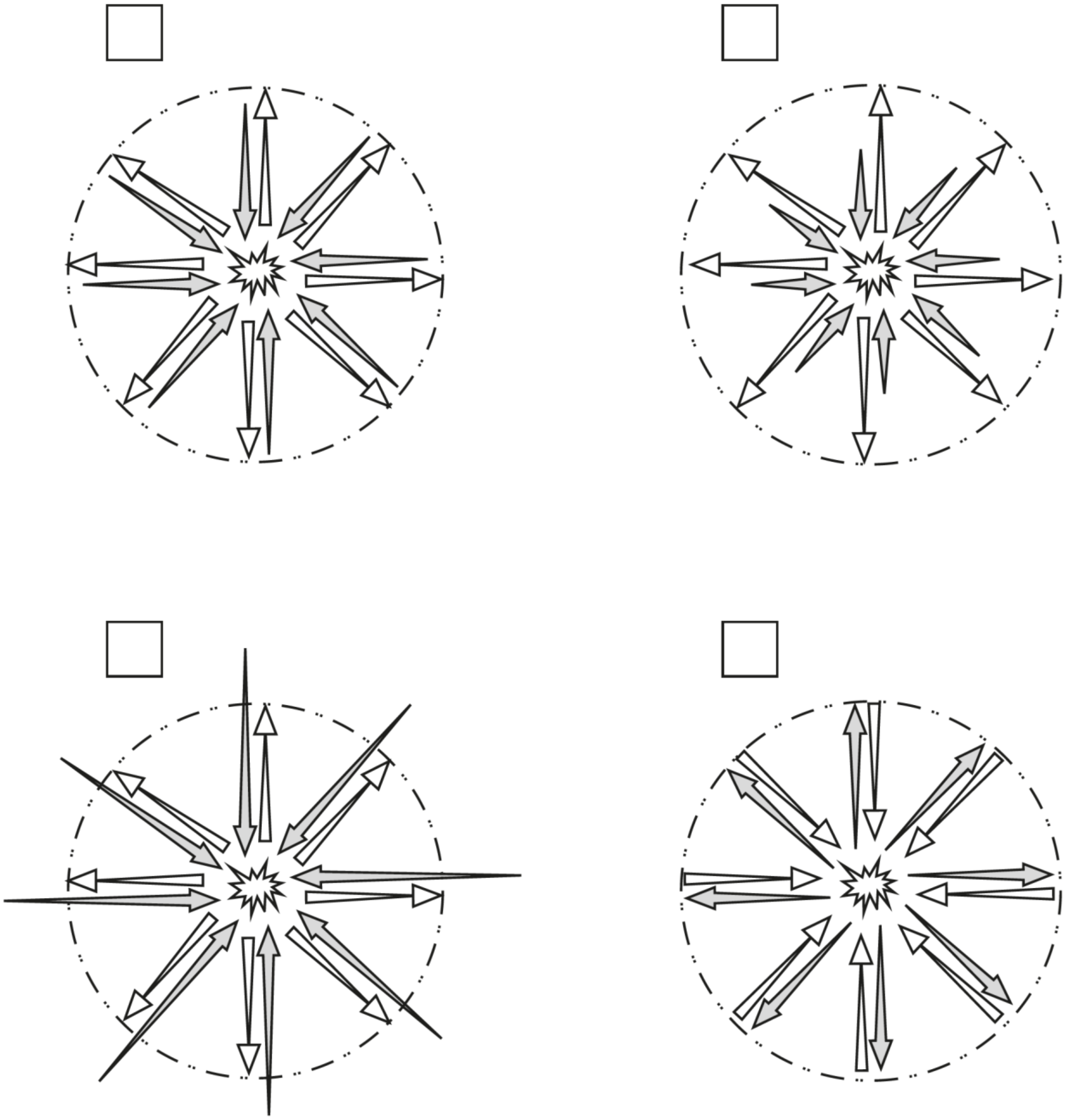
Question 2 (e)

(e) The diagrams represent the processes inside a star.

Which diagram shows how these processes keep a star, like the Sun, stable in size and shape for millions of years?

Tick (✓) **one** box.





[1]

Most candidates selected either box 1 or box 4, indicating they understood that a star has a stable size and shape due to balanced forces. The inward force of gravity is balanced by the outward radiation pressure.

Question 3 (a)

3 Many bikes use disc brakes.

Fig. 3.1 shows a diagram of a braking system fitted to a wheel.

Fig. 3.2 shows a thermal image of the same wheel, taken just after braking. On the right-hand side there is a temperature scale showing the shading.

Fig. 3.1

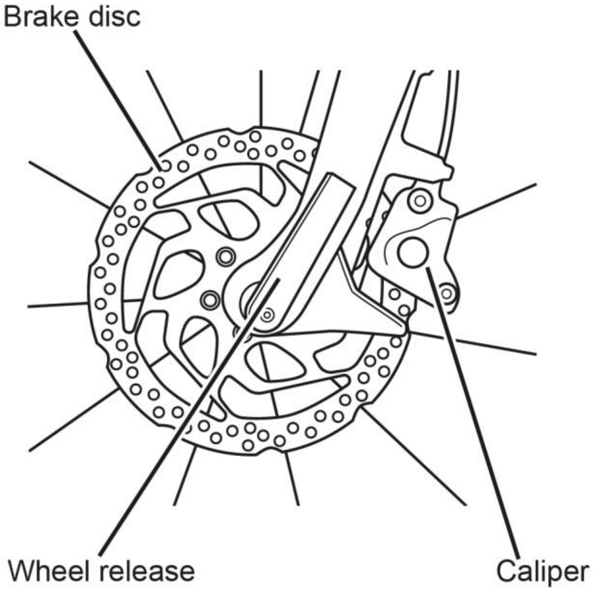
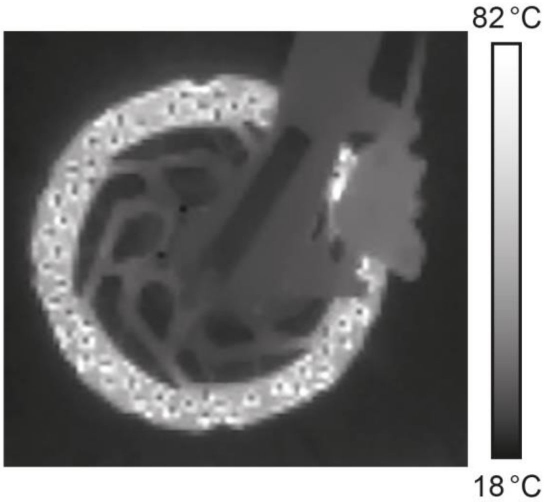


Fig. 3.2



(a) Which part of the bike visible in **Fig. 3.2** gets hottest during braking?

Tick (✓) **one** box.

Brake disc ☐

Caliper ☐

Wheel release ☐

[1]

All candidates identified the outline of the brake disc in the thermal image.

Question 3 (b)

(b) The brake disc is attached to the wheel. When the brakes are applied, calipers clamp onto the disc to slow it down.

Explain how brakes slow a bike down.

Use ideas about forces.

....

....

....

.... **[2]**

Most candidates understood that the calipers apply friction to the brake disc. Many candidates described the transfer of kinetic energy to thermal energy – this idea is tested in part (c) – and ignored the instruction to use ideas about forces. Only a very small number of candidates explained that friction is an opposing or backwards direction force.

Misconception

There is a misconception that braking decreases the resultant force. A smaller resultant force in the direction of movement would result in a lower rate of speed increase.

There is also a misconception that the friction force opposes the momentum of the bicycle. Although a force can act in the opposite direction to the motion of the bicycle, thereby reducing its momentum, momentum is a different quantity to a force. This is another example where understanding the units (kg m/s and N) will help candidates towards a better understanding of the physics.

Question 3 (c)

(c) Complete the sentence to explain why brakes get hot.

Use words from the list.

chemical	**elastic**	**gravitational**	**kinetic**	**thermal**

The brakes transfer energy from the .... store of the bike to the

.... store of the brake disc.

[2]

All candidates identified that the energy transfer is from the kinetic store of the bike to thermal store of the brake disc.

Question 3 (d)

(d) A brake disc increases in temperature by 60 °C during braking.

Calculate the change in internal energy of the brake disc.

The mass of the brake disc is 0.2 kg.
The specific heat capacity of the brake disc steel is 500 J / kg °C.

Use the Equation Sheet.

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

Most candidates selected the correct equation and substituted, without rearrangement, *m* (0.2 kg), *c* (500 J / kg °C) and ΔT (60 °C) to calculate ΔE.

Question 4 (a)

4 Microwaves are transverse waves used for mobile phone communication.

(a) Describe a transverse wave.

....

....

....

.... **[2]**

Most candidates knew that waves have a 'direction', and that for a transverse wave the direction is perpendicular or at 90° to a 'movement'. Candidates should describe this 'movement' as an oscillation, vibration or disturbance.

Question 4 (b)

(b) The signal strength on a mobile device is shown by the symbols below.

Good signal strength means that the microwaves have a high amplitude.

Define the amplitude of a wave.

You can include a diagram to support your answer.

....

.... **[2]**

Most candidates correctly indicated an amplitude on a wave diagram. Many also gained the second mark for indicating that it was the maximum displacement of the wave from the equilibrium, zero or rest position. Many candidates described the equilibrium position as 'the normal line'. References to 'the normal' were ignored. The 'normal line' is appropriate for ray diagrams, but this use is not appropriate.

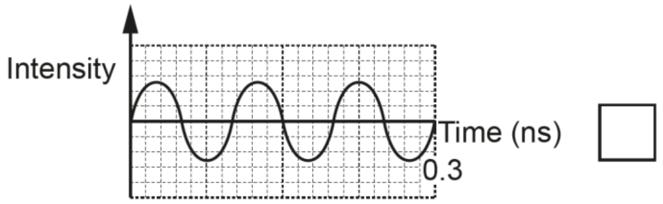
Question 4 (c)

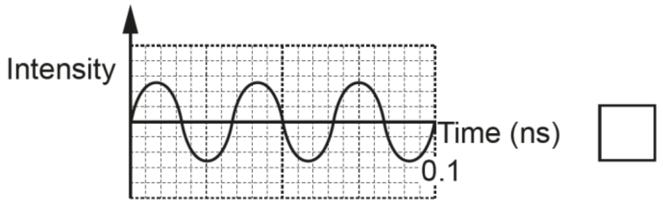
(c) The graph of a microwave signal is drawn with time on the x-axis.

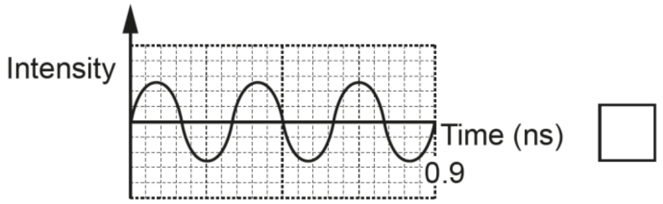
The wave has a time period of 0.3 ns.

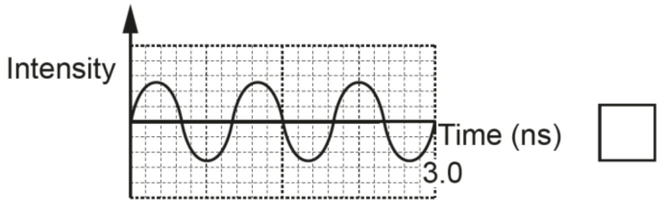
Which is the correct graph for this wave?

Tick (✓) **one** box.









[1]

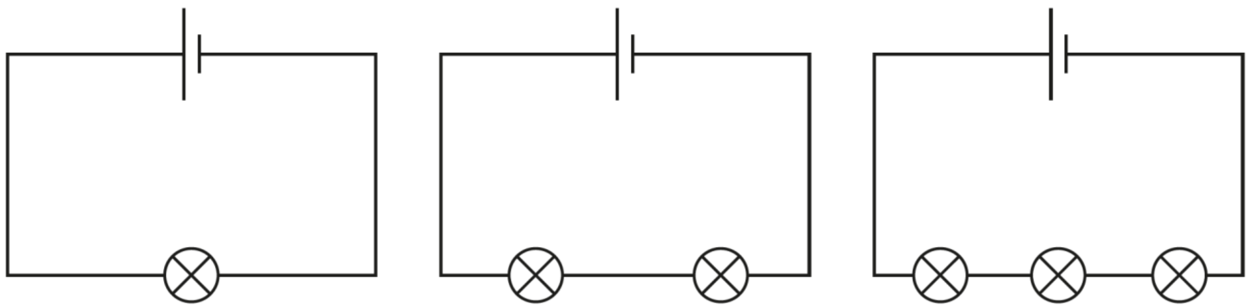
Most candidates recognise that three full wavelengths in a time of 0.9 ns means that the wave has a period of 0.3 ns.

Question 5 (a)

5 A student is investigating the brightness of lamps connected in different ways.

(a) The student makes the circuits shown in the diagram.

They observe the brightness of the lamps in each circuit and compare them by ranking them from brightest to dimmest.



Suggest how the method can be improved to give better quality data that does not rely on human judgement.

You can include diagrams to support your answer.

....

....

....

....

....

.... **[2]**

Candidates need to recognise when experimental methods are being assessed. Most candidates were able to suggest measuring the current or the voltage (or indicated the appropriate meter in a diagram). However, many candidates only referred to taking the measurement in one of the circuits.

Very few candidates referred directly to varying the number of lamps in series but often gained this mark for drawing additional circuits. A number of candidates described using a light dependent resistor without recognising that this component would also require calibration from voltage and current measurements.

Key point: measurement

When describing the use of meters and other measuring instruments candidates should be encouraged to use the word 'measure' along with the quantity being measured. Many candidates use less precise phrases such as 'to get', 'to find' and 'to see'. Phrases such as 'use a voltmeter' are insufficient and 'calculate the voltage' is incorrect.

Question 5 (b)

(b) Explain how you expect the brightness to change as the number of lamps in the circuit increases.

....

....

....

....

....

.... **[3]**

Most candidates understood that the lamps would become less bright as their number, in series, increases. The common explanation given by the candidates is that the potential difference is shared. Few candidates referred to the increase in total resistance or the reduction in power dissipated by each lamp.

Misconception

There is a misconception that current is shared as the number of lamps increase.

There is also a misconception that each lamp continues to receive the same current. Candidates need to be clear that this current is the same for each lamp, but less than in a circuit with fewer lamps.

Question 5 (c)

(c) The table shows information for two types of lamp which have the same brightness.

Type	**Lifetime in h**	**Energy transferred in one lifetime, in kWh**
LED	24 000	432
Halogen	4 000	216

Evaluate which lamp is more sustainable.

Use data from the table.

....

....

....

....

....

.... **[3]**

Most candidates were guided by the command phrases 'evaluate' and 'use data'. They were also guided by the 3 marks available for the question. Most calculated that the LED lasts six times longer than the halogen lamp and then, for each lamp, calculated the energy transferred by each lamp per hour of its use or the energy it would transfer in the lifetime of the other lamp. However, relatively few candidates used the result of this calculation to conclude that the LED is lower power than the halogen lamp, so it is less expensive to run.

Key point: fair test / fair comparison

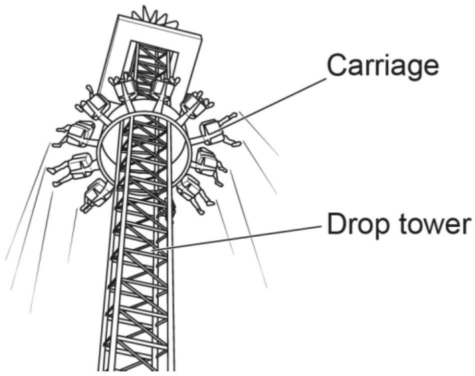
Some candidates stated simply that the LED transfers twice the amount of energy when compared to the halogen lamp.

When comparing data, candidates should consider whether they are making a fair-test comparison. In the example above, energy transfer is the variable so the time taken should be the same (control variable) for each lamp.

Question 6 (a)

6 The diagram shows a fairground ride called the Drop Tower.

Riders are pulled up to the top by a pulley. The pulley is powered by an electric motor.



(a) The ride takes 30 s to get to the top of the tower.
The pulley operates at a power of 40 kW.

Calculate the energy transferred by the pulley.

Use the Equation Sheet.

Energy transferred = ... J **[4]**

Most candidates selected the equation relating energy, power and time and substituted the values 30 s and 40 000 kW.

Assessment for learning

Candidates should practise questions where a unit conversion is required in part of a stepped calculation. In this example, 40 kW should be converted to 40 000 W and 30 s should not be converted to 0.5 minutes.

Question 6 (b)

(b) The ride drops from rest at the top of the tower.
The carriage falls under freefall for 40 m before the brakes are applied.

Calculate the maximum possible speed it could reach, assuming there is no air resistance.

Use the Equation Sheet.
The acceleration due to gravity is $10\,m/s^2$.

Maximum speed = ... m/s **[4]**

Most candidates selected the equation $v^2 - u^2 = 2as$ and substituted u = 0 m/s, a = 10 m/s^2 and s = 40 m.

Question 6 (c)

(c) The carriage reaches a maximum speed of only 25 m/s because of air resistance.

Calculate the total kinetic energy gained by the carriage and the riders between the top of the tower and when they reach a speed of 25 m/s.

The mass of the carriage is 1500 kg.
The mass of the riders is 840 kg.

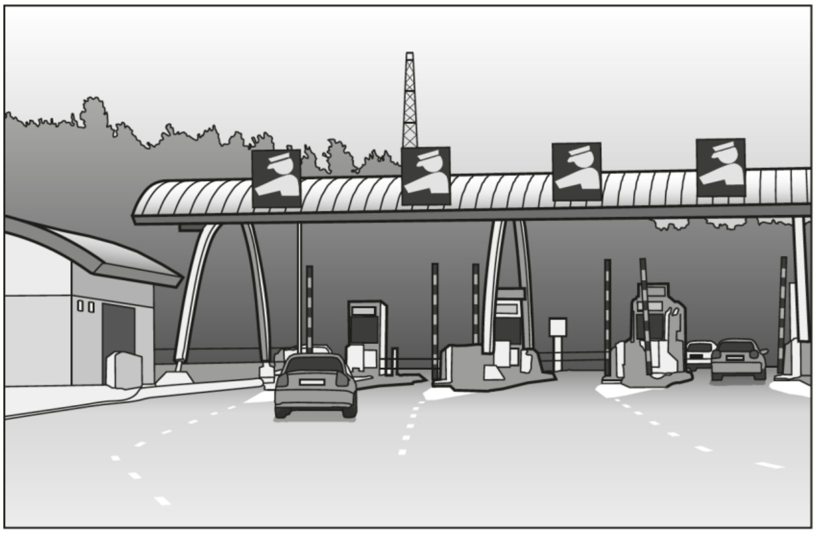
Use the Equation Sheet.

Kinetic energy gained = ... J **[3]**

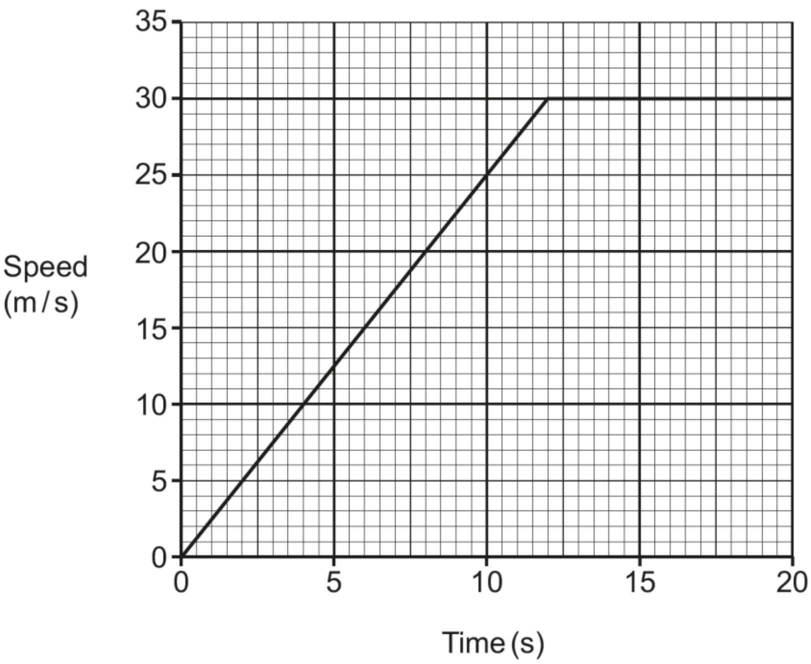
Most candidates selected the equation KE = $\frac{1}{2}mv^2$ and substituted m (= 840 kg + 1500 kg) and v (= 25 m/s).

Question 7 (a) (i)

7 Drivers pay to use a toll road. Cars stop at a payment point and then accelerate to the usual road speed.



(a) The graph shows the speed-time graph of a car after leaving the payment point.



(i) Calculate the acceleration of the car between 0 and 12 s.

Use data from the graph.

Acceleration = ... m/s^2 **[3]**

Most candidates used the graph to determine a speed change of 30 seconds in 12 seconds and used these values to calculate the acceleration.

Question 7 (a) (ii)

(ii) Which feature of the graph will give the distance the car has travelled?

Tick (✓) **one** box.

Area between the line and the x-axis ☐

Area between the line and the y-axis ☐

Gradient ☐

y-intercept ☐

[1]

Almost all candidates selected the first box. A very small number of candidates selected the third box, 'gradient'.

Question 7 (a) (iii)

(iii) Calculate the momentum of the car when it reaches a constant speed of 30 m / s.

The mass of the car is 950 kg.

Use the Equation Sheet.

Momentum = ... kg m / s **[3]**

Most candidates selected the equation for momentum and multiplied m (950 kg) by v (30 m / s).

Question 7 (b)

(b) Later in the journey, the car is driving with a momentum of 14 250 kg m / s.
The driver brakes sharply and the car comes to a stop in 3 s.

Calculate the force that stops the car.

Use the Equation Sheet.

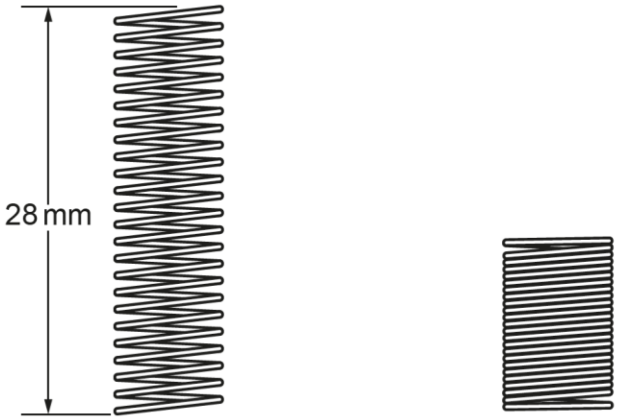
Force = ... N **[3]**

Most candidates selected the equation relating momentum and impulse and substituted values to calculate the force to stop the car.

Question 8 (a)

8 A student investigates a spring from a ball point pen.

They put small weights on top of the spring to compress it.



uncompressed spring　　spring fully compressed

The table shows their results.

Force (N)	Height of spring (mm)	Compression (mm)
0.00	28	0
0.05	27	
0.10	26	
0.15	25	
0.20	24	
0.25	23	

(a) Complete the table by working out the values of compression (mm) for the spring. **[1]**

Many candidates recognised that as the height of the spring decreases by 1 mm, its compression increases by 1 mm. Many other candidates multiplied force by height. This is another example where candidates should realise that the product of this calculation has the unit N mm, whereas the expected value from the heading of the table should have a unit in mm.

Assessment for learning

Candidates should practise making calculations where they also have to determine the unit. This can be fun! One furlong per fortnight has an equivalent value in metres per second.

Question 8 (b)

(b) The student concludes that force is directly proportional to compression.

Explain how the data shows this.

....

.... **[1]**

Candidates were awarded credit for descriptions of force and compression increasing by the same increment. Simple statements such as 'force increases and compression increases' were insufficient as this is a description of the data and not an explanation.

Assessment for learning

When the command phrase is 'explain how', candidates should be encouraged to look for patterns in how the numbers change rather than simply describing trends.

Candidates need to be taught to recognise direct proportionality in data. In this example, the same increment in force produces the same incremental change in compression. This is a linear relationship and since there is no compression when no force is applied, it also passes through the origin (0, 0).

It may also be observed that when the force doubles, for example, from 0.1 N to 0.2 N, the compression also doubles from 1 mm to 2 mm.

A third check for proportionality is to check for a constant ratio of e.g. force ÷ compression. In this case, any force and compression pair gives a ratio of 0.05 N / mm. The fact that this ratio is a constant shows that the variables are directly proportional.

Question 8 (c)

(c) Compression and extension both have the same relationship with the force on a spring.

Calculate the spring constant for this spring.

Use data from the table.
Use the Equation Sheet.

Spring constant = ... N / m **[4]**

Most candidates selected the spring equation $F = k\,x$ and substituted values from the table. This is another example where candidates need to be aware of the units of compression (mm) in the table and the spring constant N / m for the calculation. Many candidates either neglected or made errors in the conversion of mm to m.

Exemplar 2 shows that the candidate has multiplied the values in the first two columns (see also Question 8 (a) commentary). They have calculated the spring constant for each pair of values and added a column to the table. In part (c) they have used two correct pairings 0.25 and 5.75, and 0.20 and 4.8. The equation is shown but the substitution would also have gained this mark. The candidate does not convert mm to m but evaluates the spring constant for each pairing correctly.

Note that 0.04 is one significant figure. All correctly rounded calculations were accepted.

Exemplar 2

(c) Compression and extension both have the same relationship with the force on a spring.

Calculate the spring constant for this spring.

Use data from the table.
Use the Equation Sheet.

All give a rounding to 0.04. - look on table.

Spring constant $= \frac{F}{x} = \frac{F}{x} = k$

$= \frac{0.20}{4.8} = 0.0416$

$\frac{0.25}{5.75} = 0.043$

Spring constant = ~~0.0431~~ 0.04 N/m **[4]**

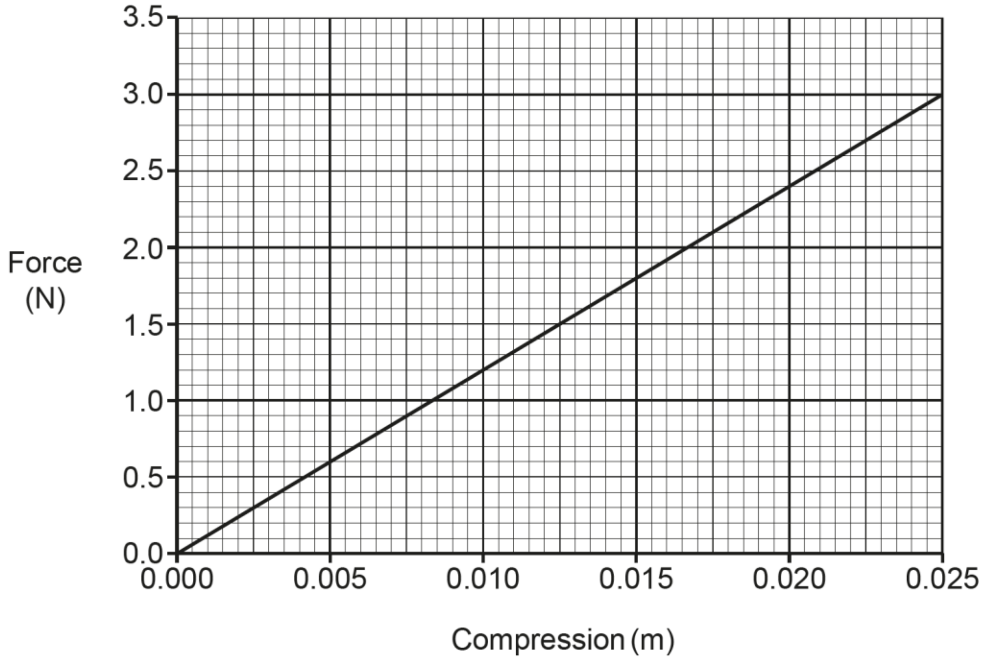
The table shows their results.

Force (N) F	Height of spring (mm)	Compression (mm) x	
0.00	28	0	0
0.05	27	1.35	0.037
0.10	26	2.6	0.038
0.15	25	3.75	0.04
0.20	24	4.8	0.0416
0.25	23	5.75	0.043

Question 8 (d) (i)

(d) Another spring has a different spring constant.

The force-compression graph is shown below.



(i) Calculate the energy stored in this spring at a compression of 0.01 m.

Energy = ... J **[3]**

The product of force (N) and compression (a distance with unit m) is equal to work done. The triangle indicates that the product must be halved. Another example of where an understanding of the units should lead to a more efficient calculation. However, almost all candidates selected the equation $E = \frac{1}{2} k x^2$ and used the graph to determine a value of k (120). A common error was to substitute a different value for the compression instead of the value given.

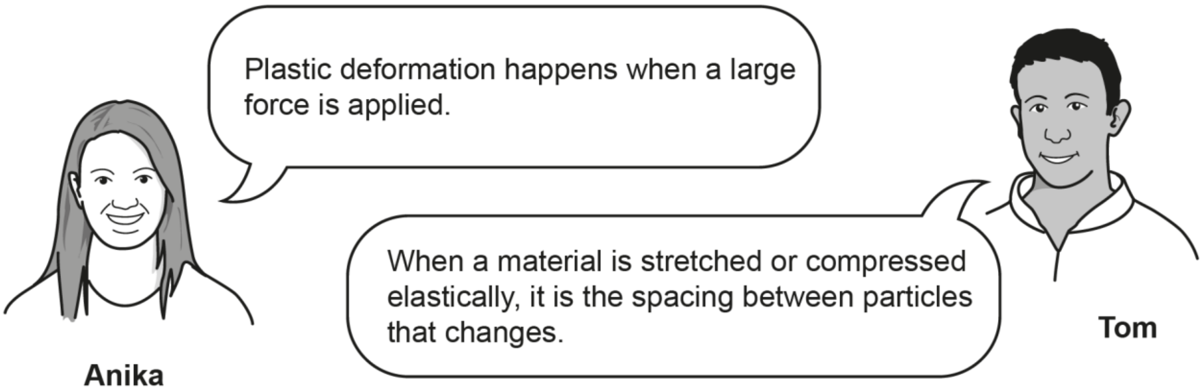
Question 8 (d) (ii)

(ii) **Draw** a second line on the graph to represent a spring with a lower stiffness. **[1]**

Most candidates drew a straight line through the origin with a less steep gradient.

Question 8 (e)

(e) Two students are discussing plastic and elastic deformation of materials when a force is applied.



Discuss whether the students are correct.

Use the particle model to explain your answer.

[3]

Candidates generally gained a mark or marks for knowing that plastic deformation results in a permanent change of shape, whereas elastic deformation is temporary and the original shape is restored once the force is removed. Some candidates also made correct references to the limit of proportionality or elastic limit and used ideas about bond breaking. Some candidates also considered that the tensile strength was a more important factor than the size of the force.

Most candidates gave quite vague answers, however. Commonly, they would agree with Tom but without explaining. For example, that stretching increases particle distance or compressing decreases the distance.

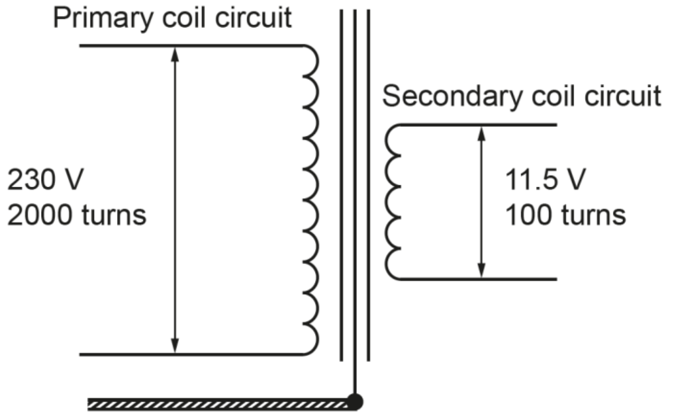
Misconception

There is a misconception that the particle model only applies when describing changes of state. Candidates used particle diagrams to show that solids cannot be compressed because all of the particles are already in contact so there are no gaps. Most materials do not have a perfect crystalline structure. Additionally, candidates explained that if the particles moved apart then they would be evaporating, concluding, incorrectly, that the particles themselves must be deforming and not the space between.

There is also a misconception, relating to plastic deformation, that the material is made from plastic.

Question 9 (a)

9 Engineers are designing a transformer to go inside a light fitting for a low voltage ceiling light.



(a) Explain why a battery cannot be used in a transformer.

....

....

....

....

....

.... **[3]**

Question 9 is a high demand question. Common incorrect answers included the idea that a battery has a fixed voltage that cannot be changed, or that the voltage of a battery is too small or that batteries are not used to power ceiling lights. Some candidates recognised that for a transformer to operate it must be connected to an alternating current supply and that a battery supplies direct current. A very small number of candidates gained the third mark for understanding that the alternating magnetic field caused the alternating current if the primary induces a voltage in the secondary coil.

Question 9 (b)

(b) Show how the potential differences of the primary and secondary coils relate to the number of turns on each coil.

Use data from the diagram in your answer.

....

....

....

.... **[2]**

Most candidates followed the command phrase 'use data' and recalled or applied the 'turns ratio to voltage ratio' equation to show a common factor of 20. Other candidates gained a mark for a calculation showing that the number of volts per turn, or the number of turns per volt, were the same in the primary and the secondary. Some candidates did not 'use' the data and simply quoted it and described which number had gone up or down.

Question 9 (c)

(c) This transformer is only 85% efficient.
The engineers want to make it more efficient to make the light fitting safer for household use.

Explain why transformers are not 100% efficient and what risk this presents.

....

....

....

.... **[2]**

Most candidates understand that inefficiency results in a transfer to the thermal energy store. They correctly describe the risk of fire or simply overheating the transformer/light fitting assembly. A common error is that the risk is one of electrocution.

Question 10 (a)

10 This question is about neutrons.

(a) Neutrons are involved in beta decay.

Explain why the atomic mass number does **not** change when a nucleus emits a beta particle.

....

....

....

.... **[2]**

Question 10 is a high demand question. Most candidates did not make use of the rubric information that neutrons are involved in beta decay. Consequently, many candidates described the negligible mass of the electron to explain why there was no mass change. Additionally, a common error was to write that the source of the beta particle is in the orbital electrons rather than the nucleus. Some candidates did understand beta decay, however, and since they knew that the decaying neutron also produces a proton, they invariably gained the second mark for explaining that the proton has the same mass as the neutron it has replaced.

Question 10 (b) (i)

(b) Beryllium-13 is an unstable isotope of beryllium.
It emits a neutron by neutron decay to turn into a more stable nucleus.

(i) Complete the equation for beryllium-13 when it decays.

$$^{13}_{4}Be \rightarrow \, ^{\square}_{4}\square + \, ^{1}_{0}n$$

[2]

Most candidates correctly completed the nuclear equation. They deduced Be from the conservation of the proton/atomic number and 12 from the conservation of mass.

Question 10 (b) (ii)

(ii) The half-life of beryllium-13 is 3×10^{-21} seconds.

Describe what is meant by half-life.

....

....

.... **[1]**

Most candidates understood that half-life is a period of time. They then correctly described this time as the time for the activity of the isotope to halve, or the time for the number of nuclei to halve. A common error was to refer to the activity or decay of a single nucleus.

Question 10 (c) (i)

(c) Neutron beam therapy is used to treat tumour cells in the neck and brain.
It includes these steps:

- A patient is injected with a solution of boron-10.
- The boron-10 becomes concentrated in the tumour cells.
- The neutron beam is aimed at the tumour.
- The neutrons cause the boron-10 to emit alpha and gamma radiation at the site of the tumour.

(i) Explain why the alpha radiation causes more damage to body tissues in the patient than the gamma radiation.

....

.... **[1]**

Most candidates understood that alpha is the most ionising and is absorbed by body tissue rather than passing through it.

Question 10 (c) (ii)

(ii) Which radiation presents the most risk to the medical staff who give this treatment?

Tick (✓) **one** box.

Explain your answer.

Alpha particles ☐

Gamma radiation ☐

Explanation ....

.... **[1]**

Most candidates understood that gamma is the most penetrating and therefore will pass out of the patient towards the medical staff.

Question 10 (c) (iii)

(iii) Suggest **one** way the risk to the medical staff can be minimised.

....

.... **[1]**

Most candidates described appropriate precautions such as lead lining in clothing, screens or simply leaving the room during the procedure. Precautions such as 'wear PPE', 'gloves', 'goggles', or 'store in a lead box'/'use tongs' were ignored as irrelevant to the situation described in the question.

Question 10 (c) (iv)

(iv) When boron-10 absorbs a neutron, it decays to become stable lithium-7 by emitting alpha and gamma radiation.

Show that total mass is conserved in the decay of boron-10 to lithium-7.

....

....

....

.... **[2]**

Only a small number of candidates were able to show mass conservation and this was most often achieved by showing a nuclear equation such as the one shown in (b) (i).

Exemplar 3 shows a very good answer to this question. The candidate understands that the values 10 and 7 indicate the mass number of the isotopes. The candidate recalls the nuclide notation for alpha and states that the mass on each side of the equation is 11. The inclusion of gamma was not necessary for the award of both marks, but this candidate knows that gamma has no charge and no mass.

The nuclear equation given in (b) (i), (which shows neutron decay, rather than absorption) may have helped some candidates to analyse this part of the question.

Exemplar 3

$10 + {}^{1}_{0}n \rightarrow 7 + {}^{4}_{2}He + {}^{0}_{0}\gamma$

~~[illegible]~~ There is an equal mass of 11 on both sides mass is conserved. **[2]**

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