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Examiners' report

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259

For first teaching in 2016

J259/03 Summer 2023 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 units aimed at Higher tier candidates studying the GCSE (9-1) Twenty First Century Science Suite.

The thirteen 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 were given for demonstrating knowledge and understanding of scientific ideas, techniques, and procedures, 30% for applying that knowledge to solve problems and 20% for analysing information, drawing conclusions, and improving experimental procedures. Approximately 30% of the marks are for simple and developed calculations. A very small number of questions worth approximately 5 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 and substituted numbers into them, with their working shown clearly • recognised when units such as km/s needed to be converted into m/s for example • processed the information provided in the rubric to draw conclusions and interpretations • suggested experimental techniques appropriate to the context of the question • demonstrated knowledge and understanding of waves, energy transfers, electrical power, the particle model, nuclide notation and momentum.	• misapplied data in equations e.g. 5 (c) I and R used to calculate voltage instead of power loss, 7 (a) current and voltage data to calculate resistance instead of power, 11 (c) (i) minutes rather than seconds used to calculate charge, 13 (b) (ii) km/s used to calculate momentum rather than m/s • rearranged equations incorrectly • showed limited understanding of the results of their calculations, e.g. a solar probe with a mass of 0.02 grams, a ball with a mass of 52 kg • made limited responses to questions requiring developed explanations.

Question 1 (a)

1 The picture shows a child on a slide. The child's hair is standing on end due to static electricity.

(a) Suggest what has happened to cause the child's hair to stand on end.

....

....

....

.... **[2]**

Most candidates recognised that friction between the child and the slide would result in the transfer of electrons. Some candidates also discussed the like charge on each hair causing repulsion. A misconception was that the hair is standing on end due to the attraction of opposite charge between the hair and the slide.

Question 1 (b)

(b) Complete the sentence to explain static electricity.

Put a ring around the correct option.

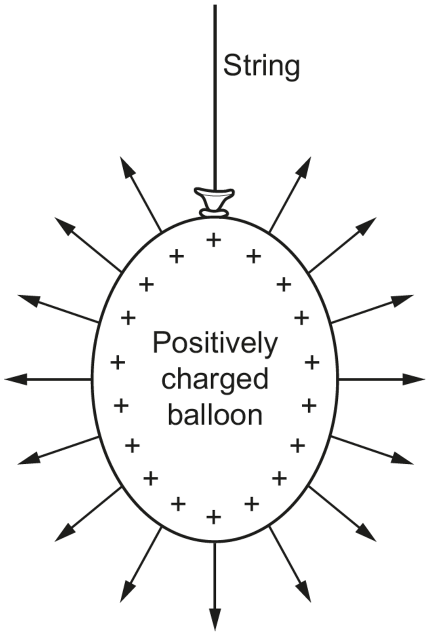
Static electricity is the **sharing / storing / transfer** of electrons between insulators. **[1]**

Almost all candidates selected 'transfer'.

Question 1 (c) (i)

(c) The diagram shows a positively charged balloon, hanging freely from a string.

There is an electric field around the balloon, as shown by the arrows.



(i) Explain what the direction and spacing of the arrows mean about the electric field.

Direction of arrows ....

....

Spacing of arrows ....

....
[2]

Candidates were unfamiliar with this area of the syllabus. Very few candidates recognised that the arrows represent force. More candidates recognised that arrow spacing is an indication of field strength, but responses were often unclear and with misconceptions about magnetic fields.

Assessment for learning

Around every electric charge, there is an electric field. In this region of space, the effects of charge can be felt; when another charge enters the field, there is an interaction between them and both charges experience a force.

Teacher can use diagrams such as the one shown in 1 (c) (i) when teaching electric fields.

Misconception

Candidates often use ideas about magnetic and electric fields interchangeably.

Exemplar 1

Direction of arrows Shows that it will attract anything that is negative and repel anything positive

Spacing of arrows It is a strong electric field

[2]

The response makes no reference to force but there is a general idea about the effect of the field on different charges. The reference to 'strong' cannot be given credit because we cannot be sure whether the candidate thinks that the spacing of the arrows is large or small.

Question 1 (c) (ii)

(ii) A second balloon is brought close to this balloon and the two balloons repel one another.

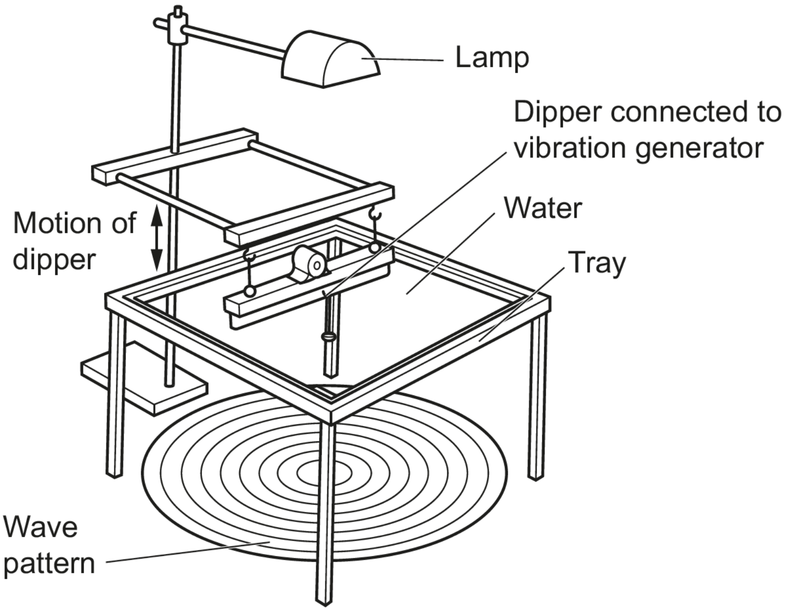
State the type of charge on the second balloon.

.... **[1]**

Almost all candidates stated 'positive'.

Question 2 (a)

2 A student sets up a ripple tank, as shown in the diagram. The dipper dips up and down and sends circular water waves outwards.



(a) Which row gives the correct definitions of wavelength and frequency?

Tick (✓) **one** box.

Wavelength	**Frequency**	
The distance a wave travels in 1 second.	The number of waves in 1 second.	
The distance a wave travels in 1 second.	The time it takes for 1 wave to pass.	
The distance from peak to peak.	The number of waves in 1 second.	
The distance from peak to peak.	The time it takes for 1 wave to pass.	

[1]

Almost all candidates selected the third box.

Question 2 (b) (i)

(b) (i) The student takes a photograph of the wave pattern.

State **one** piece of equipment which needs to be included in the photograph to find the wavelength of the water waves.

.... **[1]**

Almost all candidates recognised the need for a ruler.

Question 2 (b) (ii)

(ii) The student then uses a smart phone to record a video of the movement of the water waves for a few seconds.

Describe how the student could use a video to find the frequency of the water waves.

....

....

....

.... **[2]**

Most candidates described counting the number of waves in a period of time. Far fewer candidates indicated how this time measurement could be obtained – either by using a stopwatch or the length of time of the video.

Candidates need to recognise when practical skills are being assessed in questions and consider the apparatus required to carry out the techniques that they describe.

Question 2 (b) (iii)

(iii) How can the student now calculate the speed of the water waves?

....

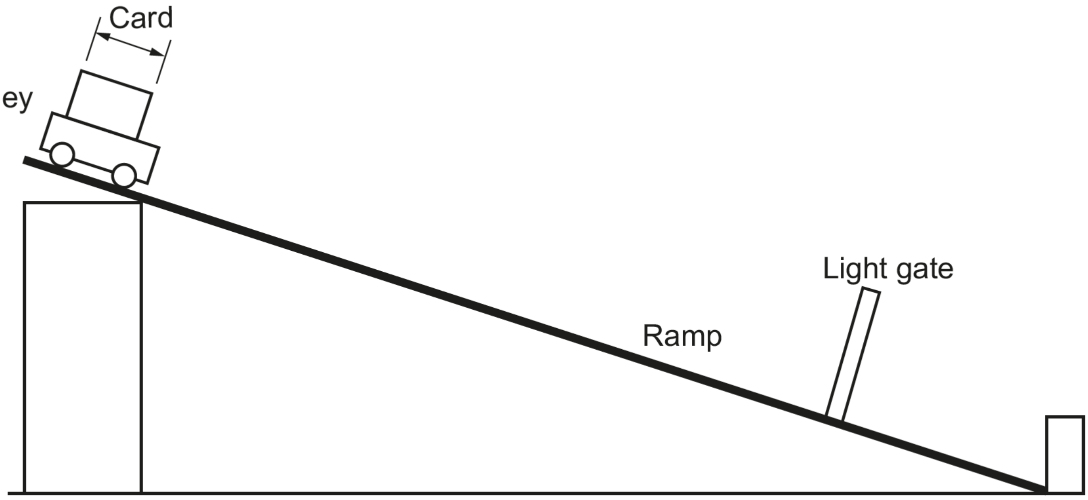
.... **[1]**

Most candidates recognised that the wave equation is applied. Some candidates suggested speed = distance ÷ time. No credit was given for this as (i), (ii) and (iii) are part of a connected question sequence, and the use of the word 'now' in the command sentence guides candidates to apply wavelength and frequency.

Question 3 (a)

3 **Fig. 3.1** shows a trolley at the top of a ramp.

Fig. 3.1



(a) The trolley is released and accelerates down the ramp. When the trolley passes through the light gate, the instantaneous speed of the trolley is displayed.

Describe how the acceleration of the trolley down the ramp can be calculated using one light gate and a stopclock.

$$\text{Acceleration} = \frac{\text{change in speed}}{\text{time taken}}$$

....

....

....

.... **[2]**

Most candidates were able to describe the time taken from the start position to the light gate. Some candidates found difficulty in expressing that the change in speed was also the speed displayed by the light gate (since the initial speed = 0).

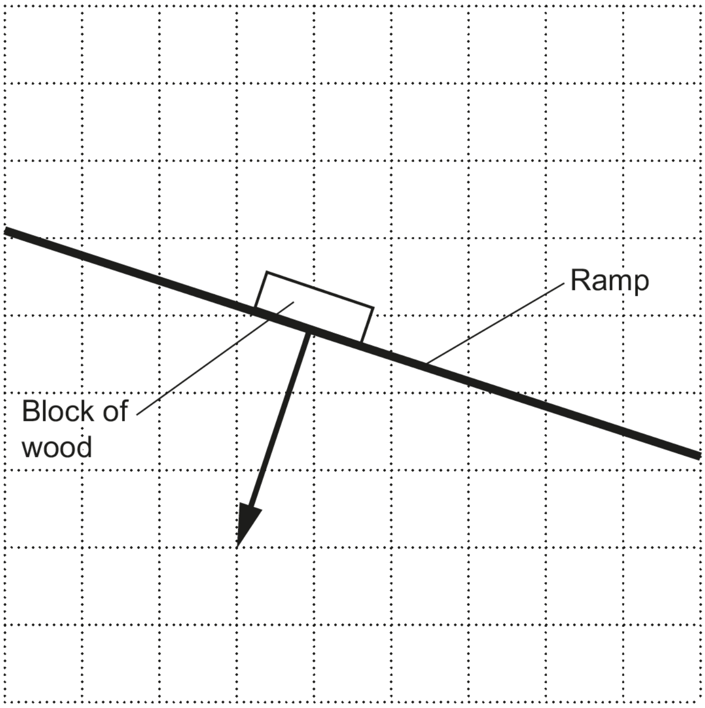
Question 3 (b)

(b) A block of wood is placed on the ramp. It exerts a force of 3.2 N on the ramp, perpendicular to the surface of the ramp. This is shown as a vector on **Fig. 3.2**.

Draw **one** vector on **Fig. 3.2** to show the force the ramp exerts on the block of wood, to complete the interaction pair.

Use a ruler.

Fig. 3.2

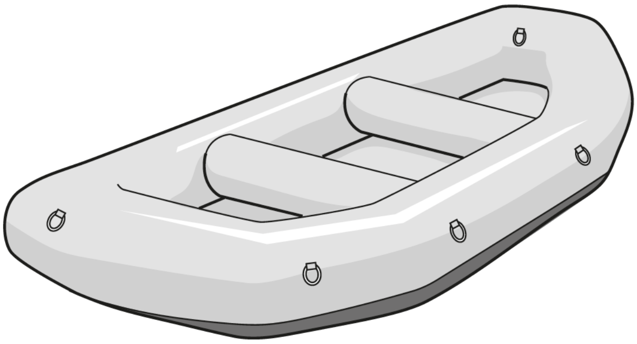


[1]

Almost all candidates gained this mark. A common error was to draw an arrow pointing up the slope and parallel to the slope (friction). Another error was to leave a gap between the block and the drawn arrow – indicating a non-contacting force.

Question 4 (a)

4 This question is about an inflatable boat.



(a) Boats float because they are less dense than water.

Define density.

....

.... **[1]**

Most candidates gained this mark. A common misconception is that density is the number of particles in a volume.

Question 4 (b)

(b) The boat is inflated in the morning and then left out in the sun. The temperature of the air inside the boat rises to 50 °C.

- The volume and mass of the air inside the inflated boat are constant.
- The table contains data about the average speed of air molecules at different temperatures and pressures.

Temperature (°C)	Average speed of air molecules (m/s)	Pressure (Pa)
20	508	115 000
40	525	122 000
60	542	129 000

Explain why the boat feels firmer after being left out in the Sun.

Use the data in the table. You do not need to do any calculations.

....

....

....

....

....

.... **[3]**

Many candidates linked increasing temperature to higher average speed and pressure. These are trends in the data and therefore descriptions. A few candidates recognised the command word 'explain' and gained a further mark, usually for an understanding that the rate or frequency of collisions between air molecules and the boat increases. Many candidates did not make full use of the data.

Exemplar 2

Because the pressure has increased, from 115000 Pa to 129000, ~~the~~ and the volume remains constant, the force of the surface must have increased. This means that there are more collisions with the gases inside of the boat, which causes the boat to feel firmer. Also, the speed has increased, so the gas molecules **[3]**

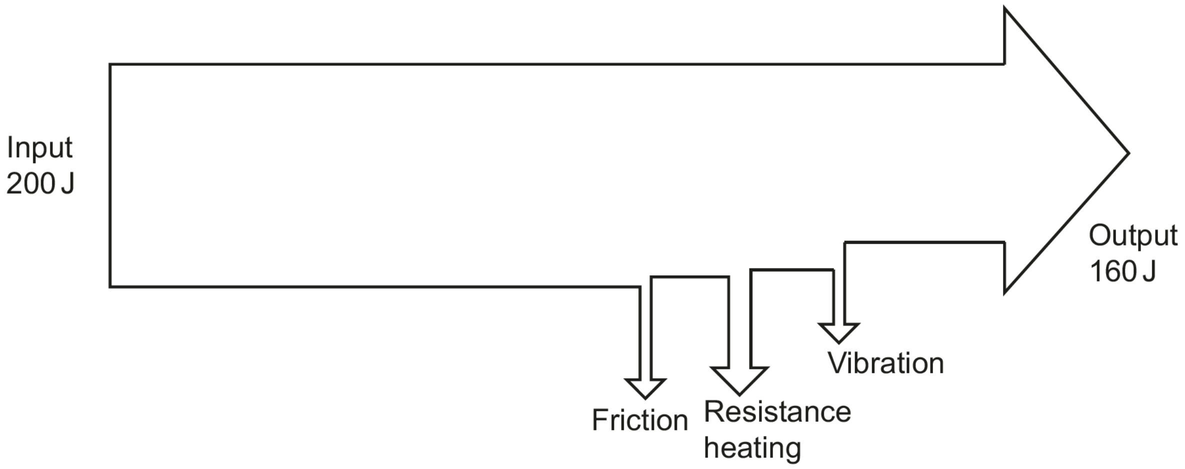
inside of the boat must also speed up to match the speed outside the boat. These both cause the boat to expand, and as it cannot expand any further, it will feel firmer.

This response identifies two trends but gives no link to the increase in temperature. It includes supporting data, but there is no mark for restating the information provided in the rubric. The 'explanation' that 'force at the surface must have increased' is incomplete without supporting evidence (e.g. of the P = F÷A equation). The reference to more collisions is not sufficient and also doesn't make reference to particles. The reference to gas molecules speeding up 'to match the speed outside the boat' is a misconception.

Question 5 (a) (i)

5 This question is about energy transfers in electric mixers.

The Sankey diagram shows the energy transferred when an electric hand mixer is in use for **one second**.



(a) (i) Describe how the Sankey diagram shows that all the energy transfers to and from the mixer are a closed system.

....

.... **[1]**

Candidates were unfamiliar with this area of the syllabus. Candidates who gained a mark recognised that the total of the outputs is equal to the input. A handful of candidates recognised that the sum of the widths of the output arrows is equal to the width of the input.

Assessment for learning

Teachers can use diagrams such as the one shown in 5 (a) (i) when teaching energy transfers to different stores.

Question 5 (a) (ii)

(ii) Calculate the power wasted when the mixer is in use.

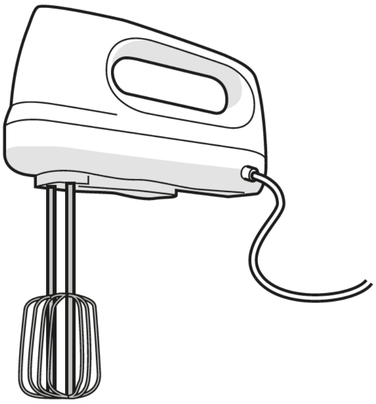
Power = ... W **[1]**

Almost all candidates recognised that 40 W is wasted.

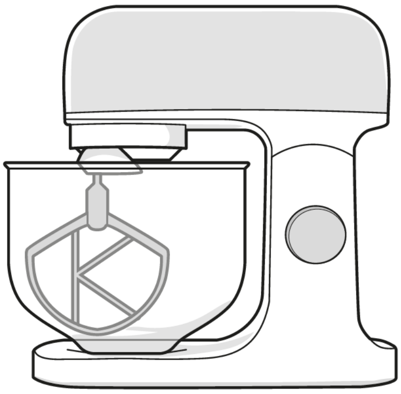
Question 5 (b)

(b) A cook makes two cakes, using a different mixer for each one. The mixers and their power ratings are shown in the two images.

200 W hand mixer



600 W stand mixer



Explain the difference in the energy stored in the cake mixtures and their surroundings when the cook uses the hand and stand mixers for the same amount of time.

....

....

....

.... **[2]**

Most candidates recognised that the stand mixer transfers more energy. However, the idea of 'transfer' was often poorly expressed, e.g. uses/produces/has more energy which did not gain credit. Many candidates missed the subtle observation that if more energy is transferred, then more energy is gained by the stores.

Question 5 (c)

(c) The hand mixer heats up when it is in use. This is caused by resistance as the current flows through the circuit in the hand mixer.

The resistance in the circuit is 40 Ω.

Calculate the power lost as heat when the current is 0.7 A.

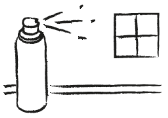
Use the Equation Sheet.

Power = ... W **[3]**

Most candidates selected the power loss equation $P = I^2R$ and 19.6 W was commonly seen.

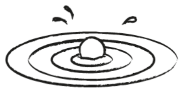
Question 6 (a)

6 **(a)** Ben records his observations from two wave demonstrations.



Sound Waves

When a can is sprayed, we hear it across the classroom 0.1 s later. We can smell it 30 s after it is sprayed.



Water Waves

When a coloured dye is thrown into a tank of water, it takes 1.5 s for the ripples to reach the end of the tank. It takes 50 s for the coloured dye to reach the end of the tank.

Explain how the demonstrations show that it is the wave and not the water or air itself that travels.

....

....

....

.... **[2]**

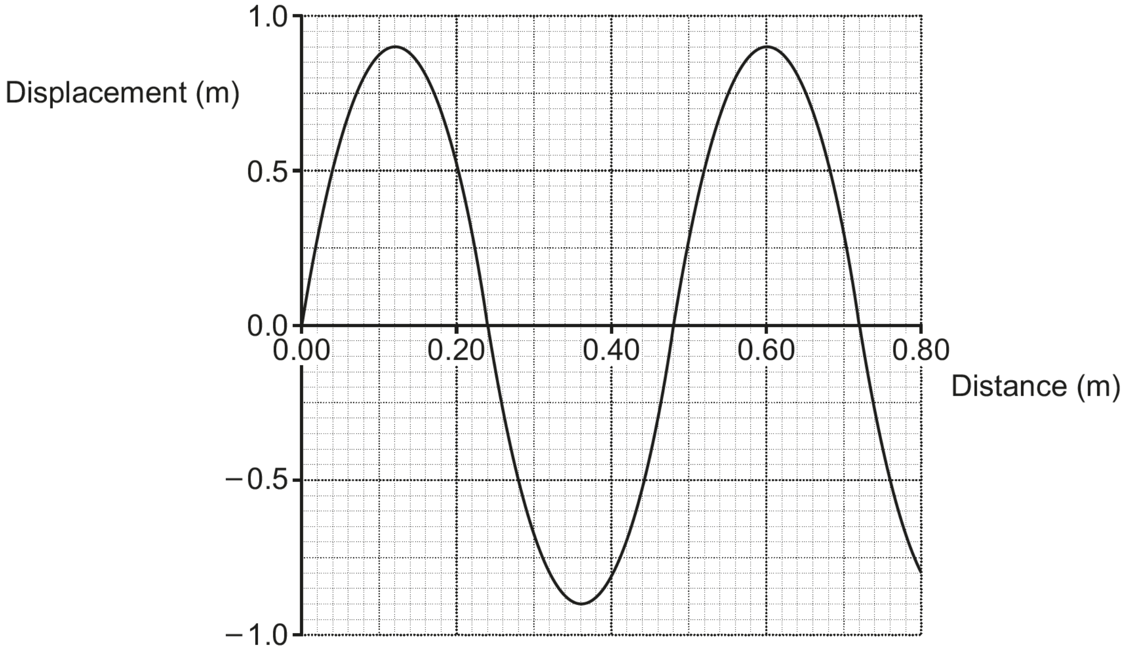
Candidates generally gained 1 mark for recognising that if the ripples or the sound take less time to travel, then they are moving faster. Many candidates, however, simply restated these values from the rubric without further processing. Very few candidates stated that the waves transferred energy (dye and scent are not) or that matter was not transferred (the water and the air remained in place). Some candidates identified that dye and scent diffuse but did not refer to the movement of particles.

Assessment for learning

Teachers often demonstrate the learning objective in P.1.3. using slinky springs to show both transverse and longitudinal waves. The demonstrations described in the question are both good ways of illustrating how waves travel through a medium and transfer energy without transferring matter.

Question 6 (b) (i)

(b) A student makes waves on a rope. The graph shows information about these waves.



(i) State the amplitude of this wave.

Amplitude = ... m **[1]**

Most candidates recorded 0.9. The most common errors: 1.8 (double the amplitude), 0.48 (confusion with wavelength) and 0.8 (misreading the scale to mean that one small square = 0.1 rather than two small squares).

Question 6 (b) (ii)

(ii) State the wavelength of this wave.

Wavelength = ... m **[1]**

Most candidates recorded 0.48. The most common errors were: 1.8 (double the amplitude), 0.24 (half the wavelength).

Question 6 (b) (ii)

(iii) The student makes 10 waves in 20 seconds.

State the time period of this wave.

Time period = ... s **[1]**

Most candidates correctly recorded 2 (the number of seconds per wave) but the most common error was 0.5 (waves per second).

Question 6 (c)

(c) Describe how waves on a rope are an example of transverse waves.

....

....

....

.... **[2]**

Only the highest scoring candidates were able to express themselves clearly in this question. Most candidates had an idea that something was happening perpendicular to something else but were confused about the motion and the wave. Candidates who compared the up-down movement of the rope with the direction of energy transfer generally gained both marks.

Question 7 (a) (i)

7 **(a)** Electrical power is transmitted via the National Grid at 400 000 V a.c. (alternating current).

Electric train power lines need an a.c. electrical power supply of 25 000 V. A step-down transformer decreases the potential difference for the electric train power lines.

Information is shown about the primary coil and secondary coil of the step-down transformer.

Primary coil	Secondary coil
400 000 V	25 000 V
.... A	1600 A

(i) Calculate the current in the primary coil of the transformer.

Use the Equation Sheet.

Current = ... A **[3]**

Most candidates selected the appropriate equation and calculated 100 A. The most common error was to calculate the ratio of voltage and current in the secondary coil and then divide the voltage of the primary coil by this ratio. Candidates who used this incorrect approach generally did not show their selected equation from the equation sheet, thereby missing an opportunity for 1 mark.

Question 7 (a) (ii)

(ii) Explain why electrical power is transmitted at 400 000 V, and **not** 25 000 V.

....

....

....

....

....

.... **[3]**

Most candidates recognised that this is to reduce the energy lost to thermal stores by minimising the current. As with many questions of this type, some candidates struggled to express themselves using comparative words. For example, 'because power is lost' was not a sufficient comparison of the effects of the two voltages.

Misconception

Common misconceptions are:

- the current will flow faster (and reach the train sooner) if 400 kV is used
- 400 kV so that 'it can travel' longer distances
- 400kV because a lot of voltage is lost to the surroundings
- 25 kV cannot transfer as much power

Exemplar 3

At 25 000 V the power is not strong enough so it would take too long to transmit it it gets there at all. Also, 400 000 V is enough to power multiple different train lines.

This candidate confused power with voltage. They also had a misconception that less power takes more time to transmit.

Question 7 (a) (iii)

(iii) Each train runs from its own parallel loop of the circuit. One train draws a current of 200 A.

Calculate the maximum number of trains that could operate from this circuit.

Number of trains = ... **[2]**

Most candidates selected the appropriate current (1600 A) from the secondary circuit and divided it by the 200 A per train in each parallel branch. A common error was to divide the voltage of the secondary circuit by 200 A.

Some candidates used their incorrect value from 7 (a) (i) – 25 600 A. There was no ECF for using this value as candidates are informed that trains operate in the 25 kV secondary circuit.

Question 7 (b) (i)

(b) Houses in the UK are supplied with a.c. electricity at a much lower potential difference than electric train power lines.

(i) State the potential difference and frequency of the household a.c. electricity supply in the UK.

Potential difference = ... V

Frequency = ... Hz
[1]

Candidates were unfamiliar with this area of the syllabus.

Assessment for learning

Candidates should have an opportunity to look at the labels on a range of mains electrical appliances. These sometimes specify a range e.g. 220 to 240 V and 50/60 Hz. A socket tester (~ £15) also displays mains voltage and frequency.

Question 7 (b) (ii)

(ii) Laptops need a d.c. (direct current) electrical power supply.

Describe the difference between a.c. and d.c. electricity.

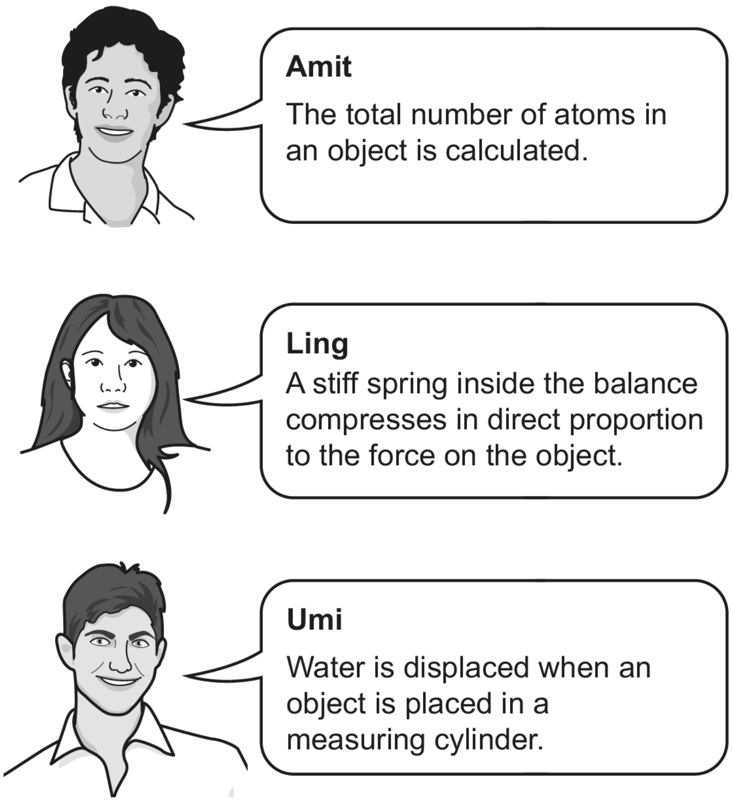
....

.... **[1]**

Many candidates were unable to give a clear distinction between a.c. and d.c. Descriptions of a.c. were often too vague to gain credit, e.g. 'a.c. can travel in different directions'. Candidates need to be clear that in a.c., current changes direction or alternates from positive to negative.

Question 8 (a)

8 (a) Three students are talking about weight.



Who is describing how weight can be measured?

.... **[1]**

Most candidates correctly selected Ling.

Question 8 (b)

(b) Amit has a ball. The weight of the ball is 5.2 N.

Calculate the mass of the ball.

Gravitational field strength = 10 N / kg

Use the Equation Sheet.

Mass = ... kg **[3]**

Most candidates correctly calculated 0.52. A common error is 52 kg. Candidates should also consider what the realistic mass of a ball is when recording the result of their calculation.

Question 8 (c)

(c) Amit kicks a ball which has a weight of 5.2 N into the air. It reaches a maximum vertical distance of 10 m and horizontal distance of 20 m.

How can the gravitational potential energy (J) of the ball at its maximum height be calculated?

Use the Equation Sheet to help you.

Tick (✓) **two** boxes.

5.2 × 10 × 10 = 520 Nm	☐
5.2 × 10 = 52 Nm	☐
5.2 × 20 = 104 Nm	☐
kg m is equivalent to J	☐
Nm is equivalent to J	☐
N / m^2 is equivalent to J	☐

[2]

Most candidates gained 1 mark for recognising that Nm is equivalent to J. The most common incorrect response was 5.2 x 10 x 10 = 520 Nm – suggesting that they recognised the form m × g × h but did recognise m × g as being equal to the weight.

Question 9 (a)

9 This question is about atoms.

(a) What is the typical diameter of an atom?

Tick (✓) **one** box.

1×10^{3} m ☐

1×10^{-3} m ☐

1×10^{-6} m ☐

1×10^{-10} m ☐

[1]

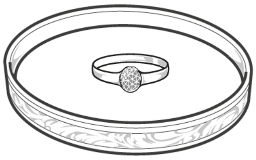
Most candidates correctly ticked the fourth box. The common incorrect response was the third box.

Question 9 (b)

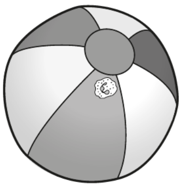
(b) Which example gives the best estimate for the ratio of the relative diameters of the atom and its nucleus?

The values in brackets are estimates for the diameters of the objects.

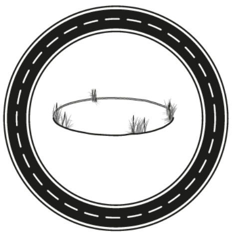
Tick (✓) **one** box.



Bracelet (10 cm) and ring (2 cm) ☐



Beachball (0.5 m) and white blood cell (1.2×10^{-5} m) ☐



Racetrack (200 m) and pond (2 m) ☐

[1]

Most candidates correctly ticked the second box. The common incorrect response was the third box.

Question 9 (c)

(c) Ideas about the model of the atom have developed over the last 200 years.

Write the numbers **2**, **3** and **4** to show the correct historical order.

The earliest idea has been labelled as 1.

Tiny nucleus with the negative charges in different energy levels around it	....
Negative charges in a ball of positive charge	....
Spherical atom, the same all the way through	1
Tiny nucleus containing almost all the mass and all the positive charge	....

[1]

Most candidates identified the correct sequence of ideas. The common error was to place energy levels earlier in the sequence than the massive, positively charged nucleus.

Question 10 (a) (i)

10 Some atoms have unstable nuclei.

An unstable sulfur nucleus changes into a chlorine nucleus by beta decay.

(a) **(i)** Complete the balanced nuclear equation.

$$ {}^{35}_{16}\mathrm{S} \rightarrow {}^{35}_{\square}\mathrm{C}l + {}^{\square}_{\square}\mathrm{e} $$

[2]

The highest achieving candidates generally had no problems with this nuclear equation. Misconceptions arose when candidates misapplied the electron charge to obtain 15 protons in chlorine. Candidates who did not recall the notation for the beta particle produced a range of imaginative responses.

Assessment for learning

Candidates need to recall the nuclear notation for alpha-particles ${}^{4}_{2}\alpha$ and beta particles ${}^{0}_{-1}\beta$. Once these are committed to memory, nuclear equations are relatively straightforward.

Question 10 (a) (ii)

(ii) Compare and contrast the composition of the sulfur and chlorine nuclei to explain where the beta particle has come from.

....

....

....

....

....

.... **[3]**

Candidates who followed the rubric instruction described the composition of the nuclei in terms of protons and neutrons rather than 'mass number' and 'atomic number'. They determined that the sum of n + p is 35 for both, but chlorine has one more proton. The most successful responses were able to deduce the change that caused this. Only this third marking point was inaccessible (in theory) to candidates who gave the incorrect proton number of chlorine in (a) (i).

Misconception

A common misconception is that the beta particle has come from the outer shell of the sulphur atom and has been donated to the chlorine atom in order to complete its outer shell. This is also a rubric error as the stem refers to the nuclei of the atoms.

Another misconception is that the mass number does not change because the emitted electron has no or negligible mass.

Question 10 (b) (i)

(b) The masses of 16 chlorine atoms are shown in the table.

Atom	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nuclear mass	35	35	35	37	35	37	37	37	35	35	35	35	37	35	35	35

(i) Explain how chlorine nuclei can have differing nuclear masses.

....

....

....

.... **[2]**

Most candidates recognised that chlorine has different isotopes and/or atoms with differing numbers of neutrons. More successful responses made both of these points and also referred to the same proton number.

Question 10 (b) (ii)

(ii) Calculate the **mean** nuclear mass.

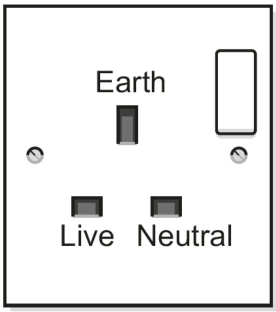
Mean nuclear mass = ... **[2]**

Almost all candidates gained both of these marks.

Question 11 (a)

11 (a) **Fig. 11.1** shows a UK 3-pin plug socket.

Fig. 11.1



Complete the table by:

- writing **live**, **neutral** and **earth** in the Pin column next to their correct functions
- writing the potential difference (p.d.) compared to earth for each pin.

Function	Pin	p.d. compared to earth (V)
Returns current to the supply	....	....
Safety	....	0
Conducts current from the supply	....	....

[2]

Most candidates correctly labelled the pin with the correct word. The common error was to put neutral and earth in the wrong order. The second column, however, proved inaccessible to most candidates. As noted previously (7 (b) (i)), candidates are unfamiliar with this area of the syllabus.

Common errors

Common errors included:

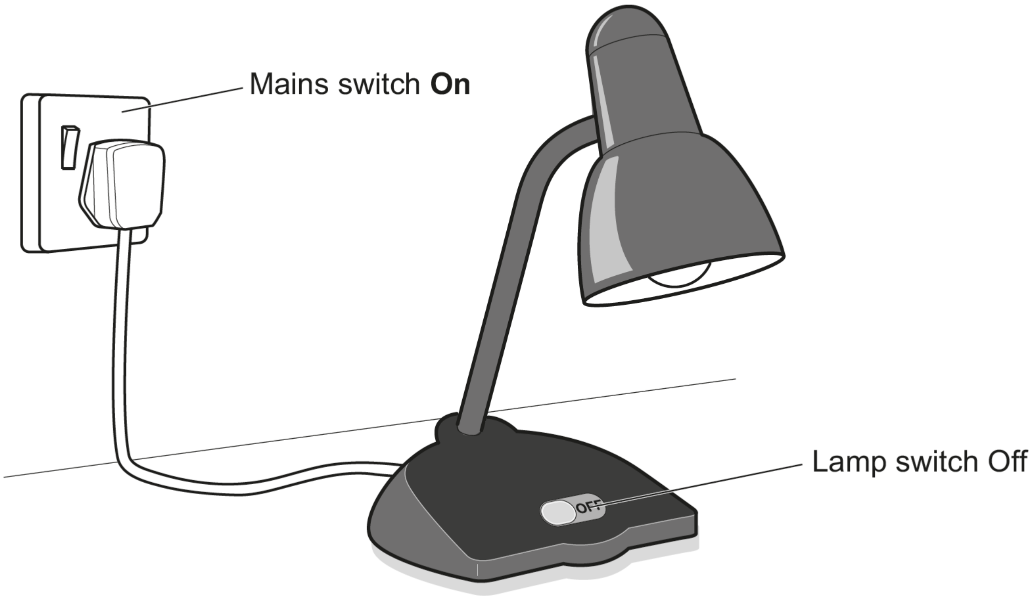
- the relative p.d. of the live is 1 and the neutral is -1.
- the p.d. of the neutral is also 230 or has the same p.d. as the live e.g. 1 and 1.

Question 11 (b)

(b) **Fig. 11.2** shows a broken desk light plugged into the wall, with the lamp switch off.

Inside the light, the live wire is touching the metal case.

Fig. 11.2



Explain why a person can get a shock if they touch the metal case, even though the lamp switch is off.

....

....

....

.... **[2]**

Candidates are unfamiliar with this area of the syllabus. Only a handful of the highest achieving candidates gained both marks. Candidates who gained one of the marks usually did so for an understanding that an electric shock occurs when a person provides a pathway for the current from the appliance to the ground or to earth. Very few candidates were able to express simply that the casing of the appliance is 'live' or 'at 230 V' or 'at mains/high voltage'.

Candidates also stated that the shock is due to touching the metal case. This is stated in the rubric.

Misconception

?

Common misconceptions:

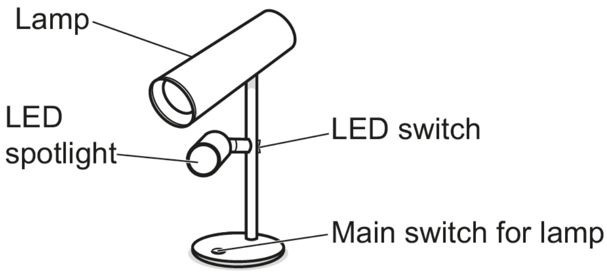
- the voltage is 'travelling' or 'flowing' through the metal case
- the current is 'flowing' in the metal case
- the current has nowhere to go so builds up in the metal case
- electricity is in the metal case

Guidance: The scenario is similar to a circuit with an open switch. Current is not possible as the circuit is incomplete. A shock is possible because the p.d. is very high. Cells with low p.d. cannot give the experience of a shock.

Question 11 (c) (i)

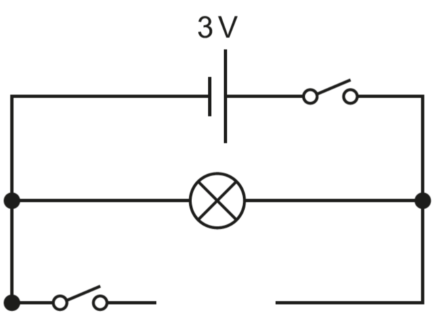
(c) **Fig. 11.3** shows a different desk light that runs on batteries. It has a lamp and an additional LED spotlight that can be switched on and off.

Fig. 11.3



(i) Complete the circuit diagram in **Fig. 11.4** by drawing the LED (light emitting diode) symbol in the gap.

Fig. 11.4



[1]

Only a handful of candidates recalled the correct circuit symbol. Some of these candidates also drew it in the correct orientation for the cell. The 'convention' here is that current is from the positive (right hand terminal of the cell) to the negative and must therefore be in a clockwise direction in the circuit. The LED must be orientated 'pointing' to the left.

Assessment for learning

Candidates should be given an opportunity to construct a simple circuit with an LED. It may be helpful to show an LED that has not been soldered into a mounting block, to show that the LED has two wires (anode (+) and cathode (-))and one wire is slightly longer (anode). The LED only lights up when the anode is connected to the positive terminal of the cell or battery which, by convention, is (also) the longer line in the cell symbol.

Question 11 (c) (ii)

(ii) When the lamp is switched on, a current of 0.015 A flows through it.

Calculate the charge that flows through the lamp in 50 minutes.

Use the equation: charge = current × time

Charge = ... C **[3]**

Many candidates calculated the correct values of 45 C. A common error, generally by the candidates who scored fewer marks overall, was to omit the conversion of 50 minutes to 3000 seconds.

Question 11 (c) (iii)

(iii) The LED has a resistance of 50 Ω.

Calculate the **total** current flowing through the cell when both switches are closed.

Use the equation: potential difference = current × resistance

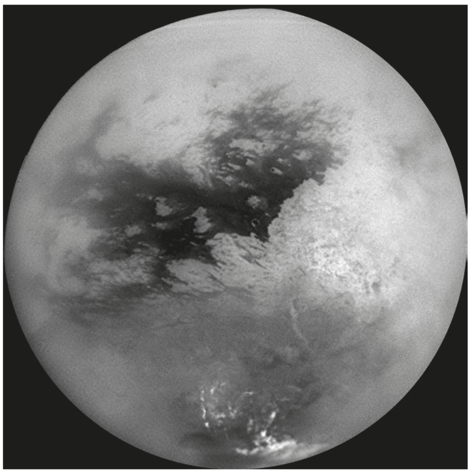
Current = ... A **[3]**

Most candidates located the p.d. of the circuit in the circuit diagram. They used this in the rearranged equation I = V÷R where R = 50 to calculate 0.06 A. More successful candidates recognised from the emboldened **'total'** that the current in the lamp branch must be added, and they located the value of this current in part (ii) of this connected question sequence.

Question 12 (a)

12 This question is about methane on the surface of Saturn's largest moon, Titan.

Methane is found as a solid, liquid, and a gas on Titan.



(a) The table shows the densities of methane as a solid, liquid and a gas at –182 °C, and 150 kPa, the typical conditions on the surface of Titan.

Density of methane (g / cm^3)		
Solid	Liquid	Gas
0.45	0.42	7.2×10^{-4}

Explain why the density of solid and liquid methane are similar.

Use the particle model in your answer.

....

....

....

.... **[2]**

Many candidates struggled to express clearly that particles in solids and liquids are in contact with each other. However this was the idea that generally gained credit. A few candidates recognised that this also made them incompressible and gained a second mark. Only the highest scoring candidates recognise that since it is the same compound but in a solid and a liquid state, then the number of particles in 1 cm^3 will also be similar.

Question 12 (b) (i)

(b) A 100 g puddle of liquid methane evaporates on Titan.

(i) What mass of methane gas has been added to the atmosphere on Titan?

Explain your answer using the particle model.

....

....

....

.... **[2]**

Most candidates stated correctly that 100 g of gas methane is added to the atmosphere. Weaker responses were generally unable to explain why in terms of particles. A common error was to assume that a calculation was needed. Candidates used the density of the gas given in the table and divided 100 g by this value. This is a rubric error; when a calculation is required, the command word 'calculate' is used.

Question 12 (b) (ii)

(ii) A different puddle of liquid methane freezes.

- The mass of the puddle is 90 g.
- The volume of the puddle when it is solid is 200 cm^3.

Calculate the change in volume of the puddle as it freezes.

Give your answer to **2** significant figures.

Use the table and the Equation Sheet.

Change in volume = ... cm^3 **[4]**

Most candidates were able to calculate the volume of a 90 g mass of liquid methane using the density value (0.42) given in the table. The change in volume is determined by subtracting the volume of the solid. Some candidates lost 1 mark for not converting their response to 2 s.f., and some converted to 2 s.f. at the liquid volume step in the calculation. Candidates who did not correctly apply the rearranged formula still gained credit for recording or converting 2 s.f. values shown in working on to the answer line.

Question 12 (c)

(c) Explain how the volume and pressure of methane in a container changes when it has been compressed.

The temperature of the methane remains constant.

....

....

....

.... **[2]**

Most candidates did not score any marks on this question. A few gained 1 mark. To gain credit here, candidates needed to relate the decreased volume with decreased distance between the molecules of methane. At the same marking point, they also needed to describe the increased rate of collisions *with the walls* of the container. Few were able to do this. For 'explain how' questions, candidates should be aware that responses such as 'the volume goes down and the pressure goes up' are unlikely to be given credit. For the second marking point, many candidates referred simply to increased pressure. This was not sufficient. Candidates needed to refer to the increased *outward* pressure or give a clear idea that the increased pressure is exerted by the particles on the walls.

Assessment for learning

Candidates can investigate the freely available applet 'Gas Properties' from PhET Interactive Simulations. In the Ideal Gas simulation, they can control volume, temperature and particle density while measuring the effect on pressure.

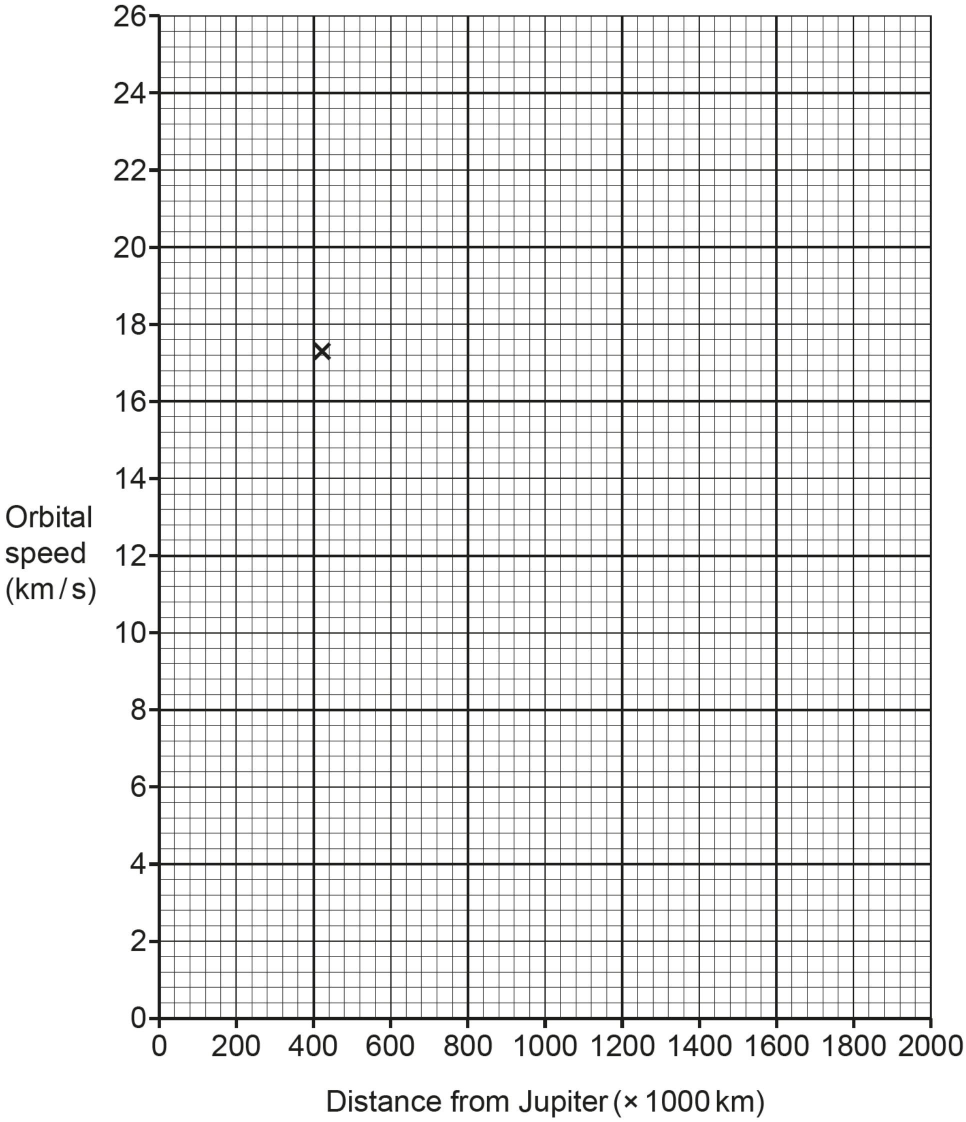
Question 13 (a) (i)

13 This question is about the motions of objects in the solar system.

(a) **(i)** The table shows data about four moons of Jupiter.

Moon Name	**Distance from Jupiter (× 1000 km)**	**Orbital speed (km/s)**
Thebe	222	23.9
Io	420	17.3
Europa	670	13.7
Callisto	1880	8.2

- Plot the data on the axes. One point has been plotted for you.
- Draw a line of best fit.



[2]

Most candidates were able to plot the three points with precision. Lack of precision with just one point cost many candidates a mark. Many candidates drew straight lines through points that should have been connected by a curve. Some candidates seemed unaware of the accepted convention for best fit lines. They should be encouraged to draw a single line, as smoothly as possible, with an even distribution of points above and below the line.

Assessment for learning

There is excellent guidance for teachers in the Language of Maths in Science (ASE). Specifically, on p31:

When pupils draw a line of best fit in mathematics, it is more likely to be for the type of data shown in Figure 3.10 (a 'scatter graph') rather than for that shown in Figure 3.9, and the fitted line would be straight. In science lessons, pupils are expected to judge whether a line of fit should be straight or curved.

Question 13 (a) (ii)

(ii) Another moon called Ganymede orbits 1 070 000 km from Jupiter.

Predict the orbital speed of Ganymede.

Use the graph.

Orbital speed = ... km/s **[1]**

Most candidates interpolated a value within an acceptable range from either a curve or a straight line of best fit.

Common errors

Some candidates quoted orbital speeds that were interpolated from distances on the x-axis.

Some candidates quoted orbital speeds that were higher than 13.7 (against the trend) or with negligible decrease (>13) compared with the trend in the raw data in the table.

Question 13 (a) (iii)

(iii) Describe the relationship shown by the graph.

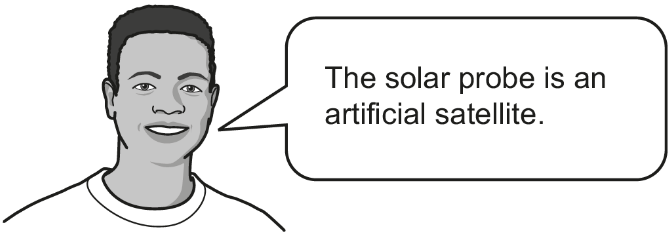
....

.... **[1]**

The 'graph' in this context is the plotted points (objective) rather than the best fit line (subjective). Many candidates who described the trend of a straight line – greater distance, lower speed – did not gain credit. However, many candidates who correctly drew curves with decreasing gradients were unable to describe how the change in speed became much smaller for the same increase in distance.

Question 13 (b) (i)

(b) (i) Scientists have sent a solar probe to the Sun to collect data on its activity.
Leo says:



What is an artificial satellite?

....

.... **[1]**

Most candidates recognised that 'artificial' means made by humans. Many candidates also recognised that a satellite has an orbit. Many candidates should have completed their response by suggesting an object (e.g. Earth) that the satellite orbits.

Question 13 (b) (ii)

(ii) The solar probe will reach a speed of 190 km/s, with a momentum of 9.5×10^6 kg m/s.

Calculate the mass of the solar probe.

Use the Equation Sheet.

Mass = ... kg **[4]**

Many candidates selected the correct equation for momentum and calculated a mass of 50 kg. Common errors were either not converting the speed to m/s or converting incorrectly. Incorrect substitutions, conversions and use of standard form resulted in some implausible values, e.g. 20 trillion kg or 2 millionths of a kilogram.

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