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<td></td>
</tr>
<tr>
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Introduction

These exemplar answers have been chosen from the summer 2018 examination series.

OCR is open to a wide variety of approaches and all answers are considered on their merits. These exemplars, therefore, should not be seen as the only way to answer questions but do illustrate how the mark scheme has been applied.

Please always refer to the specification http://www.ocr.org.uk/qualifications/gcse/gcse-twenty-first-century-science-suite-physics-b-j259-from-2016/ for full details of the assessment for this qualification. These exemplar answers should also be read in conjunction with the sample assessment materials and the June 2018 Examiners’ report or Report to Centres available from Interchange http://interchange.ocr.org.uk/Home.mvc/Index

The question paper, mark scheme and any resource booklet(s) will be available on the OCR website from summer 2019. Until then, they are available on OCR Interchange (school exams officers will have a login for this and are able to set up teachers with specific logins – see the following link for further information http://www.ocr.org.uk/administration/support-and-tools/interchange/managing-user-accounts/).

It is important to note that approaches to question setting and marking will remain consistent. At the same time OCR reviews all its qualifications annually and may make small adjustments to improve the performance of its assessments. We will let you know of any substantive changes.
Question 1(a)

1 Nina is writing a report about the Solar System. 
She has written an introduction.

The planets in our Solar System all move around the Sun. 
They orbit in perfect circles and in the same direction. 
Each planet has at least one moon orbiting it. 
The planets and their moons are all made of rock.

Exemplar 1  
2 marks

(a) Identify two mistakes in Nina’s introduction.

1. The orbits of planets are not perfect circles. — they are elliptical.
2. Not all planets are made of rock — some are made of gas (gas giants) further out. [2]

Examiner commentary
To gain marks on this foundation/higher tier overlap question it was sufficient for the candidate to identify the mistakes in the text. This candidate has provided a more thorough answer by identifying two of the mistakes and explaining why they are incorrect.
**Question 1(b)**

**Exemplar 1**

2 marks

(b) Nina wants to include a section about how the Solar System was formed.

Describe how the Solar System was formed.

Dust and gas particles attracted to one another because of gravity and as they became denser in the centre, the gas compressed, temperatures increased until a nuclear fusion reaction formed the sun and left over gas clouds formed planets.

**Examiner commentary**

The mechanism of formation is described by the second line of this response. The candidate has used the extra space to differentiate between the formation of the sun and the planets.

**Exemplar 2**

0 marks

(b) Nina wants to include a section about how the Solar System was formed.

Describe how the Solar System was formed.

The big bang and planets formed by the sun releasing energy for the planets to move and orbit.

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

**Examiner commentary**

Many candidates have similar misconceptions about the Big Bang as the mechanism for creating the matter (gas and dust) for star formation.
Exemplar 1

(c) Nina researches how the Sun releases energy. She finds this information in a textbook.

![Image](https://via.placeholder.com/150)

Explain why nuclear fusion causes the mass of the Sun to decrease.

...when ... hydrogen nuclei fuse, some ... mass is ... energy, so the Sun ... mass... [1]

Examiner commentary

The candidate gives a basic explanation of mass loss in nuclear fusion. Other candidates who gained marks on this question used $E = mc^2$ as part of their explanation.

Exemplar 2

(c) Nina researches how the Sun releases energy. She finds this information in a textbook.

![Image](https://via.placeholder.com/150)

Explain why nuclear fusion causes the mass of the Sun to decrease.

...2 hydrogen atoms form one helium atom, but energy from the reaction dissipates to the surroundings so mass is lost in the form of energy... [1]

Examiner commentary

The misconception about the formation of helium can be ignored as it is not relevant to the question. The response may also indicate some confusion with exothermic reactions. However the idea that mass is lost in the form of energy is sufficient to gain the mark.
Question 2(a)

Exemplar 1 1 mark

2. A toothbrush uses a rechargeable battery.

(a) The energy that is stored in the battery comes from a power station.

State how the energy is transferred from the power station to the chemical store in the battery.

Examiner commentary

The candidate has given a thorough answer by stating what is being transferred (electrical energy) and what is doing the transferring (wires). Many candidates only made reference to transformers, the National Grid or cables indicating that the stores and transfers model has not yet replaced the old fashioned nine types of energy model.

Exemplar 2 1 mark

2. A toothbrush uses a rechargeable battery.

(a) The energy that is stored in the battery comes from a power station.

State how the energy is transferred from the power station to the chemical store in the battery.

Examiner commentary

A similar response from another high performing candidate. The question is answered in the first nine words but the candidate is uncertain that they have provided enough information for the mark.
**Question 2(b)(i)**

**Exemplar 1**

3 marks

(b) The potential difference across the battery is 1.2 V.

During a typical use, 360 C of charge moves through the toothbrush motor over a time of 2 minutes.

(i) Calculate the total energy transferred by the toothbrush in one day if it is used two times a day.

\[ \text{power charge} = \text{current} \times \text{time} \]
\[ \text{current} = \frac{\text{charge}}{\text{time}} = \frac{360}{120} = 3 \text{ A} \]
\[ \text{power} = \text{potential difference} \times \text{current} = 1.2 \times 3 = 3.6 \]
\[ \text{energy transferred} = \text{power} \times \text{time} = 3.6 \times (120 \times 2) = 864 \]

Examiner commentary

This candidate shows two methods of calculating the energy transferred. The fourth line of their response is the expected answer using \( E = QV \). In the first three lines, they calculate the value of the current and then substitute this into \( P = VI \) to calculate the power and then \( E = Pt \) for the energy. Both methods are set out very clearly.

**Exemplar 2**

3 marks

(b) The potential difference across the battery is 1.2 V.

During a typical use, 360 C of charge moves through the toothbrush motor over a time of 2 minutes.

(i) Calculate the total energy transferred by the toothbrush in one day if it is used two times a day.

\[ 360 + 360 = 720 \text{ C per day} \]
\[ 720 \times 1.2 = 864 \text{ J} \]

\[ J = V \times C \]

Examiner commentary

This candidate applies the ‘used two times’ information on the first line of their response. The third line of the response indicates that the candidate has an understanding of p.d. as a measure of Joules per Coulomb as they have not used the symbols \( E \) and \( Q \).
Question 2(b)(ii)

**Exemplar 1**

(iii) Calculate the current in the toothbrush when used for 2 minutes each time.

\[ I = \frac{Q}{t} \]

\[ Q = 360 \text{ C} \]

\[ t = 2 \text{ min} = 120 \text{ sec} \]

\[ \frac{360}{120} = 3 \text{ A} \]

Current = \[
\]


**Examiner commentary**

The candidate understands the convention of examination questions in the form b(i) and b(ii). They have referred back to the stem of part (b) to find 360 C and shown the unit conversion and substitution clearly.

**Exemplar 2**

(iii) Calculate the current in the toothbrush when used for 2 minutes each time.

\[ \frac{360}{2} = 180 \]

Current = \[
\]


**Examiner commentary**

The substitution is evidence for the rearranged equation. The candidate has made a single error in omitting to convert minutes to seconds.
Exemplar 1 2 marks

(a) Show that more than 700 000 J of energy is needed to heat the oil from 20°C to 120°C.

Use the equation:
change in internal energy = mass × specific heat capacity × change in temperature

\[ 4.5 \times 1600 \times 100 = 720,000 \text{ J} \]

Therefore more than 700,000 J are needed.

Examiner commentary
The candidate extracted data about the mass and specific heat capacity of oil from a table. They have substituted this data in the same sequence as the equation.
Examiner commentary

The candidate has recalled the relationship between energy, time and power and rearranged the equation to make time the subject. They have extracted data about the power of the heater (1500W) from the same data table used in part (a).
Examiner commentary

Few candidates appreciated that the energy supplied to heat the oil (calculated in part (a)) would also transfer to the metal parts of the radiator or to the surrounding air during heating. Perhaps many did not make the distinction between the time to heat the oil calculated in b(i) and the time to heat the heater b(ii). While it is correct that energy transfers are rarely 100% efficient the candidate needs to address this specific case. In this regard ‘energy…dissipated as sound’ is a very weak (but just sufficient) explanation.
Question 4(a)

Exemplar 1

4 (a) The maximum speed of a racing car is 320 km/hour.

Calculate this speed in metres per second.

\[
\frac{320 \times 1000}{60} = 320,000 \text{ m/hour} \\
\frac{320,000}{60} = 5333.3 \text{ m/min} \\
\frac{5333.3}{60} = 88.9 \text{ m/s} \\
\]

Maximum speed = 88.9 \text{ m/s} [2]

Examiner commentary

The candidate shows the conversion of km/h to m/s in a logical sequence. Their final answer is rounded appropriately.

Exemplar 2

4 (a) The maximum speed of a racing car is 320 km/hour.

Calculate this speed in metres per second.

\[
\text{speed} = \frac{320 \text{ km}}{1 \text{ hour}} = \frac{320,000 \text{ m}}{3600 \text{ s}} = 88.9 \\
\approx 89 \text{ m/s} \\
\]

Maximum speed = 88.9 \text{ m/s} [2]

Examiner commentary

This candidate shows the alternative approach of converting both units and rounding their answer appropriately.
Question 4(b)(i)

Exemplar 1 3 marks

(b) (i) A different racing car is moving with a speed of 80 m/s.

Before turning a corner, it slows down to a speed of 20 m/s.

While slowing down, it has a constant acceleration of -40 m/s².

Calculate the distance that it travels as it slows down.

\[ v^2 - u^2 = 2 \times a \times s \]

\[ 20^2 - 80^2 = 2 \times (-40) \times s \]

\[ -6000 = -80 \times s \]

\[ s = 75 \text{ m} \]

Examiner commentary

This candidate used the expected method to calculate the distance. They have not attempted to rearrange the equation in terms of the distance travelled ‘s’. But they have substituted values from the stem of the question in the same order as their equation. Many candidates omitted to square 20 and 80 at this stage and others were uncertain how to resolve 2x -40.

Exemplar 2 2 marks

(b) (i) A different racing car is moving with a speed of 80 m/s.

Before turning a corner, it slows down to a speed of 20 m/s.

While slowing down, it has a constant acceleration of -40 m/s².

Calculate the distance that it travels as it slows down.

Acceleration = \( \frac{\text{change in speed}}{\text{time}} \) \[ -40 = \frac{80 - 20}{t} \]

Time = \( \frac{\text{distance}}{\text{speed} \times \text{time}} \) \[ t = \frac{20}{60} = 1.67 \text{ s} \]

Distance travelled = \( 30 \text{ m} \)

Examiner commentary

The candidate has correctly calculated the time taken for this change in speed due to the constant acceleration given. However, in the second part of their calculation using \( s = vt \), they have used the final speed of the car (20 m/s) rather than the average speed (80+20)/2 = 50 m/s. Their method is essentially correct so the candidate gains 2 marks credit for a correct application, although their final answer was incorrect. It is always important to set down workings to minimise losing marks if the marker is unable to see the method used by the candidate.
Question 4(b)(ii)

Exemplar 1

(ii) The car moves at a constant speed around the corner.

Explain why its velocity is changing as it moves around the corner.

...velocity is a vector... so has magnitude and direction... 
...the car is moving in a different direction as it goes round the corner... so only some of its movement is in the direction of velocity, so it changes... [2]

Examiner commentary

The candidate gives a clear definition of velocity and explains why it is changing using the information about the movement of the car given in the stem of the question.
**Question 5(a)**

5    Eve and Amir make a toy telephone out of plastic cups and string.

![String Telephone Diagram](image)

*Sound waves in the air change when they become sound waves in the string.*

**Exemplar 1**  

2 marks

(a) How do the **speed**, **frequency** and **wavelength** of the sound waves change when they leave the air and enter the string?

Put one tick (√) in each row. One has been done for you.

<table>
<thead>
<tr>
<th></th>
<th>Increase</th>
<th>Decrease</th>
<th>Stay the same</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>√</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency</td>
<td></td>
<td></td>
<td>√</td>
</tr>
<tr>
<td>Wavelength</td>
<td>√</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[ \nu = \frac{p \times \lambda}{2} \]

\[ 2 = 2 \times 1 \]

\[ 4 = 2 \times 2 \]

\[ 8 = 2 \times 4 \]

**Examiner commentary**

The stem of this question has a diagram showing a student speaking into a string telephone. The candidate has applied knowledge that the voice will sound the same so the frequency will not change. The candidate has written out the wave equation to determine what happens to the wavelength.
**Question 5(b)**

**Exemplar 1**

3 marks

(b) The speed of sound in the string is 600 m/s.

Calculate the frequency of a sound with wavelength 1.2 m in the string.

\[ f = \frac{v}{\lambda} \]

\[ f = \frac{600}{1.2} \]

\[ f = 500 \text{ Hz} \]

**Examiner commentary**

The candidate has recalled, rearranged and substituted values into the wave equation. They have used the space provided to show the sequence of their calculation. Although it is the convention to award all marks for the correct final answer, this approach ensures that all marking points are met in case of any accidental mis-keying of the calculator.
Question 6(a)

James and Mia investigate their hearing.

James uses an app on his phone to make sounds with different frequencies. For each frequency, he starts with the volume on his phone set at zero. Then he turns the volume up step by step until Mia can just hear the sound. The results show the volume setting needed before Mia can hear the noise for each frequency.

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>Volume setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>13</td>
</tr>
<tr>
<td>110</td>
<td>11</td>
</tr>
<tr>
<td>220</td>
<td>7</td>
</tr>
<tr>
<td>440</td>
<td>1</td>
</tr>
<tr>
<td>880</td>
<td>1</td>
</tr>
<tr>
<td>1760</td>
<td>1</td>
</tr>
</tbody>
</table>

Exemplar 1

(a) Explain why Mia finds it easier to hear some of these frequencies.

Some frequencies make the ossicles, tiny bones in the ear, vibrate. Mia can hear frequencies easier that fall within a suitable range that her bones can vibrate within. As ossicles are tiny bones, many of them can vibrate.

(b) They repeat the experiment.

This time there is a wall between the phone and Mia. They want to see what effect the wall has on the results.

Examiner commentary

The candidate has circled the command word 'explain' and has underlined two parts of the question stem that need to be addressed in their answer. In the first sentence they explain how we hear frequencies. Their spelling of ossicles is incorrect but would probably have gained credit even without the reference to tiny bones. In the second sentence they explain that only the frequencies that are within a suitable range cause these bones to vibrate and so can be heard more easily. Few candidates scored marks on this question and of the ones that did, most recognised that our sensitivity to sound varied within a fixed range of frequencies. Very few recognised that the mechanism of this sensitivity was due to the action of the ear bones.
Question 6(b)(i)

(b) They repeat the experiment. 

This time there is a wall between the phone and Mia. They want to see what effect the wall has on the results.

Exemplar 1 1 mark

(i) Suggest one variable that should be controlled to make this new experiment a fair comparison with the first experiment.

...the distance between her and the phone... should stay the same... [1]

Examiner commentary

The experiment described in part (a) is repeated with a wall between the phone and the listener. This candidate has identified the distance between them as a correct variable to be controlled. Many candidates incorrectly gave the distance between the wall and the listener. However, candidates who suggested variables such as distance, frequency and time to listen were identifying continuous variables. Discrete variables such as 'the phone' or 'the app' were ignored as too vague or insufficient to gain credit.
Question 6(b)(ii)

Exemplar 1

(ii) The volume setting needed for each frequency is higher in the new experiment.

Describe how the sound waves reach Mia and why they sound more faint.

The sound waves are emitted by the phone speaker, transmitted through the air, reflected and transmitted through the wall, and absorbed by Mia’s ear. They sound more faint as the wall is more dense than air so absorbs some of the vibrations. It reaches the ear with less energy and amplitude.

Examiner commentary

The candidate has answered the question in the same sequence as the instruction. In the first sentence they give a detailed description of transmission to Mia. In the second sentence they explain the faintness of the sound in terms of energy loss due to absorption.

Exemplar 2

(ii) The volume setting needed for each frequency is higher in the new experiment.

Describe how the sound waves reach Mia and why they sound more faint.

In solids, sound waves move faster and the wavelength becomes longer; however, the sound is more muffled so harder for Mia to hear. This is because longitudinal waves travel by particles moving through the material to carry the frequency and their are more solids in the wall than the air.

Examiner commentary

The candidate gains credit for the implication that sound travels as a longitudinal wave in the wall – but it isn’t clear that this is where the waves are until the end of the second sentence. ‘Particles moving’ is insufficient for the idea of particle vibrations. Stating that the sound is ‘more muffled’ is simply another form of words for ‘more faint’.
Exemplar 1

Question 6(c)

2 marks

Exemplar Candidate Work

(c) Mia reads on the internet that the human ear is most sensitive at a frequency about 2000 Hz. Describe how James and Mie could improve their experiment to test this hypothesis.

- They should test more frequencies, including those above 2000 Hz and frequencies above this.
- They should use a device with more volume settings to be able to better distinguish between close results, like the bottom 3 of the table.
- They should repeat it with many people, not just 30.
- They should have their intervals between measured frequencies be constant.

Examiner commentary

Candidates scored one or two marks on this question. The mark credited for the first bullet point of this response was most commonly seen. Candidates who did not refer to measuring frequencies above 2000 Hz narrowly missed this mark. For the second bullet point here, 'more volume settings' on its own is not sufficient as it is not clear whether this means a wider range (incorrect) or more settings within the range (correct). However the qualifying remark 'to better distinguish between close results' gives sufficient idea of more sensitivity to gain this mark. The fourth bullet point almost gains the third mark. The data table showed frequencies doubling with each measurement. Constant intervals addresses this point but would not work if the constant intervals were too large. Many candidates also expressed a form of the third bullet point shown here. However the reason this did not gain credit is due to the premise that this is a flawed experiment and that repeating it with a wider population will not improve it.
**Question 7(a)**


He pushes a magnet quickly into a coil of wire. He uses an ammeter to record the biggest current produced in the coil.

He repeats the experiment for coils with different numbers of turns.

Table 7.1 shows his results.

<table>
<thead>
<tr>
<th>Number of turns</th>
<th>Current (mA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>1.1</td>
</tr>
<tr>
<td>400</td>
<td>3.0</td>
</tr>
<tr>
<td>600</td>
<td>5.4</td>
</tr>
<tr>
<td>800</td>
<td>6.7</td>
</tr>
<tr>
<td>1000</td>
<td>9.1</td>
</tr>
<tr>
<td>1200</td>
<td>11.0</td>
</tr>
</tbody>
</table>

Table 7.1

**Exemplar 1**

2 marks

(a) Explain why a current is produced in the coil.

As the magnet moves, the wire feels experiences a charge in magnetic field. This induces voltage, which drives a current.

Examiner commentary

Both parts of the explanation are expressed clearly and succinctly in this response. Few candidates were able to make the link between movement and changing magnetic field. A common error was to refer to the induction of current rather than voltage.
Question 7(b)(i) & 7(b)(ii)

Exemplar 1

Part (b)(i) 2 marks, part (b)(ii) 1 mark

Examiner commentary

The candidate has plotted crosses with sufficient precision and a line of best fit that has two points on the line, two slightly above and two slightly below. The line below 200 turns was ignored due to insufficient data in the table. The candidate has clearly used a ruler and sharp pencil. The candidate has followed the rubric and shown on the graph how they determined the current at 700 turns.
Exemplar 1

1 mark

Question 7(b)(iii)

(iii) Amaya says that this experiment is not valid because the speed of the magnet may be different each time. Suggest how Ali could control the speed of the magnet. Use a machine to insert the magnet at the same speed. [1]

Examiner commentary

The candidate has referred back to the stem of the question to the description of Ali pushing the magnet quickly into the coil. They have built on this description to suggest a relevant improvement to this method.
Question 7(c)
Exemplar 1 1 mark

Examiner commentary
Few candidates gained both marks for this question. There are two magnetic fields around the wire. One is due to the magnet, which the candidate identifies on the third line of their response. The other is the magnetic field caused by the current in the wire, identified in the first sentence. However, in common with many other candidates who got this close but no further, they have not been able to apply knowledge of like poles to explain why these two fields have a repulsive force between them.
Exemplar Candidate Work

Question 8(a)

Table 8.1 shows data for four radioactive isotopes.

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Half life</th>
<th>Type of decay</th>
</tr>
</thead>
<tbody>
<tr>
<td>molybdenum-98</td>
<td>stable</td>
<td></td>
</tr>
<tr>
<td>molybdenum-99</td>
<td>66 hours</td>
<td>beta</td>
</tr>
<tr>
<td>technetium-99m</td>
<td>6 hours</td>
<td>gamma</td>
</tr>
<tr>
<td>thallium-201</td>
<td>73 hours</td>
<td>gamma</td>
</tr>
</tbody>
</table>

Table 8.1

Technetium-99m is used in hospitals.

Technetium-99m is produced when molybdenum-99 emits beta radiation.

One method of producing molybdenum-99 is by firing neutrons at molybdenum-98.

Exemplar 1

(a) Complete these nuclear equations to show the production of technetium-99m.

\[
^{98}_{42}\text{Mo} + ^{0}_{\phantom{0}0}\text{n} \rightarrow ^{99}_{42}\text{Mo}
\]

\[
^{99}_{42}\text{Mo} \rightarrow ^{99}_{43}\text{Tc} + ^{0}_{\phantom{0}1}\text{e}
\]

Examiner commentary

Most candidates gained the first mark as the equation is simply read from left to right. The second equation is more complicated however but this candidate's response shows a common error. The proton number has gone up by one so the candidate must identify e as an electron and the '1' not as an atomic number but as a charge compared to the charge on a proton (-1).
Question 8(b)

Exemplar 1

2 marks

(b) Molybdenum-99 is produced in nuclear reactors and then transported to hospitals. It may take several days for the molybdenum-99 to be transported. In the hospital molybdenum-99 decays and the technetium-99m is produced as shown in part (a).

Using information from Table 8.1, explain why technetium-99m is not transported directly to hospitals.

Its half-life is very short, only 6 hours compared to molybdenum-99 which is 66 hours. By the time it arrived at the hospital it may have decayed beyond use. It is therefore better that molybdenum-99 decays on the journey so the most possible technetium-99m is produced.

Examiner commentary

The candidate has used the data to make a correct comparison of half-lives. A characteristic of lower ability candidates is that very often they do not make comparisons e.g. ‘the half-life of Tc is 6 hours’ – a response which is insufficient to gain the mark. This candidate struggles to express clearly the idea that due to a journey time much longer than the half-life, there will be no Tc left but is given benefit of doubt (BoD) for ‘beyond use’. Table 8.1 also shows that Tc is a gamma emitter compared with Mo which is a beta emitter. Some candidates gained credit for recognising that this would make Tc more difficult to shield during transportation.
Question 8(c)(i)

Exemplar 1

2 marks

(c) Production of technetium-99m is becoming more expensive. An alternative for many medical procedures is thallium-201.

A patient is injected with a compound containing thallium-201. After 24 hours, 80% of the thallium-201 has not decayed.

A second patient is injected with a compound containing technetium-99m.

(i) Calculate the percentage of technetium-99m remaining after 24 hours.

<table>
<thead>
<tr>
<th>Time (hours)</th>
<th>Percentage Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>50%</td>
</tr>
<tr>
<td>12</td>
<td>25%</td>
</tr>
<tr>
<td>18</td>
<td>12.5%</td>
</tr>
</tbody>
</table>

24 hours = 6.25%

Percentage remaining = ........................................... 6.25% [2]

Examiner commentary

The candidate has used the 6 hour half-life of Tc given in the table and halved 100% every 6 hours until the elapsed time is 24 hours.
Question 8(c)(ii)

Exemplar 1

(ii) A doctor is deciding which radioactive isotope is best to use.

Dr Phillips

Using technetium-99m is safer for the patient than using thallium-201.

Evaluate this statement.

Use the data in Table 8.1 and the information above in your answer.

<table>
<thead>
<tr>
<th>Candidate response</th>
<th>Examiner feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.</td>
</tr>
</tbody>
</table>

Examiner commentary

Candidates who gained marks for this question generally expressed the idea that Tl remains in the body for a longer time. This candidate is one of the few to consider why Tc 'is safer' by explaining the risk associated with exposure to radiation.
Question 9(a)

9. The picture shows a glass of water with a vitamin tablet at the bottom.

The tablet reacts with the water to produce bubbles of carbon dioxide. The tablet stays at the bottom of the glass. The bubbles rise to the top of the glass.

Exemplar 1

(a) Which two of the statements below, taken together, explain why the bubbles rise but the tablet sinks?

Tick (√) two boxes.

- The bubbles are made of gas, but the tablet is solid.
- The material in the tablet is denser than water.
- The tablet is heavier than the bubbles.
- The water pressure at the bottom of the glass is greater than the water pressure at the top.
- Water is denser than the gas in the bubbles.

Examiner commentary

The candidate understands that rising and sinking are due to density differences. They have identified both density statements and used annotations to confirm they are correct.
Question 9(b)

Exemplar 1

2 marks

Examiner commentary

The candidate has applied the information ‘resting on the bottom’ to determine the additional upward force required to balance the 32 mN weight so that the resultant force is zero. They have correctly labelled this upward force. Many candidates drew a downward force labelled ‘gravity’ and their responses also indicated that they were unsure about the term ‘magnitude’.
Question 9(c)(i) & 9(c)(ii)

Exemplar 1

Part (c)(i) 2 marks, part (c)(ii) 1 mark

Examiner commentary

The candidate has applied the equation $P = \rho gh$ to explain that as height $h$ increases, so does the pressure of the liquid $P$. This is a good technique. Equations are most often used to calculate values. This candidate has realised that they can also be used to explain the relationships between variables. In part (ii) the incorrect equation is ignored as it is irrelevant to the question and the idea of greater area gains credit. Many candidates showed misconceptions on this question citing the tablet’s greater mass, weight or density.
Question 10(a)

10 Alex wants to use a thermistor as a temperature sensor.

He sets up the circuit shown below.

Exemplar 1

Examiner commentary
The candidate has sketched in the space to help them recall the thermistor symbol.
Question 10(b)(i)

(b) To investigate the sensitivity of the thermistor, Alex places it in a water bath with a temperature control.

He records the potential difference across $R_1$ for different temperatures set by the water bath. His results are shown in the graph.

![Graph showing the potential difference across $R_1$ vs. temperature]

Exemplar 1 3 marks

(i) Describe and explain the relationship shown in the graph.

The graph shows that as the temperature is increased, the potential difference across $R_2$ increases. The graph also shows the rate of increase is higher at higher temperatures. This is because when the temperature above is higher, the resistance of $R_2$ is lower. It takes up a smaller share of the total...

Examiner commentary

The candidate has followed the sequence of the rubric. Their first point is to describe the graph. Most candidates were able to do this. This candidate has made two further points of explanation. Both of these points make use of the information that the p.d. from the supply (12 V labelled on the circuit diagram) does not change. In consequence the p.d. across $R_2$ must be decreasing which can only be explained by the lower resistance of $R_2$. 
Question 10(b)(ii)

Exemplar 1

1 mark

(ii) Alex plans to use the sensor to monitor temperature in a greenhouse. To find the temperature, Alex will measure the potential difference across $R_1$.

He will then read the temperature off the graph.

Alex
My temperature sensor will be more sensitive at lower temperatures.

Evaluate Alex’s statement using evidence from the graph.

The temperature sensor will be more sensitive at a higher temperature as with each time the temperature and voltage increase, the gradient becomes steeper.

[2]

Examiner commentary

The candidate has made a correct comment about the shape of the graph. They could also have said that the voltage goes up 0.1 V between 10°C and 20°C and by 0.6 V between 80°C and 90°C. This would have gained two marks for comparing the voltage increase due to the same temperature change with low and high values. Of the few candidates who gained marks on this question most recognised that the voltage changes were smaller at low temperatures but did not support this observation with values taken from the graph.
Question 10(c)(i)

Exemplar 1 1 mark

(c) Mr Orton, Alex’s teacher, says that his temperature sensor will not work properly.

(i) What is the name of this type of error?

Examiner commentary

Very few candidates were able to identify the type of error from the description and recall the term 'systematic'. The syllabus requires candidates to be able to identify potential sources of error as being either random or systematic. In general, candidates could only distinguish between errors due to measurement and errors due to the arrangement of apparatus. In this response the candidate gains credit for ‘equipment [sic] error’ as sufficient for the idea that the error is built in to the design of the apparatus.
Question 10(c)(ii)

Exemplar 1

1 mark

(ii) Explain why Mr Orton is correct, and suggest how this problem could be reduced.

Examiner commentary

The candidate recognises that the additional heat of the temperature sensor is due to the current in it. Very few candidates were able to make this connection. Fewer still were able to suggest a method to reduce the problem e.g. reduce the current. This candidate is on the right lines but the method would not work as soon as the circuit was switched on again. Suggesting improvements to practical methods is a skill that candidates are unfamiliar with.
Question 11(a)

Exemplar 1

(b) Calculate the moment of the 1.0 kg mass about the pivot, in units of Nm.

Use the equation: moment of a force = force \times distance (normal to the direction of the force)

gravitational field strength = 10 N/kg

\[ 1 \text{ kg} \times 10 \text{ N/kg} = \text{ weight} = 10 \text{ N} \]

\[ \text{Moment} = 10 \text{ N} \times 0.2 \text{ m} = 2 \text{ N m} \]

Examiner commentary

The candidate recognises that the force in the moment equation is the weight of the 1.0 kg mass and calculates this first. The substitution of values into the moment equation follows the same sequence as the equation on line 2 in the stem of the question. A good method.
Question 11(b)(i) & 11(b)(ii)

(b) Jack predicts where he should put masses on the right-hand side of the seesaw to make it balance.

He then carefully places those masses at points which make the seesaw balance and measures the actual distances to the pivot.

The table shows his results.

<table>
<thead>
<tr>
<th>Mass (g)</th>
<th>Predicted distance to pivot (m)</th>
<th>Measured distance to pivot (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>0.50</td>
<td>0.46</td>
</tr>
<tr>
<td>600</td>
<td>0.33</td>
<td>0.31</td>
</tr>
<tr>
<td>800</td>
<td>0.25</td>
<td>0.23</td>
</tr>
<tr>
<td>1000</td>
<td>0.20</td>
<td>0.19</td>
</tr>
</tbody>
</table>

(i) The measured distances to the pivot are all slightly smaller than the predicted distances to the pivot.

Exemplar 1

Part (b)(i) 1 mark, part (b)(ii) 0 marks

(i) The measured distances to the pivot are all slightly smaller than the predicted distances to the pivot.

Explain why.

The mass of the ruler will affect the moments.

(ii) Suggest one way to improve his experiment to remove this difference.

Make more runs and average the results.

Examiner commentary

The stem of the question shows a metre rule balanced on a pivot. The pivot is placed to the left of the centre of the rule. Very few candidates recognised that the rule would have a clockwise moment due to its own weight. Even fewer candidates were able to suggest an improvement e.g. put the pivot in the centre. The candidate in (i) gains credit for identifying the mass of the rule as a factor. The candidate in (ii) shows a very common response to the prompt to suggest an improvement. This indicates that many candidates are in a mind-set that only allows them to consider that there are flaws in data rather than flaws in the arrangement of apparatus.
Question 12(a)

Exemplar 1

12 Trolley A of mass 5.0 kg moves at a constant speed of 1.6 m/s.

(a) Calculate the momentum of trolley A.

\[ \text{momentum} = \text{mass} \times \text{velocity} \]

\[ 5 \times 1.6 = 8 \]

Momentum = \[8\] \text{kg m/s} [2]

Examiner commentary

The mass and the speed are given to 2 significant figures. Candidates should be encouraged to give their answers to at least this number. In general however, when this skill is tested, candidates will be prompted by the question to give their answer to a suitable number of significant figures.
Exemplar 1

4 marks

(b) Trolley B of mass 2.5 kg heads straight towards the first trolley in the opposite direction at the same speed of 1.6 m/s.

Trolley A of mass 5 kg

The two trolleys collide and stick together.

(i) Show that the velocity of the joined-up trolleys after the collision is about 0.5 m/s.

Conservation of momentum!

Momentum of trolley A = 8 kg m/s

Momentum of trolley B = 2.5 × 1.6 = 4 kg m/s

Overall momentum = 8 - 4 = 12 kg m/s

Velocity = \( \frac{\text{Momentum}}{\text{Mass}} \) = \( \frac{8 - 4}{7.5} \) = 0.53

0.53 = 0.5 (1 s.f.)

Examiner commentary

The candidate gives themselves a clear prompt to apply the principle of the conservation of momentum. The candidate determines the total momentum before the collision (8 + -4 = 4). Recognising that '4' is the momentum after the collision they rearrange the momentum equation to divide 4 by the combined mass of the trolleys.
Question 12(b)(ii)

Exemplar 1

4 marks

(ii) The collision takes a total time of 0.20 s.

Calculate the average force acting on trolley A during the collision.

\[
F_{\text{avg}} = \frac{m \Delta v}{t}
\]

\[
\begin{align*}
F_{\text{avg}} &= \frac{6 \times (0.5 - 1.6)}{0.2} \\
&= -27.5 \text{ N}
\end{align*}
\]

Examiner commentary

The candidate uses the mass of trolley A (5 kg) and calculates its change in momentum by recognising that its speed decreases from 1.6 m/s to 0.5 m/s (the value given in the stem of part (i)). They equate the change in momentum to force x time and rearrange to make F the subject. Some candidates used the equation \( F = ma \). They calculated the acceleration using the change in speed (1.6 – 0.5) and divided this by the time taken (0.2) to get 5.5 m/s\(^2\). Multiplied by the mass of trolley A this also gives 27.5 N.
Question 12(b)(ii)  

Exemplar 2  

3 marks

(ii) The collision takes a total time of 0.20 s.

Calculate the average force acting on trolley A during the collision.

\[
\text{force} = \text{mass} \times \text{acceleration}
\]

\[
40 = 7.5 \times 5.3
\]

\[
\text{acceleration} = \frac{\text{change in velocity}}{\text{time}}
\]

\[
= 1.6 - 0.83 \div 0.2
\]

\[
= 5.3
\]

Average force = ........................................... N [4]

Examiner commentary

This candidate uses \( f = ma \) as described in the previous exemplar. They make a single error by multiplying the acceleration by the combined mass of the two trolleys (7.5 kg) rather than the mass of trolley A (5 kg). The examiner has treated this as an internal error.
Question 13(a) & (b)

The diagram shows part of a loudspeaker. It contains specially-shaped permanent magnets with south poles, $S$, in a ring around the outside and a circular north pole, $N$, in the centre.

In the gap between the shaped magnets there is a circular coil carrying electrical current.

The direction of the magnetic field between the poles is shown as $\rightarrow$.

The magnetic field through the coil has strength 0.40 T.

The coil has circumference 25 mm and has 200 turns. The diagram shows only 3 turns of this coil.

A clockwise current of 0.60 A in the coil produces a force on the coil.
Exemplar 1

(a) What is the direction of the force on the coil?

Tick (√) one box.

- Anti-clockwise
- Clockwise
- Into the page
- Out of the page

Out of the page

(b) Calculate the magnitude of the force acting on the coil.

\[
\text{Force} = \text{magnetic flux density} \times \text{current} \times \text{length of conductor}
\]

\[
0.40 \, \text{T} \times 0.60 \, \text{A} \times \frac{25 \times 200 \, \text{mm}}{500 \, \text{cm}} = 1.2 \, \text{N}
\]

Examiner commentary

The stem of this question shows a current circling around a coil placed inside a circular magnetic field. The direction of the field and the current are indicated to show how they change moving around the circle. The candidate has realised that Fleming’s left hand rule can be applied at any single point to determine the direction of the force on the coil and that it will always be out of the page in this arrangement. This candidate, in common with most others, was also able to select the correct equation from the data sheet. They have methodically set out the equation and substituted the correct values underneath. They have used the information from the stem of the question that there are 200 coils, each with a circumference of 25 mm to calculate the length of the conductor and they have remembered to convert this to metres.
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