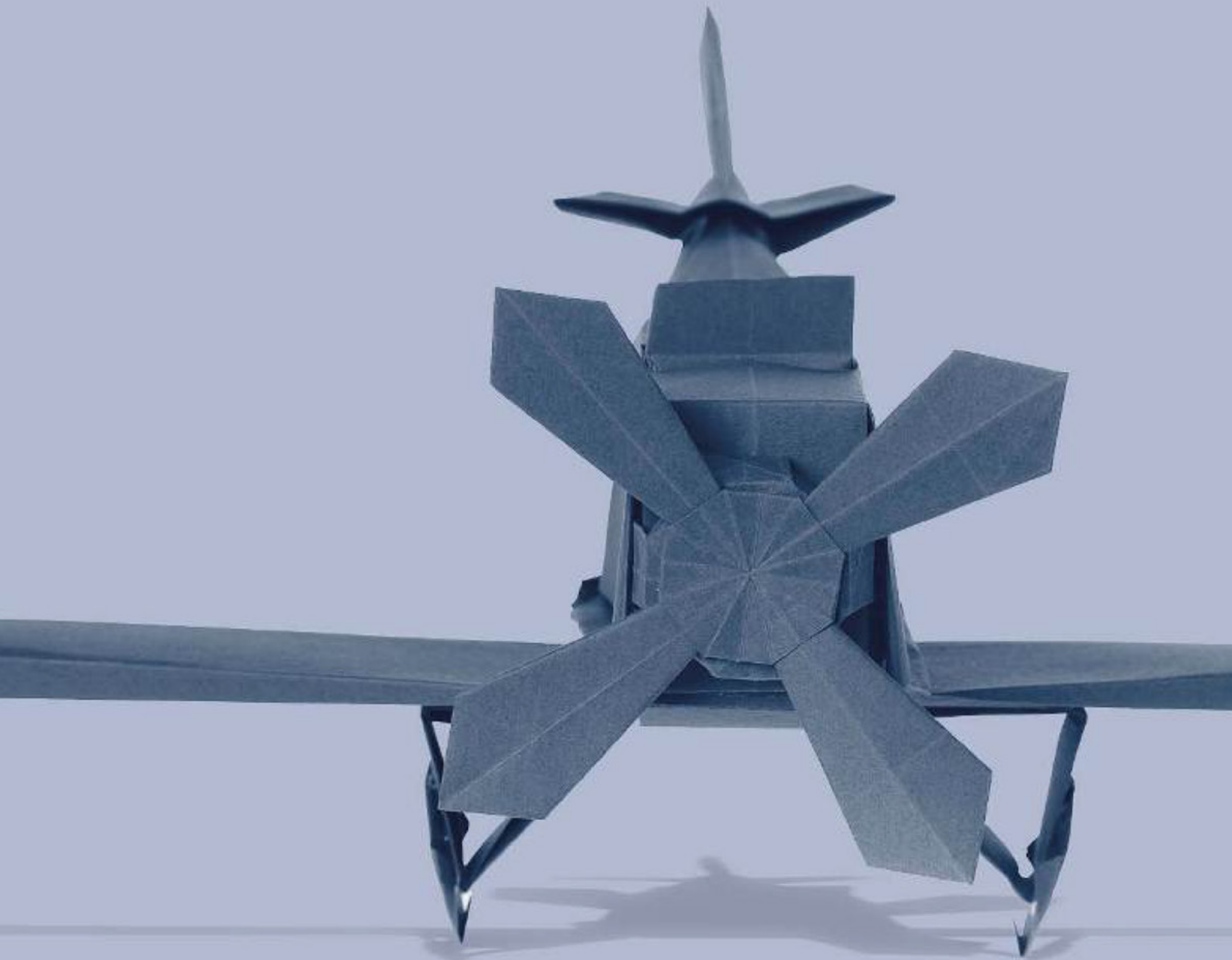
A Level Physics



EXEMPLAR WORK WITH COMMENTARIES

Pearson Edexcel Level 3 Advanced GCE in Physics

A2039_d

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Contents

About this booklet

This booklet has been produced to support physics teachers delivering the new GCE A level Physics specification (first assessment summer 2017).

The booklet looks at questions from the Sample Assessment Materials. It shows real student responses to these questions, and how the examining team follow the mark schemes to demonstrate how the students would be awarded marks on these questions.

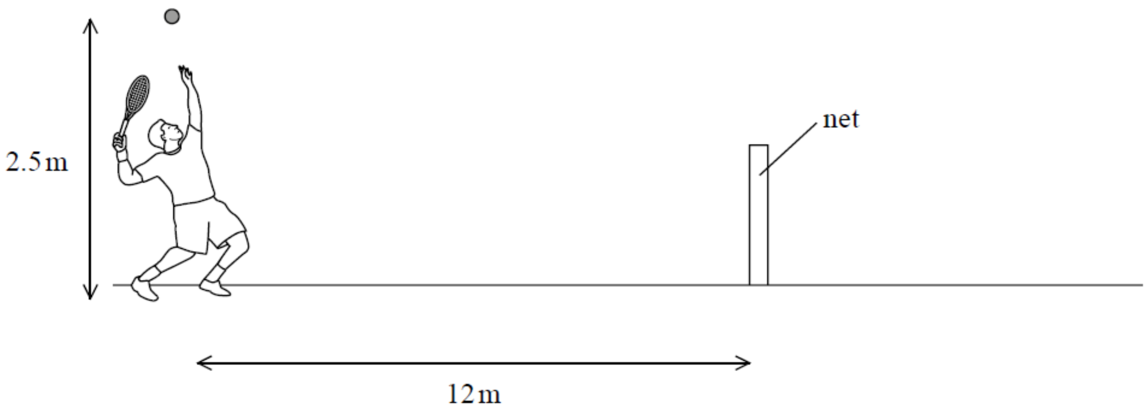
How to use this booklet

Our examining team have selected student responses to 9 questions from the trialling of the Sample Assessment Materials. Following each question you will find the mark scheme for that question and then a range of student responses with accompanying examiner comments on how the mark scheme has been applied and the marks awarded, and on common errors for this sort of question.

Paper 1: Advanced Physics I

Exemplar question 1

A tennis player uses a racket to hit a ball over a net.



The player stands 12 m from the net. He throws the ball vertically upwards and hits the ball at a height of 2.5 m above the ground. The ball leaves the racket **horizontally** with a velocity of 25 m s^{-1}. The ball has a mass of 0.06 kg.

(a) The ball is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

(3)

(b) The ball must land within 6.1 m of the other side of the net.

Determine whether the ball hits the ground within this distance. Support your answer with a calculation. Ignore the height of the net.

(6)

Mark scheme

Question number	Acceptable answers	Additional guidance	Mark
1 (a)	**Either** • Calculate acceleration **(1)** • Use of $F = ma$ **(1)** • F = 38 N **(1)** **OR** • Calculate change in momentum **(1)** • Use of $F = \frac{\Delta mv}{\Delta t}$ **(1)** • F = 38 N **(1)**	Example of calculation: $F = \frac{0.06 \times 25}{0.04} = 37.5$ N	**3**
1 (b)	• Use of $s = ut + \frac{1}{2}at^2$ **(1)** • Use of $s = \frac{1}{2}at^2$ with vertical components to find t **(1)** • Use of $s = ut$ with horizontal components to find s **(1)** • Subtract 12 from their answer for horizontal distance **(1)** • Distance from net = 6 m **(1)** • Makes conclusion whether the ball is within the required range of the net **(1)**	Answer consistent with calculated value. Example of calculation: $t = \sqrt{\frac{2 \times 2.5}{9.81}}$ = 0.714 s $s = 25 \times 0.714 = 17.85$ m Distance from net = 17.85 – 12 = 5.9 m	**6**

Answers to parts a) and b)

Student answer A

(a) The ball is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

(3)

$25 \times 0.06 = 1.5 \text{ kg m s}^{-1}$

$1.5 \div 0.04 = 37.5 \text{ N}$

(b) The ball must land within 6.1 m of the other side of the net.

S	U	V	A	T
2.5	0	~~2~~	9.81	?

Determine whether the ball hits the ground within this distance. Support your answer with a calculation. Ignore the height of the net.

(6)

2.5 m above ground $s = ut + \frac{1}{2}at^2$

$2.5 = \frac{1}{2}(9.81)(t^2)$

$t = \sqrt{\frac{2.5}{4.905}} = 0.714$ seconds to reach ground

$25 \times 0.714 = 17.8 \text{ m}$

$17.8 - 12 = 5.84$ m on the other side of the net. So the ball does indeed hit the ground within this distance.

Examiner comments

a) This is a correct calculation of the average force with a correct unit and so scores the full 3 marks. It would have been a better answer if words had been used, e.g. change in momentum = 2.5 x 0.06………and force = change in momentum/time = 1.5 /0.4 = ….. If students make an arithmetic error and do not explain what they are doing, it can be difficult to award method marks.

b) This is also a correct calculation with the student initially finding the time for the ball to reach the ground. We can tell by the numbers used that the next calculation is finding the horizontal distance travelled by the ball but it would have been useful if the student had actually written that. This type of question, which asks for a conclusion, needs a clear statement from the student. In this case, stating that the 5.84 m is the distance on the other side of the net so that the ball does hit the ground within the distance is sufficient for the last marking point and so this scores the full 6 marks.

Student answer B

(a) The ball is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

(3)

$F = ma$ $m = 0.06$

$a = \frac{25}{0.04}$

$F = 0.06 \times \frac{25}{0.04}$

$F = 37.5N$

Average force = 37.5N

(b) The ball must land within 6.1 m of the other side of the net.

Determine whether the ball hits the ground within this distance. Support your answer with a calculation. Ignore the height of the net.

(6)

$\sqrt{\frac{2s}{a}} = t$ $\cancel{\frac{v-u}{a}} = t$

$t = \sqrt{\frac{2 \times 2.5}{9.81}}$ distance

$t = 0.7139s$ $6.1 + 12m$

$= 18.1m$

$25ms^{-1} \times 0.7139s = 17.85m$

~~It~~ The ball hits the ground within this distance.

Examiner comments

a) Another full 3 mark answer

b) This is a slightly different method for dealing with the distances since it adds the 6.1 m to the 12 m but this is an acceptable alternative and scores the first 5 marks for the calculations. However the lack of words to explain the steps taken makes this script difficult to follow so the last marking point for the conclusion has not been awarded. The first calculation could have referred to the time to reach the ground, the 18.2 m could have been identified as the maximum possible distance that the ball can travel and the last calculation as the distance it actually travels.

Student answer C

(a) The ball is in contact with the racket for 0.04 s.

Calculate the average force on the ball.

(3)

$$\frac{0.06125 - 0}{0.04} = 37.5\text{N}$$

(b) The ball must land within 6.1 m of the other side of the net.

Determine whether the ball hits the ground within this distance. Support your answer with a calculation. Ignore the height of the net.

(6)

$v^2 = u^2 + 2as$

$u^2 = 625$

$s = ut + \frac{1}{2}at^2$

$2.5 = \frac{1}{2} \times 9.81 \times t^2 = 0.71$ seconds

$s = \left(\frac{u+v}{2}\right)t$

$s = \left(\frac{25+0}{2}\right) \times 0.71 = 8.875\text{M}$

doesn't go over net!

Examiner comments

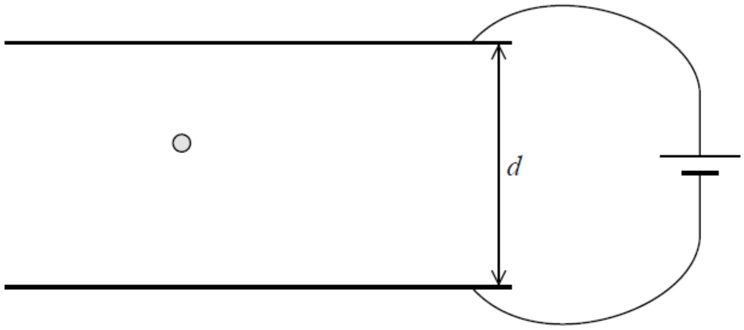
a) Another correct answer that would be better with some annotation.

b) This student has calculated the time correctly to score the first 2 marking points but then assumes that there is a horizontal acceleration, which is wrong, and so the distance travelled is incorrect. This student thinks that the ball only travels 8.875 m so as a conclusion should have said 'since 8.875 m is less than 12 m the ball will not pass over the net'. However, since the distance calculation was based on incorrect physics the student could not score the last marking point.

Exemplar question 2

In an experiment to determine the charge on an electron, negatively charged oil drops are allowed to fall between two parallel metal plates separated by a distance d.

A potential difference (p.d.) is applied across the plates. The diagram shows one oil drop between the plates.



When the p.d. is 0 V the oil drop accelerates to terminal velocity. The p.d. is increased. It is observed that at a particular p.d. V the oil drop stops falling and remains stationary between the plates.

*(a) Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to V.

(6)

(b) The oil drop has a mass m. Show that the charge q on the oil drop is given by

$$q = \frac{mgd}{V}$$

(2)

(c) Explain what would happen to the oil drop if the p.d. is increased further.

(2)

Mark scheme

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr>
<td>2 (a)*</td>
<td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
</td>
<td>Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td>
<td></td>
</tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>2 (a)*
(continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table></td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
2 (a)* **(continued)**	**Indicative content** • At terminal velocity the forces on the drop are balanced **OR** weight = drag • The p.d. creates an electrostatic force acting upwards on the drop • The electrostatic force increases as p.d. increases • The net upward force causes the drop to have a negative acceleration • As speed decreases the drag decreases • The drop remains stationary when the forces are balanced **OR** until the drop remains stationary when weight = electrostatic force		**6**
2 (b)	• Equate the electric force and the gravitational force **(1)** • Use of E=V/d to obtain $q = mgd/V$ **(1)**	$qE = mg$ $q(V/d) = mg$ $q = mgd/V$	**2**
2 (c)	An explanation that makes reference to: • Electrostatic/upward force (on drop) would be greater than the weight/downward force **(1)** • So drop would <u>accelerate</u> upwards **(1)**	Indication of which force is greater, unbalanced is insufficient.	**2**

Answers to part a)

Student answer A

*(a) Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to V.

(6)

At 0V, there is no resultant force on the oil drop as the ~~wei~~ force due to gravity ~~has~~ = the ~~resistant~~ ~~resistive~~ viscous force ~~act~~ opposing the motion of the oil droplet. As p.d. is increased, there is a force felt upwards on the droplet. As the p.d continues to increase, the ~~f~~ upward force increases proportionally, until the force due to the electric field equals mg. The upwards plate is positive, which is why the ~~das~~ negative droplet ~~is att~~ feels an electrostatic force of attraction towards the top plate, and a repulsion from the negative bottom plate. When mg equals the electrostatic force, the ~~particle re~~ droplet remains stationary.

Examiner comments

In this example the student identifies that at 0V the resultant force is zero, that as p.d. increases there is an increasing upwards electrostatic force on the drop and that when the weight is equal to the electrostatic force the drop remains stationary, hence marking points 1, 2, 3 and 6 are achieved. There is no mention of negative acceleration or drag increasing with speed, so marking points 4 and 5 are not achieved. This means that 3 marks are awarded for indicative content. The answer contains some structure and lines of reasoning, so an extra 1 mark is awarded giving a total of 4 marks.

Student answer B

*(a) Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to V.

(6)

- At 0V gravity acts downwards on the ~~oil~~ oil drop causing it to reach terminal velocity. Resistance of the air acts upwards and opposes gravity. It is a smaller force than gravity.
- As V increases an electrical force acts upwards in ~~com~~ combination with air resistance to oppose gravity, that is still acting downwards.
- At a certain point, ~~the~~ ~~[illegible]~~ as V continues to increase, the electrical force acting upwards increases. When V reaches a critical value the combined upwards force of the electrical force and air resistance will balance the downwards force of gravity and the droplet will be suspended.

Examiner comments

This example does not correctly explain why the oil drop reaches a terminal velocity, so does not achieve marking point 1. Marking points 2 and 3 are achieved as the student refers to an increasing upward electrical force, but there is no mention of negative acceleration or drag increasing with speed so marking points 4 and 5 are not. The student does explain why the drop becomes stationary – marking point 6. This means that overall the student gains 2 marks for indicative content. The answer contains some structure and lines of reasoning, so an extra 1 mark is awarded giving a total of 3 marks.

Student answer C

*(a) Explain the motion of the oil drop in terms of the forces acting on it as the p.d. is increased from 0 to V.

(6)

When the p.d. is 0V the resultant force downwards due to gravity is at a maximum and so the oil drop accelerates downwards. As the p.d. is increased the charged plate attracts the oil drop upwards and so the resultant force downwards decreases. When the force due to the electrostatic attraction is equal to the force due to gravity when p.d. = V, the resultant force is zero and ~~it~~ so the drop ~~acc~~ does not accelerate in either direction.

Examiner comments

The student is unable to explain the motion of the oil drop and achieves marking point 2 only, for a reference to an upwards force of electrostatic attraction. However there is a linking of ideas and some reasoning so in total the student is awarded a total of 2 marks, 1 for indicative content and 1 for linking ideas.

Answers to part b)

Student answer A

(b) The oil drop has a mass m. Show that the charge q on the oil drop is given by

$$q = \frac{mgd}{V}$$

(2)

$F = ma$
$= mg$ ...

~~charge between plates =~~

electric field $= E = V/d = F/Q$

$\therefore V/d = mg/q \rightarrow q = mgd/V$

Examiner comments

This example shows a clear and logical sequence so is awarded 2 marks.

Student answer B

(b) The oil drop has a mass m. Show that the charge q on the oil drop is given by

$$q = \frac{mgd}{V}$$

$E = mg\,d$

$V = \frac{W}{Q}$

(2)

$Q = \frac{W}{V}$

$q = \frac{W}{V}$

$q = \frac{mgd}{V}$

Examiner comments

Although this student apparently arrives at the correct answer there is no evidence of the use of *E=V/d* or *Ee = mg* not clear so is not awarded any marks. Students should include sufficient words in their response that an examiner is able to follow their working.

Student answer C

(b) The oil drop has a mass m. Show that the charge q on the oil drop is given by

$$q = \frac{mgd}{V}$$

$\uparrow \downarrow mg \quad E = \frac{F}{Q} \quad E = \frac{V}{d}$

(2)

$\frac{F}{q} = \frac{V}{d} \rightarrow \frac{mg}{q} = \frac{V}{d}$

$\frac{V}{dmg} = \frac{1}{q} \therefore q = \frac{dmg}{V}$

F = mg because
force upwards = force downwards

Examiner comments

This example shows a clear sequence with written clarification, so is awarded 2 marks.

Answers to part c)

Student answer A

(c) Explain what would happen to the oil drop if the p.d. is increased further.

(2)

~~the oil droplet will stretch out as the electro~~
the oil droplet will accelerate to the +ve plate as the electrostatic attraction will be stronger.

Examiner comments

The student is awarded marking point 2, for stating that the drop will accelerate towards the positive plate, but the response does not compare the forces, so is not awarded marking point 1.

Student answer B

(c) Explain what would happen to the oil drop if the p.d. is increased further.

(2)

~~Net~~ It would experience a net upwards force and accelerates upwards.

Examiner comments

The student is awarded marking point 2, for stating that the drop will accelerate towards the positive plate, but only refers to net force so does not score marking point 1.

Student answer C

(c) Explain what would happen to the oil drop if the p.d. is increased further.

(2)

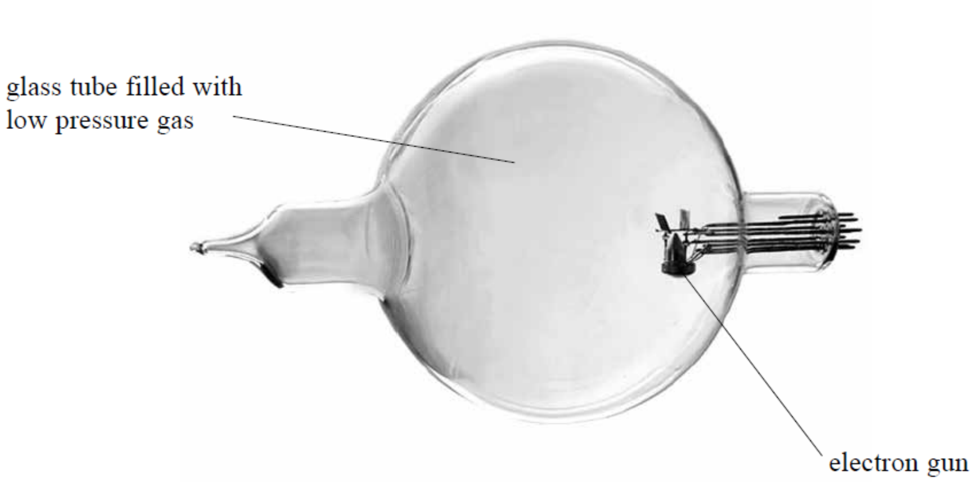
If the pd is increased further, the oil droplet will begin to move upwards because upwards force due to electrostatic forces will be greater than the downwards force

Examiner comments

This example correctly compares the forces for marking point 1 but refers to 'move' rather than 'accelerate' so is not awarded marking point 2.

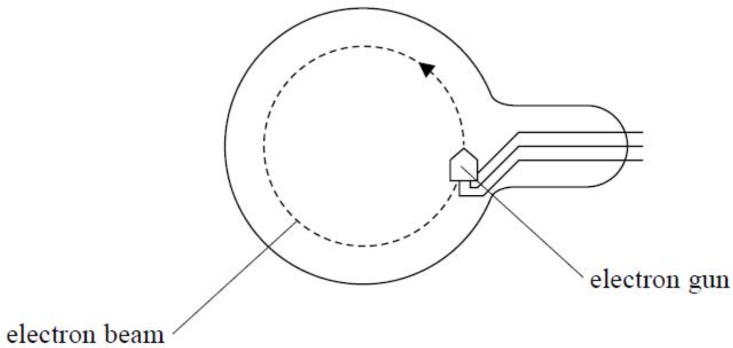
Exemplar question 3

An electron beam tube can be used to demonstrate the deflection of electrons in a uniform magnetic field. The tube contains a very low pressure gas so that electron paths can be seen.



(Source: http://www.klingereducational.com/images/products/thumbs/555571.jpg)

Electrons are emitted from the electron gun travelling vertically upwards into a region of uniform horizontal magnetic flux density.



(a) Show that the unit of magnetic flux density (Tesla) in SI base units is kg A^{-1} s^{-2}.

(2)

(b) Explain why the electrons follow a circular path.

(3)

(c) The magnetic flux density is varied while the speed of the electrons remains constant. The following data is obtained.

Radius/cm	Magnetic flux density/mT	
8.0	0.63	
9.5	0.52	
11.0	0.46	

Theory suggests that the radius of the electron path is inversely proportional to the magnetic flux density.

Analyse the data and comment on this suggestion, you may use the table to show any calculated values.

(4)

Mark scheme

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>3 (a)</td><td>• Use of $F = BIl$ or use of $F=Bqv$ (1)
• Converts N to kg m s^{-2} (1)</td><td>Example
$B = \frac{F[\text{kg m s}^{-2}]}{I[\text{A}]\ l[\text{m}]}$
So units are kg A^{-1} s^{-2}</td><td>2</td></tr>
<tr><td>3 (b)</td><td>An explanation that makes reference to:
• The magnetic force on the electrons acts at right angles to (the plane containing B and) v (1)
• Hence the force is always towards the centre of the circle (1)
So providing a centripetal force on the electron or a centripetal acceleration that maintains circular motion (1)</td><td></td><td>3</td></tr>
<tr><td>3 (c)</td><td>• Calculates B x r (1)
• Calculate the percentage uncertainty (1)
• Suitable comment on difference from expectation (1)
• Weak conclusion because only three readings (1) OR no repeats (1) OR limited range (1)</td><td>Example of calculation:
%U = (0.06/5.01) x 100% = 1.2%
<table><tr><th>Radius /cm</th><th>Magnetic flux density/mT</th><th></th></tr><tr><td>8.0</td><td>0.63</td><td>5.04</td></tr><tr><td>9.5</td><td>0.52</td><td>4.94</td></tr><tr><td>11.0</td><td>0.46</td><td>5.06</td></tr></table></td><td>4</td></tr>
</table>

Answers to part a)

Student answer A

(a) Show that the unit of magnetic flux density (Tesla) in SI base units is kg A^{-1} s^{-2}.

(2)

$F = BIL \qquad B = \frac{F}{IL} \qquad F = \text{kgms}^{-2} \qquad I = A \qquad L = m$

$\frac{F}{IL} = \frac{\text{kg}\cancel{m}s^{-2}}{A\ \cancel{m}} = \frac{\text{kgs}^{-2}}{A}$

$= \text{kg}\,A^{-1}s^{-2}$

Examiner comments

This example scores 2 marks. The student clearly identifies all units before substituting them and cancelling, so the work is easy to follow.

Student answer B

(a) Show that the unit of magnetic flux density (Tesla) in SI base units is kg A^{-1} s^{-2}.

(2)

$F = BIL$

$B = \frac{F}{IL} = \frac{\text{kg}\cancel{m}s^{-2}}{A\cancel{m}} = \text{kg}A^{-1}s^{-2}$

Examiner comments

This example scores 2 marks. The work is correct, but there is minimal explanation. It would have been helpful if the student had identified the units for each term before substituting them.

Student answer C

(a) Show that the unit of magnetic flux density (Tesla) in SI base units is kg A^{-1} s^{-2}.

(2)

~~Flux density: B~~ ~~Bqv~~ $F = Bqv$

~~B: flux q: charge v: velocity~~

$$B = \frac{F}{qv} \rightarrow \frac{kgms^{-2}}{\frac{A}{s} \times ms^{-1}} = \frac{kgms^{-2}}{A \times m} = kgA^{-1}s^{-2}$$

Examiner comments

This example starts correctly, but the unit for charge is incorrect and the student then 'fudges' to arrive at the final answer, so scores 1 mark.

Answers to part b)

Student answer A

(b) Explain why the electrons follow a circular path.

(3)

The magnetic force acting on the electron is perpendicular to direction of its velocity. A charged particles (like electrons) experience a centripetal force (provided by the magnetic force) when it ~~enters a~~ is moving ~~perpendicular~~ ~~in a magnetic~~ in a magnetic field & is perpendicular to the direction of the magnetic field.

Examiner comments

This student correctly refers to the magnetic force acting perpendicular to *v*, scoring marking point 1 and centripetal force, scoring marking point 3. The second marking point is not awarded, as there is no reference to the force being towards the centre of the circle. The total mark is 2.

Student answer B

(b) Explain why the electrons follow a circular path.

(3)

~~There is a~~ A moving charge in a magnetic field, cutting the flux lines will experience a ~~per~~ force perpendicular to its velocity and to the magnetic field. ~~As the velocity~~ As the particle changes direction due to the force, the force felt also changes such that it remains perpendicular to the particles velocity and the magnetic flux.
The force due to the field acts as the centripetal force.

Examiner comments

This student refers to the magnetic force acting perpendicular to *v* and the magnetic field, scoring marking point 1. There is also a reference to centripetal force, scoring marking point 3. Again the second marking point is not awarded, as there is no reference to the force being towards the centre of the circle. The total mark is 2.

Student answer C

(b) Explain why the electrons follow a circular path.

(3)

According to Fleming's left hand rule, a charged particle will experience a force when in a magnetic field that is at right angles to ~~both~~ its velocity (direction of motion) and magnetic field direction.

Examiner comments

The student gives a full description of the magnetic force on the electrons, to gain the first marking point. However there is no reference to circular motion so no further marks are awarded.

Answers to part c)

Student answer A

(c) The magnetic flux density is varied while the speed of the electrons remains constant. The following data is obtained.

Radius/cm	Magnetic flux density/mT	Br
8.0	0.63	5.04
9.5	0.52	4.94
11.0	0.46	5.06

Theory suggests that the radius of the electron path is inversely proportional to the magnetic flux density.

Analyse the data and comment on this suggestion, you may use the table to show any calculated values.

(4)

range of values for Br

% uncertainty = half the range / mean value

= 0.06 / 5.01 = 1.2%

low % u implies relationship correct but this is based on only 3 readings, which is not enough.

Examiner comments

This example is awarded all 4 marks. The student has correctly calculated values for *Br*, then used half the range and the mean value to determine the percentage uncertainty and commented that the low value of this implies that the suggested relationship is correct. The final mark is awarded for the comment that the conclusion is based on three readings only.

Student answer B

(c) The magnetic flux density is <u>varied</u> while the speed of the electrons remains constant.
The following data is obtained.

Radius/cm	Magnetic flux density/mT	r×B
8.0	0.63	5.04
9.5	0.52	4.94
11.0	0.46	5.06

Theory suggests that the radius of the electron path is inversely proportional to the magnetic flux density.

Analyse the data and comment on this suggestion, you may use the table to show any calculated values.

(4)

values

$r \propto \frac{1}{B}$ ∴ $rB = k$. for the ~~first three sets of values~~ the relationship is true because rB = constant (as seen in table). ~~However for the final set of values this~~ The numbers are roughly similar when rB is multiplied suggesting that there is a relationship

Examiner comments

This student has correctly calculated the values for the table to score marking point 1. However the following comment is vague and there is no attempt to quantify the uncertainty so no further marks are awarded.

Student answer C

(c) The magnetic flux density is varied while the speed of the electrons remains constant. The following data is obtained.

Radius/cm	Magnetic flux density/mT	Magnetic flux density = k (1/radius) k = Magnetic flux density × radius
8.0	0.63	5.04
9.5	0.52	4.94
11.0	0.46	5.06

Theory suggests that the radius of the electron path is inversely proportional to the magnetic flux density.

Analyse the data and comment on this suggestion, you may use the table to show any calculated values.

(4)

As shown on the table, the constant obtained from a simple ~~inverse~~ equation that describe the proportinality is about 5 for 3 of the data. It is clear to see the relationship when there is a constant.

Examiner comments

This student gains 1 mark for correct calculation of the values in the table but the following comments are too vague to score further marks.

Paper 2: Advanced Physics II

Exemplar question 1

An electric drinks cooler is an appliance consisting of a thermally insulated compartment and a heat pump that transfers heat from the inside of the cooler to the room in which the cooler is placed.

This maintains the temperature of the inside of the cooler below the temperature of the room.

(Source: http://www.americanas.com.br/produto/110863245/adega-de-vinhos-easycooler-12 garrafas)

On closing the door of the cooler, warm air at atmospheric pressure and at a temperature of 22.5°C is trapped inside. After a time, the internal temperature stabilises at 3.3°C.

A student notices that the door is difficult to open and concludes that this is because the air inside has cooled down and reduced the pressure.

Carry out a calculation to assess the validity of the student's conclusion.

atmospheric pressure = 102 kPa

area of door = 0.15 m^2

Mark scheme

Question Number	Acceptable answers	Additional guidance	Mark
1	• Use of $pV = NkT$ **(1)** • Conversion of temperature to Kelvin **(1)** • $p = 95.4$ kPa **(1)** • Calculation of excess pressure **(1)** • Use of $p = F/A$ **(1)** • $\Delta F = 995$ N **(1)** • Sensible comment, e.g. this is a large force so could make the door hard to open **(1)**	Example of calculation: $\frac{p_1}{T_1} = \frac{p_2}{T_2}$ $p_2 = p_1 \times \frac{T_2}{T_1} = 102 \times 10^3 \text{ Pa} \times \frac{(273 + 3.3)\text{K}}{(273 + 22.5)\text{K}}$ $= 95.37 \times 10^3 \text{ Pa}$ $\Delta p = (102 - 95.37)$ kPa $= 6.63$ kPa $\Delta F = A\Delta p = 0.15\text{m}^2 \times 6.63 \times 10^3 \text{ Pa} = 994.5\text{N}$	7

Answers

Student answer A

Carry out a calculation to assess the validity of the student's conclusion.

atmospheric pressure = 102 kPa

area of door = 0.15 m^2

Initial temperature = 22.5 °C = 295.65 K.

Final temperature ~~is~~ 3.3 °C = 276.45 K.

Initial pressure = 102 kPa.

Final pressure = ?

$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2}$

$P_2 = \left(\frac{276.45}{295.65}\right)(102)$

$= 95.4$ kPa.

$\Delta P = (102 - 95.4)$ kPa

$= 6.624$ kPa.

$pV = nRT$, n & V constant

$\frac{P}{T} = \frac{nR}{V}$, $\frac{nR}{V} =$ constant.

$\frac{P}{T} = k$.

F needed to open the door

$= PA$.

$= 6.624 \times 0.15$ kN.

$= 994$ N.

Examiner comments

The student converts the temperatures given to kelvin and uses them to correctly calculate the new pressure inside the drinks cooler and hence the pressure difference between the inside and the outside. The force needed to open the door is then also calculated correctly. The working is clear and easy to follow and the student is awarded the first 6 marks. To gain the final marking point the student needed to make a comment about the validity of the conclusion.

Student answer B

Carry out a calculation to assess the validity of the student's conclusion.

atmospheric pressure = 102 kPa

area of door = 0.15 m²

22.5°C = 295.65 K $\frac{295.65}{276.45}$ = 1.0695

3.3°C = 276.45 K

102000 ÷ 1.0695 = 95376 Pa

$P = \frac{F}{A}$ 102 000 × 0.15 = 15300 N.

95376 × 0.15 = 14306 N

The force exerted on the door has ~~increased~~ decreased by almost 1000 N, so the student's claim is valid.

Examiner comments

This student correctly calculates the new pressure in the drinks cooler, and hence the force needed to open the door when the inside is at atmospheric pressure and the force needed to open the door at the new pressure. This is an acceptable alternative method and gains the first 5 marks. The difference between these forces is determined for a further mark, but the student's conclusion is unclear so the final mark is not awarded, giving 6 marks in total.

Student answer C

Carry out a calculation to assess the validity of the student's conclusion.

atmospheric pressure = 102 kPa

area of door = 0.15 m^2

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_1}$ Volume remains constant inside the cooler.

$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2} \therefore \boxed{P_1 T_2 = P_2 T_1}$

$102 \times 10^3 \times (3.3 + 273) = (22.5 + 273) P_2$

$\therefore P_2 = 95373 \text{ K}$

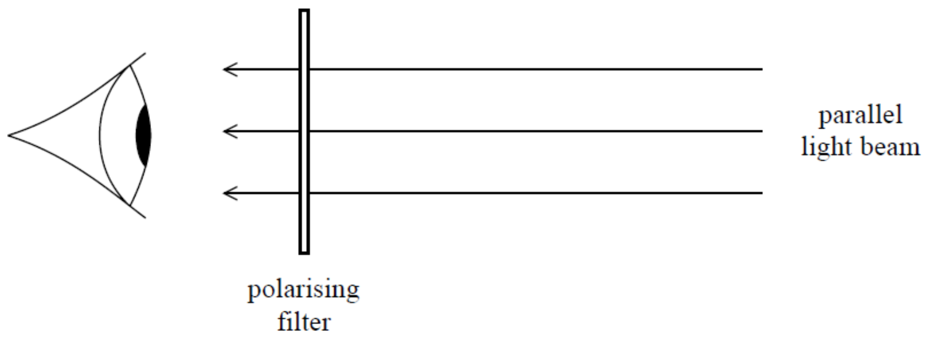
We see pressure has been reduced, thus his conclusion is valid.

Examiner comments

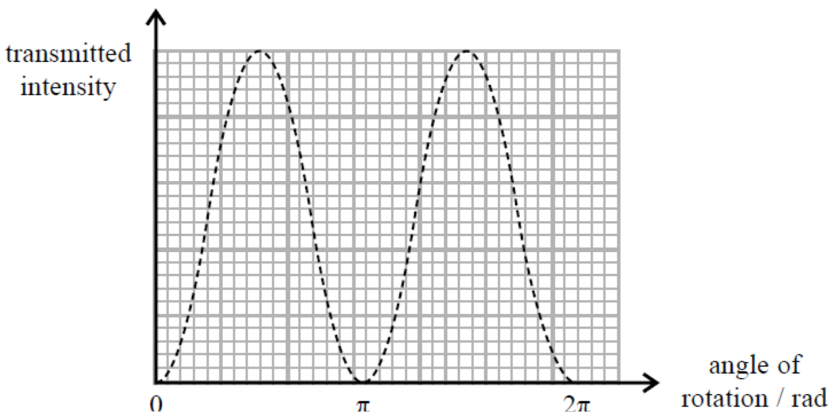
In this example the temperatures are successfully converted to kelvin and the new pressure inside the drinks cooler is correctly calculated. This gains the first 3 marks. However the student does not go on to calculate the pressure difference or attempt to determine a force, so no further marks are awarded.

Exemplar question 2

A student observes a parallel beam of light through a polarising filter.



The polarising filter is rotated through 2π rad in its own plane. The intensity of the light transmitted through the filter varies as shown.



*(a) Explain the observed variation in intensity of the transmitted beam.

(6)

(b) Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

Devise a simple test to determine whether the sunglasses use polarising lenses.

(2)

Mark scheme

<table>
<tr><th>Question Number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>2 (a)*</td><td>
This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5–4</td><td>3</td></tr>
<tr><td>3–2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained line of reasoning</th></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>
Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).
</td><td>6</td></tr>
</table>

Question Number	Acceptable answers	Additional guidance	Mark
2 (a)* (continued)	**Indicative content** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single plane • including the direction of propagation of the light • the light incident on the filter must be plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of $\pi/2$ rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		

Question Number	Acceptable answers	Additional guidance	Mark
2 (a)* (continued)	**Alternative answer** • a polarising filter restricts the (electric field) vibrations of the (transverse) light wave to a single direction • perpendicular to the direction of propagation of the light • the light incident on the filter is plane polarised • when the angle of rotation is a multiple of π rad (including zero), the plane of polarisation of the incident light is perpendicular to the transmission axis of the polarising filter hence the intensity of the transmitted light is zero • when the angle of rotation is an odd multiple of $\pi/2$ rad the plane of polarisation of the incident light is the same as that of the transmission axis of the polarising filter hence maximum light is transmitted • the intensity of the transmitted light varies from a minimum to a maximum as the angle of rotation varies as shown by the graph		
2 (b)	• Pass light through one lens of the glasses and view the light through the lens of the second pair of glasses. Rotate one pair of glasses through 90° **(1)** • If the light intensity varies then the glasses use polarising filters **(1)**	Allow full credit for a suitably annotated diagram.	2

Answers to part a)

Student answer A

*(a) Explain the observed variation in intensity of the transmitted beam.

(6)

At 0 the direction of the waves is perpendicular to that of the slits in the filter, so no light passes, it is all blocked. As the filter is rotated more and more light is transmitted as the angle from perpendicular increases more and more. At $\frac{\pi}{2}$ the light wave intensity is maximum because the waves and the slits are in the same direction so all light passes. As the filter is rotated, the angle between the waves and the slit gets closer to being perpendicular again, so more light is blocked meaning less is transmitted. When π is reached the light and the filter are perpendicular again, as at 0, so no light passes. The process repeats from here all the way to 2π.

Examiner comments

This student has made no reference to how the polarising filter works and has not identified that the incident light is plane polarised. This means that marking points 1, 2 &3 are not awarded. However there is a very good explanation as to what happens when the filter is rotated and so scores marking points 4, 5 & 6. three indicative content points gains 2 marks. The answer is well written with good linkage and so scores 2 marks for linkage giving a total mark of 6.

Student answer B

*(a) Explain the observed variation in intensity of the transmitted beam.

(6)

· Polaroid filter blocks out light completely when beams of light occur at right angles to filter

· This occurs ~~twice~~ three times during one rotation of the polaroid filter, i.e. at 0 ~~...~~, π and 2π radians (komplete backscattering of light)

· Maximum light can pass through filter when light beams are not affected by filter, ie. can pass straight through without deflection. This occurs twice during one rotation, at $\frac{\pi}{2}$ and $\frac{3\pi}{2}$ radians

Examiner comments

This candidate attempts to explain the effect of the polarising filter but does not refer to a single plane or to the direction of travel of the light so does not score any marks for this. The next two bullet points score marking points 4 & 5 so there are two indicative content points gaining 2 marks. There is some linkage so scores 1 mark for linkage giving a total mark of 3.

Student answer C

*(a) Explain the observed variation in intensity of the transmitted beam.

(6)

Beam is initially transmitted with oscillations in one plane ~~and~~. When the polarising filter is parallel to the direction of propagation of light waves they are all transmitted. As you rotate the polarising filter ~~is rotated~~ the waves are blocked out increasingly and when it is perpendicular to the oscillation of the wave these are completely blocked. Less photons reach the eye so the overall intensity ~~is much lower~~ ~~until~~ becomes zero.

Examiner comments

There is sufficient detail in this answer to award marking points 1 and 3. The response does not relate to the graph and specific angles of rotation so marking points 4, 5 & 6 cannot be awarded. There are two indicative points scoring 2 marks with 1 mark for some linkage giving a mark total of 3.

Answers to part b)

Student answer A

(b) Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

Devise a simple test to determine whether the sunglasses use polarising lenses.

(2)

Hold the sunglasses in front of each other and rotate one slowly while keeping one still. If the intensity of observed light is 0 at 90°, then they are polarising lenses.

Examiner comments

A good answer with reference to rotating one whilst keeping the other one still and scores 2 marks.

Student answer B

(b) Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

Devise a simple test to determine whether the sunglasses use polarising lenses.

(2)

Hold one of the sun glasses lens perpendicular to another. If no light is transmitted, they are polarised lens.

Examiner comments

The diagram helps explain what the student means and marking point 1 can be awarded for either the diagram or the first sentence. However there is no rotation and variation of intensity so does not score the 2^{nd} mark.

Student answer C

(b) Some sunglasses have lenses made from polarising filters.

You are given two pairs of identical sunglasses.

Devise a simple test to determine whether the sunglasses use polarising lenses.

(2)

~~Turn~~ Rotate the lens from 0 rad to 2π rad then obtain a transmitted intensity against angle of rotation graph and compare with the polarised filter graph. Which ever that gives the shape ~~#~~ same as the polarised filter graph will be a polarised lens.

Examiner comments

This response does not answer the question, it is referring back to the graph and scores zero.

Exemplar question 3

About 100 years ago the first measurements of spectra from galaxies beyond the Milky Way were made. Wavelengths of spectral lines were observed to be shifted and Hubble discovered a rough correlation between the shift in the spectral line and the distance to the galaxy.

The graphs below show plots for data collected in 1929 (Figure 1) and 1931 (Figure 2).

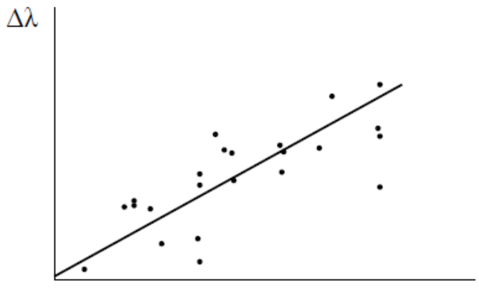


Figure 1

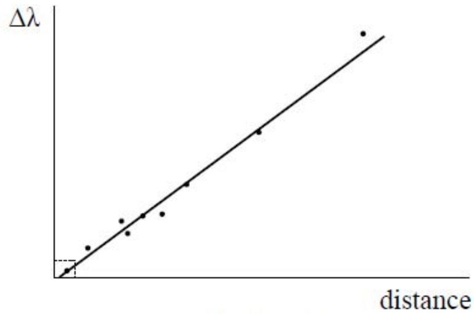


Figure 2

(a) The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

(5)

(b) The light emitted from a star is due to the energy released by fusion reactions taking place in the core of the star. Our Sun is a main sequence star with a luminosity of 3.85×10^{26} W.
An analysis of the Sun's spectrum gives $\lambda_{max} = 502$ nm

Use the data provided to calculate the radius of the Sun.

(4)

(c) The Sun is believed to be about 4.5 billion years old. To determine this, scientists measure the ratios of the lead isotopes found in meteorites. Since uranium undergoes radioactive decay in a chain to eventually become an isotope of lead, the ratios of lead isotopes can be used to find the age of a meteorite.

(i) $^{238}_{92}U$ decays to $^{206}_{82}Pb$ via the emission of α and β^- radiation.
In the transition of U-238 to Pb-206 eight alpha decays must occur.

State the number of beta decays that must occur. Justify your answer.

(2)

....

....

....

Number of β^- decays = ...

(ii) One isotope produced in the chain is thorium-230, which decays to an isotope of radium with a half-life of 75,000 years.

Calculate the time in years it would take for 90% of an initial sample of thorium to have decayed.

(4)

Mark scheme

Question Number	Acceptable answers	Additional guidance	Mark
3 (a)	• The wavelength change is bigger the further away the galaxies are **(1)** • The further away galaxies are the faster they are moving, so all distant galaxies are moving away from each other (and the universe is expanding) **(1)** • There is a large amount of scatter in Hubble's original data set. **(1)** • The original data set covers a very small range of distances [only the closest galaxies considered] **(1)** • Hence, on the basis of the original data, the conclusion drawn by Hubble was quite speculative **(1)**		**5**
3 (b)	• Use of $\lambda_{max}T = 2.9\times10^{-3}$ **(1)** • $T = 5800$ K [accept 5780 K and 6000 K] **(1)** • Use of $L = 4\pi r^2\sigma T^4$ **(1)** • r = 6.9×10^8 m **(1)**	Example of calculation: $T = \dfrac{2.9\times10^{-3}\ \text{mK}}{5.02\times10^{-7}\ \text{m}} = 5780\ \text{K}$ $r = \sqrt{\dfrac{3.85\times10^{26}\ \text{W}}{4\pi\times5.67\times10^{-8}\ \text{Wm}^{-2}\text{K}^{-4}\times(5800\text{K})^4}} = 6.91\times10^8\ \text{m}$	**4**

Question Number	Acceptable answers	Additional guidance	Mark
3 (c)(i)	• 8 alpha decays reduce the proton number by 16 **(1)** • proton number decreases by only 10, so there must be 6 β decays **(1)** **OR** • balanced equation written for overall decay **(1)** • explicit solution to give 6 β^- decays **(1)**	Example of calculation: ${}^{238}_{92}U \rightarrow {}^{206}_{82}Pb + 8 \times {}^{4}_{2}\alpha + N \times {}^{0}_{-1}\beta^-$ 92 = 82 + (8×2) – N 92 = 82 + 16 – N N = 98 - 92 = 6 Proof must be given to obtain these marks.	**2**
3 (c)(ii)	• use of $\lambda t_{1/2} = \ln 2$ **(1)** • use of $N = N_0 e^{-\lambda t}$ **(1)** • $N/N_0 = 0.1$ **(1)** • t = 2.5 × 10^5 years **(1)**	Example of calculation: $\lambda = \frac{0.693}{75000} = 9.24 \times 10^{-6}\ \text{y}^{-1}$ $\lambda t = -\ln\left(\frac{N}{N_0}\right)$ $\therefore t = \frac{-\ln(0.1)}{9.24 \times 10^{-6}\ \text{y}^{-1}} = 2.49 \times 10^5\ \text{y}$	**4**

Answers to part a)

Student answer A

(a) The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

(5)

As the distance to the other galaxies increases, the shift in wavelength of light from the galaxies also increases, suggesting that, since $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ approximately and the speed of light is constant, the further away the galaxy is, the faster its ~~reg~~ regressional speed ~~is~~. This red shift in the wavelength of light from these galaxies is explained by the idea that the universe is expanding. Hubble's original data is quite spread out but still shows a positive correlation between red shift and distance - so his data is quite reliable.

Examiner comments

In this example the student identifies that as the distance increases the shift in wavelength increases and also that the further galaxies are moving faster, so the universe is expanding. This scores marking points 1 and 2. The student also recognises that there is a large spread in the original data so scores marking point 3. There is no attempt to assess the reliability of the conclusions based on the two graphs so marking points 4 and 5 are not awarded. The total mark is 3.

Student answer B

(a) The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

(5)

Hubble's observations show that as distance to the galaxy increased their red shifts increased as well.
This suggests that the galaxies were moving away from each other, ~~and more so~~ and hence that the universe is expanding.
~~Hubble's original data appears to have much in say that galaxies' spectral lines were much more redshifted than they actually were.~~ Hubble's original data ~~isn't too reliable due to is quite~~ clearly suggests the differences in red shift between near and far away galaxies.

Examiner comments

This example scores marking point 1 for recognising that as the distance to a galaxy increases the red-shift increases. The student states the galaxies are moving away from each other but fails to link this with the idea that the further galaxies are moving faster so does not score marking point 2. There is no further relevant comment on the data or graphs so the total mark is 1.

Student answer C

(a) The data used by Hubble for his 1929 plot (Figure 1) is contained within the rectangle close to the origin of the 1931 plot (Figure 2).

Explain how Hubble's observations support the conclusion that the universe is expanding, and assess the reliability of this conclusion on the basis of Hubble's original data.

(5)

Hubbles data suggests that the further away a galaxy the greater the change in wavelength + the faster they are moving. This supports the conclusion that the universe is expanding. ~~The~~ Hubbles original data is quite spread out + only dealt with the galaxy that are closest to us. Because of the spread of the data it's difficult to pick the right line of best fit.

Examiner comments

This response scored all 5 marks. The response clearly links the furthest galaxies with the greatest change in wavelength and the greatest speeds, gaining marking points 1 and 2. The student recognises the large spread in the original data and that it only dealt with the closest galaxies gaining marking points 3 and 4. The comment regarding the line of best fit is an alternative wording that is sufficient to score the final mark.

Answers to part b)

Student answer A

(b) The light emitted from a star is due to the energy released by fusion reactions taking place in the core of the star. Our Sun is a main sequence star with a luminosity of 3.85×10^{26} W.
An analysis of the Sun's spectrum gives $\lambda_{max} = 502$ nm

Use the data provided to calculate the radius of the Sun.

(4)

$\cancel{L = 4\pi d^2 F}$

$\lambda_{max} T = 2.898 \times 10^{-3}$

$\therefore T = \cancel{4.49655.77k}$ $5772.9k$

$L = 4\pi r^2 \sigma T^4$

$\therefore r^2 = L / 4\pi\sigma T^4$

$\therefore r = \sqrt{L / 4\pi\sigma T^4}$

$= \sqrt{\dfrac{3.85 \times 10^{26}}{4\pi \cdot 5.67 \times 10^{-8} \cdot 5773^4}}$ $\cancel{(5 \times 10^{5})^4}$

$= 6.975 \times 10^{8}$ m

Examiner comments

This student scores all 4 marks for a correct answer with the corresponding unit.

Student answer B

(b) The light emitted from a star is due to the energy released by fusion reactions taking place in the core of the star. Our Sun is a main sequence star with a luminosity of 3.85×10^{26} W.
An analysis of the Sun's spectrum gives $\lambda_{max} = 502$ nm

Use the data provided to calculate the radius of the Sun.

(4)

$T = \dfrac{2.898 \times 10^{-3}}{502 \times 10^{-9}} = 5772.9$

$r = \sqrt{\dfrac{L}{4\pi T^4 \sigma}} = 4.87 \times 10^{17}$

Examiner comments

The example shows the calculation of a correct value for *T* and this scores the first 2 marks. The student then correctly rearranges an appropriate equation to make *r* the subject, but the final answer is incorrect and as the student does not show the substitution of any values no compensation marks could be awarded, so the total mark is 2.

Student answer C

(b) The light emitted from a star is due to the energy released by fusion reactions taking place in the core of the star. Our Sun is a main sequence star with a luminosity of 3.85×10^{26} W.
An analysis of the Sun's spectrum gives λ_{max} = 502 nm

Use the data provided to calculate the radius of the Sun.

(4)

$L_{\odot} = 3.85 \times 10^{26}$ W

$\lambda_{max} = 502 \times 10^{-9}$ m

$\boxed{\lambda_{max} T = 2.898 \times 10^{-3}}$

$\therefore T = \frac{2.898 \times 10^{-3}}{\lambda_{max}} = \frac{2.898 \times 10^{-3}}{502 \times 10^{-9}}$

$= 5772.908367$

$\boxed{L = 4\pi r^2 \sigma T^4}$

$r = \sqrt{\frac{L}{4\pi\sigma T^4}}$

$= \sqrt{\frac{3.85 \times 10^{26}}{4\pi \times 5.67 \times 10^{-8} \times (\cancel{5800})^2}}$ 5772.9

$r = 4.0266 \times 10^{12}$

Radius of the Sun = 4.03×10^{12} m

Examiner comments

This example shows the calculation of a correct value for *T* and this scores the first 2 marks. The student then correctly rearranges the equation for *r* but substitutes for T^2 rather than T^4. As this is an error of physics no further marks are awarded, so the total mark is 2.

Answers to part c) i)

Student answer A

(c) The Sun is believed to be about 4.5 billion years old. To determine this, scientists measure the ratios of the lead isotopes found in meteorites. Since uranium undergoes radioactive decay in a chain to eventually become an isotope of lead, the ratios of lead isotopes can be used to find the age of a meteorite.

(i) $^{238}_{92}U$ decays to $^{206}_{82}Pb$ via the emission of α and β^- radiation.
In the transition of U-238 to Pb-206 eight alpha decays must occur.

State the number of beta decays that must occur. Justify your answer.

(2)

$238 \rightarrow 206 = \Delta 32$

$92 \rightarrow 82 = \Delta 10$

$16 - 10 = 6$

8 alpha decays = loss of 16 protons, but only 10 are lost so 6 β^- decays must occur.

Number of β^- decays = 6

Examiner comments

This student provides a complete, clear answer that scores both marks.

Student answer B

(c) The Sun is believed to be about 4.5 billion years old. To determine this, scientists measure the ratios of the lead isotopes found in meteorites. Since uranium undergoes radioactive decay in a chain to eventually become an isotope of lead, the ratios of lead isotopes can be used to find the age of a meteorite.

(i) ${}^{238}_{92}U$ decays to ${}^{206}_{82}Pb$ via the emission of α and β^- radiation.

In the transition of U-238 to Pb-206 eight alpha decays must occur.

State the number of beta decays that must occur. Justify your answer.

(2)

~~5 as β- ${}^4_2He$ loss of 92-~~ 6

6 As proton no would be 76 ∴ needs to be 82

82 - 76 = 6.

Number of β^- decays = 6

Examiner comments

This response is just sufficient for both marks.

Student answer C

(c) The Sun is believed to be about 4.5 billion years old. To determine this, scientists measure the ratios of the lead isotopes found in meteorites. Since uranium undergoes radioactive decay in a chain to eventually become an isotope of lead, the ratios of lead isotopes can be used to find the age of a meteorite.

(i) ${}^{238}_{92}U$ decays to ${}^{206}_{82}Pb$ via the emission of α and β^- radiation.

In the transition of U-238 to Pb-206 eight alpha decays must occur.

State the number of beta decays that must occur. Justify your answer.

(2)

82 - 76 = 6

Number of β^- decays = 6

Examiner comments

This student states the number of beta decays correctly, so gains the first mark, but there is insufficient justification given to gain the second mark.

Answers to part c) ii)

Student answer A

(ii) One isotope produced in the chain is thorium-230, which decays to an isotope of radium with a half-life of 75,000 years.

Calculate the time in years it would take for 90% of an initial sample of thorium to have decayed.

(4)

$0.1 A_0 = A_0 e^{-\lambda t}$

$\lambda = \frac{\ln 2}{\cancel{75000} \; 2.37\times10^{12}} = 2.93\times10^{-13}$

$0.1 = e^{-2.93\times10^{-13} t}$

$\frac{\ln(0.1)}{-2.93\times10^{-13}} = t = 7.859\times10^{12}\text{ s} = 249,196\text{ yrs}$

Time taken = 249,196 years

> **Examiner comments**
> This is a complete calculation, with working shown, that produces the correct final answer. The student is not penalised for the excessive number of significant figures and in this particular calculation the unit is given. The total mark is 4.

Student answer B

(ii) One isotope produced in the chain is thorium-230, which decays to an isotope of radium with a half-life of 75,000 years.

Calculate the time in years it would take for 90% of an initial sample of thorium to have decayed.

(4)

$t_{1/2} = 75000\text{ yr.}$

$\lambda = \ln 2 / t_{1/2} = 9.242\times10^{-6}$

$\frac{N}{N_0} = e^{-\lambda t}$

$\ln(0.9) = -\lambda \cdot t$

$\therefore t = \frac{\ln(0.9)}{-9.242\times10^{-6}} = 11400.19\text{ yrs}$ //

Time taken = ... years

> **Examiner comments**
> In this example the student correctly calculates λ, but then uses $N/N_0 = 0.9$, rather than 0.1, so the final answer is incorrect. Scores 2 marks.

Student answer C

(ii) One isotope produced in the chain is thorium-230, which decays to an isotope of radium with a half-life of 75,000 years.

Calculate the time in years it would take for 90% of an initial sample of thorium to have decayed.

(4)

$\ln \frac{A}{A_0} = -\lambda t$ $\quad t = \frac{\ln \frac{A}{A_0}}{-\lambda}$

$\lambda = \frac{\ln 2}{75000}$

$\lambda = 9.24 \times 10^{-6}$ $\quad t = \frac{\ln 0.9}{-9.24 \times 10^{-6}}$

$t = 11400.2$

Time taken = 11400 years. years

> **Examiner comments**
> The student calculates the decay constant for 1 mark. This student then uses the activity equation and substitutes a number of atoms as an activity. This is an incorrect use of an equation and so the candidate does not score any more marks.

Paper 3: General and Practical Principles in Physics

Exemplar question 1

Small electrical devices are often powered by electric cells; different devices use different types of cell.

(a) The cells normally used in a television remote control have an e.m.f. of 1.5 V.

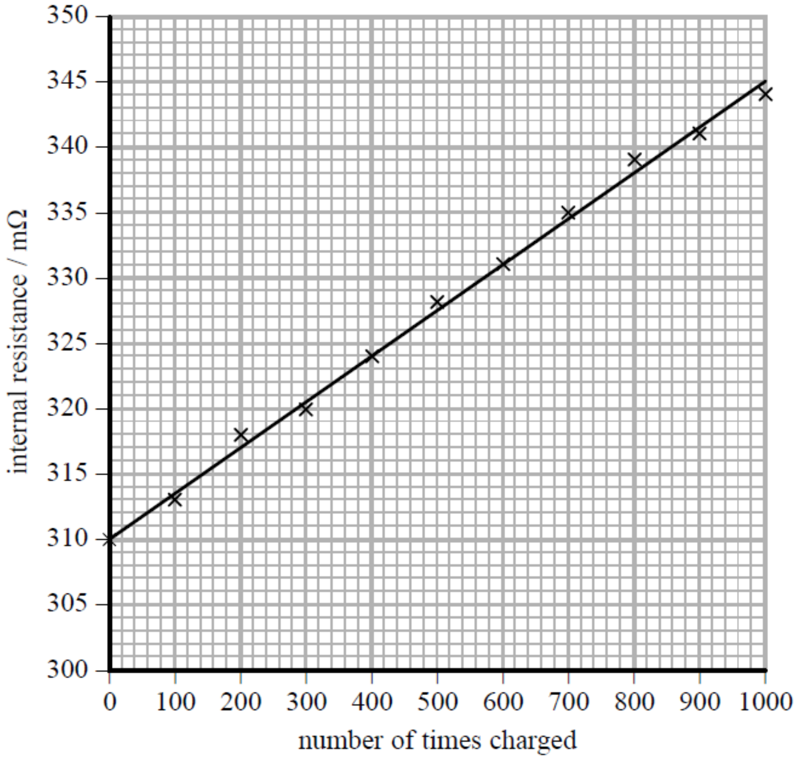
(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

(3)

(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

(3)

(b) The cells used in a camera to charge the flash unit are 3.6 V lithium ion rechargeable cells. The data sheet supplied with such a cell includes a graph which shows how the internal resistance of the cell varies with the number of times it has been charged and discharged.



The cell is recommended for use in a camera flash charger which typically draws a supply current of 800 mA. The manufacturer claims that even after 500 charging cycles the cell terminal potential difference (p.d.) will be more than 99% of the terminal p.d. when new and supplying the same current.

Analyse the data from this graph to explain whether it supports the claim, supporting your answer with a calculation.

(4)

Mark scheme

Question number	Acceptable answers	Additional guidance	Mark
1 (a)(i)	A description that makes reference to the following points: Circuit diagram showing: • Cell, variable resistor and ammeter in series and voltmeter in parallel with cell **(1)** • Recording pairs of readings of terminal p.d. and current **(1)** • Use the variable resistor to obtain 5 other pairs of readings**(1)**	Should be between 5 and 10 other pairs	**3**
1 (a)(ii)	A description that makes reference to the following points: • Plot a graph of terminal potential difference on the y-axis and current on the x-axis **(1)** • Intercept on the y-axis equals e.m.f. **(1)** • And gradient = -r **(1)**		**3**
1 (b)	• From graph: after 500 charging cycles internal resistance of cell is 327 mΩ **(1)** • Use of $V = \varepsilon - Ir$ **(1)** • Use of $\frac{V_{500}}{V_0} \times 100\%$ $\frac{V_{500}}{V_0} \times 100\% = 99.6\%$ **(1)** • So manufacturer's claim is correct **(1)**	Example of calculation: $V_0 = 3.6\,\text{V} - 0.800\,\text{A} \times 0.310\,\Omega$ $= 3.6\,\text{V} - 0.248\,\text{V} = 3.352\,\text{V}$ $V_{500} = 3.6\,\text{V} - 0.800\,\text{A} \times 0.327\,\Omega$ $= 3.6\,\text{V} - 0.262\,\text{V} = 3.338\,\text{V}$ $\frac{V_{500}}{V_0} \times 100\% = \frac{3.338\text{V}}{3.352\text{V}} \times 100\% = 99.6\%$ This last mark is awarded only if the conclusion is correctly supported by the calculation.	**4**

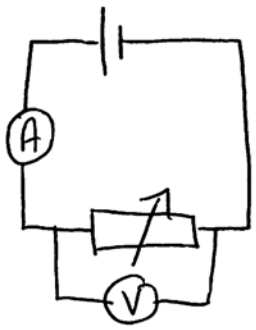
Answers to part a)

Student answer A

(a) The cells normally used in a television remote control have an e.m.f. of 1.5 V.

(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

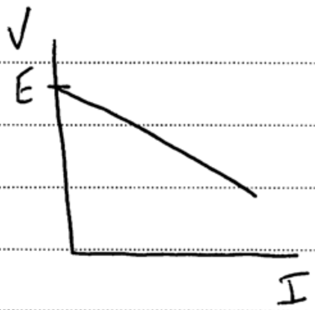
(3)



I will record readings of current and voltage using the variable resistor to get a range of value.

(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

(3)



$E = V + Ir \quad V = -Ir + E.$

I would plot a graph as shown.

emf is the intercept on the y axis and the gradient = $-r$

Examiner comments

(i)This scores the diagram mark. The position of the voltmeter can be in parallel across the cell or the resistor and could be across the ammeter as well. 2nd marking point is there for pairs of readings, accepting voltage instead of terminal potential difference but the student does not specify how many readings are to be taken and so does not score marking point 3. Total marks 2.

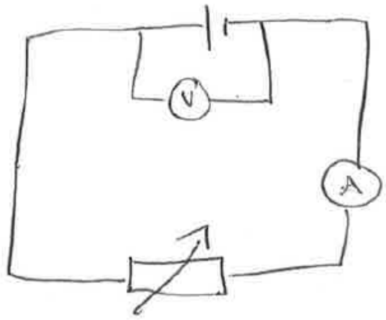
(ii) A sketch graph on its own is acceptable for MP1. This scores all 3 marks.

Student answer B

(a) The cells normally used in a television remote control have an e.m.f. of 1.5 V.

(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

(3)



· Use variable resistor to obtain series of readings for ~~V~~ V and I

· Use eqn V = IR to calculate resistance for each reading

(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

(3)

e.m.f. = IR − Ir − internal resistance

emf will be max value of V, as shown on voltmeter

− use values of I (shown on ammeter) and ~~R~~ ~~(V)~~ emf to workout internal resistance : Ir = ~~IR~~ IR (V) − emf

Examiner comments

(i) 2 marks are scored. There is no mention of how many pairs of reading will be taken.

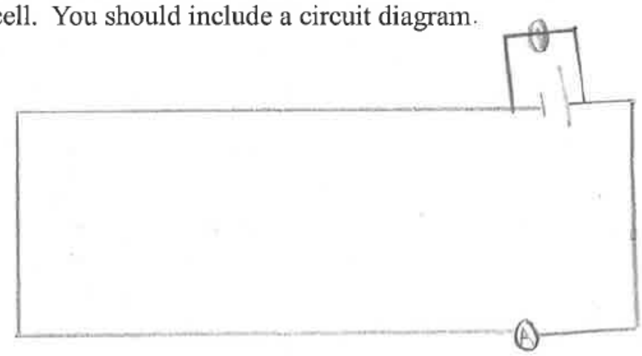
(ii) There is an expectation that unless otherwise stated, descriptions of practical experiments will involve a graphical method. Some marks might be awarded for a non-graphical method but in this case the initial equation is incorrect so this scores 0.

Student answer C

(a) The cells normally used in a television remote control have an e.m.f. of 1.5 V.

(i) Describe a procedure to determine the internal resistance and e.m.f. of an electrical cell. You should include a circuit diagram.

(3)



Placewire to each end of the cell and an ammeter in parallel to the cell to measure current. To measure emf place a voltmeter in parallel to the cell. To calculate internal resistance use the equation ~~V=IR~~ $R = \frac{V}{I}$

(ii) Describe how you would use your results to find a value for the e.m.f. and internal resistance of the cell.

(3)

To find the value for the emf you would read the value from the voltmeter and to calculate internal resistance you would use the equation $R = \frac{V}{I}$ where V = p.d. on voltmeter and I = current

Examiner comments

This is a very weak response, there is an attempt at a diagram but no means of varying current to obtain pairs of readings. This scores 0 for both parts.

Answers to part b)

Student answer A

Analyse the data from this graph to explain whether it supports the claim, supporting your answer with a calculation.

(4)

r increases from 300 – 327

initially

$V = 3.6 - 800 \times 0.31 = 3.35V$

after 500 flashes

$V' = 3.6 - 800 \times 0.327 = 3.34V$

$\frac{V'}{V} \times 100 = \frac{3.34}{3.35} \times 100 = 99.7\%$

This means manufacturer's claim is correct

Examiner comments

This candidate correctly reads from the graph, does two calculations to find two values of terminal potential difference and a % calculation to score all 4 marks. The student has worked to 3 significant figures rather than the 4 in the MS so gets a slightly different answer to that in the markscheme but this is acceptable.

Student answer B

Analyse the data from this graph to explain whether it supports the claim, supporting your answer with a calculation.

(4)

~~p.d when new = $I_0 R_0$ = $800 \times 10^{-3} \times 310 \times 10^{-3}$~~

~~= 0.248~~

~~P.D p.d. when charged 500 times = IR = $800 \times 10^{-3} \times 328 \times 10^{-3}$~~

~~= 0.2624~~

Using ratios for V = IR, as V ∝ R, ratio of original internal resistance to internal res. after 500 charges = $\frac{310}{328}$ = 0.945

∴ Only 95% of terminal p.d. remains so claim not supported

Examiner comments

There is evidence that the candidate has used the graph to find the internal resistance after 500 flashes because of the ratio 310/328 so this scores 1 mark only. Although the markscheme says 327 Ω there is a tolerance when readings are taken from a graph and 328 Ω is acceptable.

Student answer C

Analyse the data from this graph to explain whether it supports the claim, supporting your answer with a calculation.

(4)

~~R~~ $R = 328 \text{ m} \times 10^{-3}\ \Omega$ after 500 charges.

$V = 328 \times 10^{-3} \times 800\text{ m} \times 10^{-3} = 0.2624$ ~~for~~ V

$\frac{0.2624}{3.6} = 7.29\%$

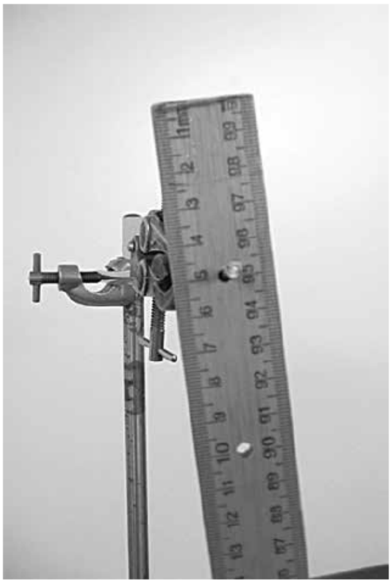
So the claim is false.

Examiner comments

A similar example where the student has failed to use the terminal potential difference formula and so scores 1 mark only.

Exemplar question 2

A metre rule has a small hole drilled at the 5 cm mark. The rule is hung on a horizontal pin passing through the hole.



(a) The rule is rotated through a small angle and released. It then oscillates about the pin as a pendulum with a time period T.

(i) Describe how to use a stopwatch to determine a value for T.

(2)

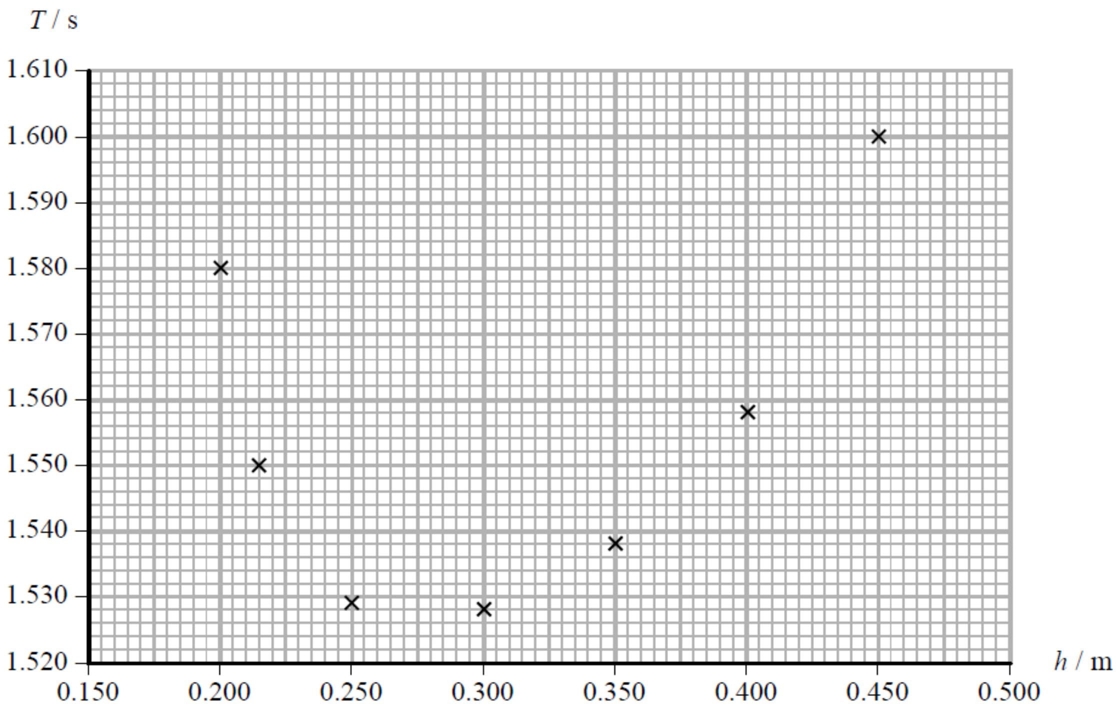
(ii) State **two** reasons why repeating the readings will improve the results for T.

(2)

(b) There are six more holes drilled at intervals down the rule. The rule is hung from each hole and the distance h from the pin to the 50 cm mark is recorded.

T is determined for each value of h and a graph of T against h is plotted.

h/m	T/s
0.450	1.601
0.400	1.558
0.350	1.538
0.300	1.528
0.250	1.529
0.215	1.550
0.200	1.580



(i) Draw a line of best fit on the graph.

(1)

(ii) Use your line to determine the value of h that would produce the smallest value of T.

Record these values.

(2)

h = ... T = ...

(c) The graph of T against h does **not** produce a straight line.

The variables T and h are related by

$T^2 h = 4\pi^2 h^2/g + C$

where C is a constant.

Describe a graphical method to determine a value for C and state the unit for C.

(3)

Mark scheme

Question number	Acceptable answers	Additional guidance	Mark
2 (a)(i)	A description that makes reference to the following points: • Record nT (where n is at least 5) **(1)** • Divide measurement by n **(1)**		**2**
2 (a)(ii)	• Anomalies can be spotted **(1)** • Reduce the effect of random error **(1)**		**2**
2 (b)(i)	• BFL is smooth and thin with a definite minimum and minimum is in range 0.26 m – 0.28 m **(1)**		**1**
2 (b)(ii)	• Values read correctly from candidate's line **(1)** • h to 3 sig fig **and** T to 4 sf **(1)**	Values from their curve to within 1 small square with no unit penalty.	**2**
2 (c)	A description that makes reference to the following points: • Plot T^2h against h^2 **(1)** • C is intercept on T^2h axis **(1)** **OR** C is the value of T^2h when h^2 is zero **(1)** • Unit is m s^2 **(1)**		**3**

Answers to part a)

Student answer A

(a) The rule is rotated through a small angle and released. It then oscillates about the pin as a pendulum with a time period T.

(i) Describe how to use a stopwatch to determine a value for T.

(2)

Set the ruler swinging from amplitude A_0, ~~there~~ and ~~measure~~ start stop watch. Count ~~each time~~ how many times the ruler reaches its starting position in ~~5~~ 10s. To find T, use $T = \frac{N}{10}$ where N is the number of times the ruler reached its starting position.

(ii) State **two** reasons why repeating the readings will improve the results for T.

(2)

Any anomalous error can be identified.
The error due to your reaction time will decrease.

> **Examiner comments**
>
> (i) This a description of how to determine the frequency, not the time period, so scores 0.
>
> (ii) Both reasons are correct so scores 2 marks.

Student answer B

(a) The rule is rotated through a small angle and released. It then oscillates about the pin as a pendulum with a time period T.

(i) Describe how to use a stopwatch to determine a value for T.

(2)

Press start immediately when releasing the ruler and press stops after ruler back to original position 10 times. Divide the value obtain by 10 to get value for each oscillation.

(ii) State **two** reasons why repeating the readings will improve the results for T.

(2)

- Repeating readings can obtain an average value which is closer to true value.
- It can remove outliers readings.

Examiner comments

(i) This is not a very clear description of the method, but just enough to score both marks.

(ii) There is no credit for the first part of the response, but the second part scores 1 mark for 'outliers', meaning anomalies.

Student answer C

(a) The rule is rotated through a small angle and released. It then oscillates about the pin as a pendulum with a time period T.

(i) Describe how to use a stopwatch to determine a value for T.

(2)

Use a laser light triggered stopwatch to eliminate human error. When it starts to oscillate the stopwatch will be turned on and start counting the time.

(ii) State **two** reasons why repeating the readings will improve the results for T.

(2)

By taking two or more. readings the random error could be reduced because it is averaged out.

Repeating the readings will ~~make~~ allow us to find out an outlier because comparison can be made.

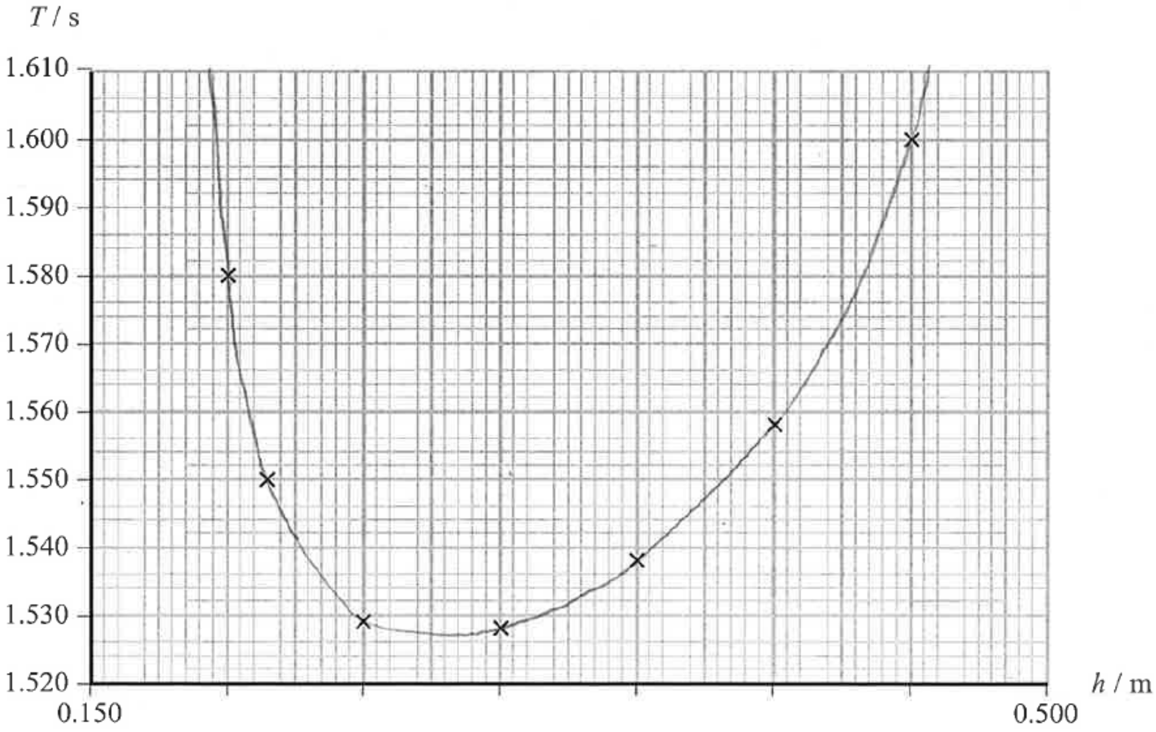
Examiner comments

(i) This is not a correct method so scores 0.

(ii) The student refers to both reducing random errors and finding anomalies, so scores 2 marks.

Answers to part b)

Student answer A



(i) Draw a line of best fit on the graph.

(1)

(ii) Use your line to determine the value of h that would produce the smallest value of T.

Record these values.

(2)

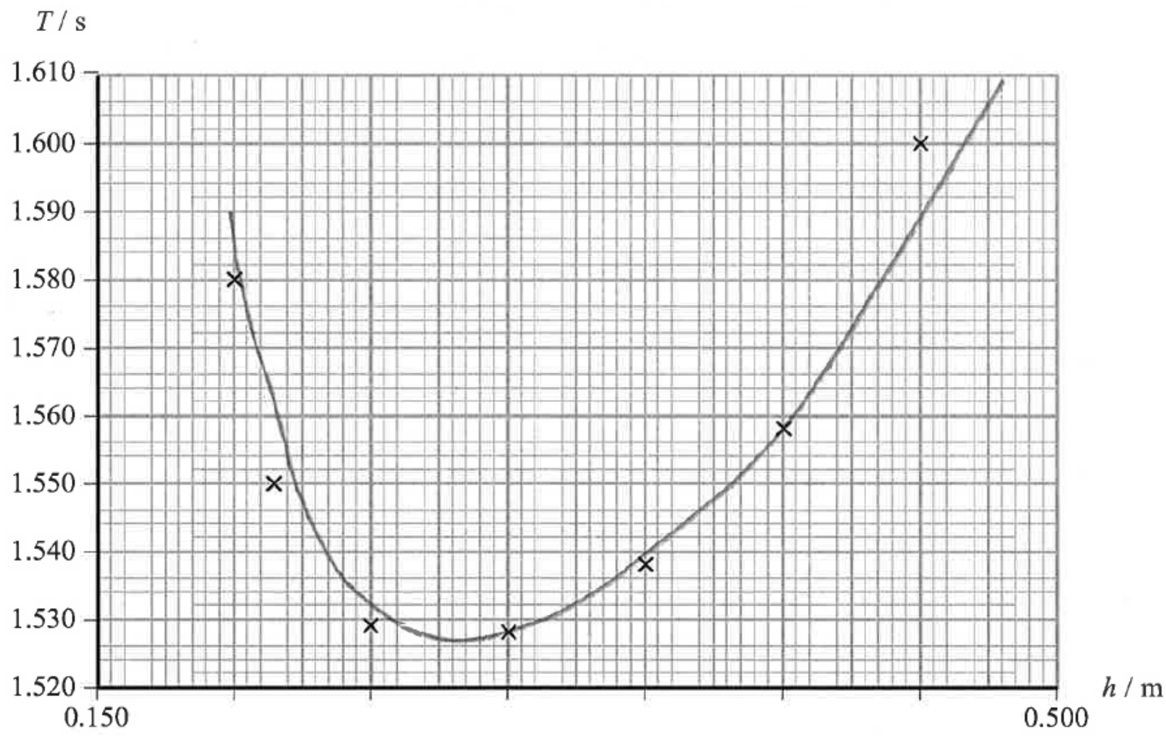
$h =$ 0.250m $T =$ 1.529s

Examiner comments

(i) A good line of best fit scores 1 mark.

(ii) The values given are taken from the table and has not read the minimum as drawn on the graph, so this answer scores 0.

Student answer B



(i) Draw a line of best fit on the graph.

(1)

Record these values.

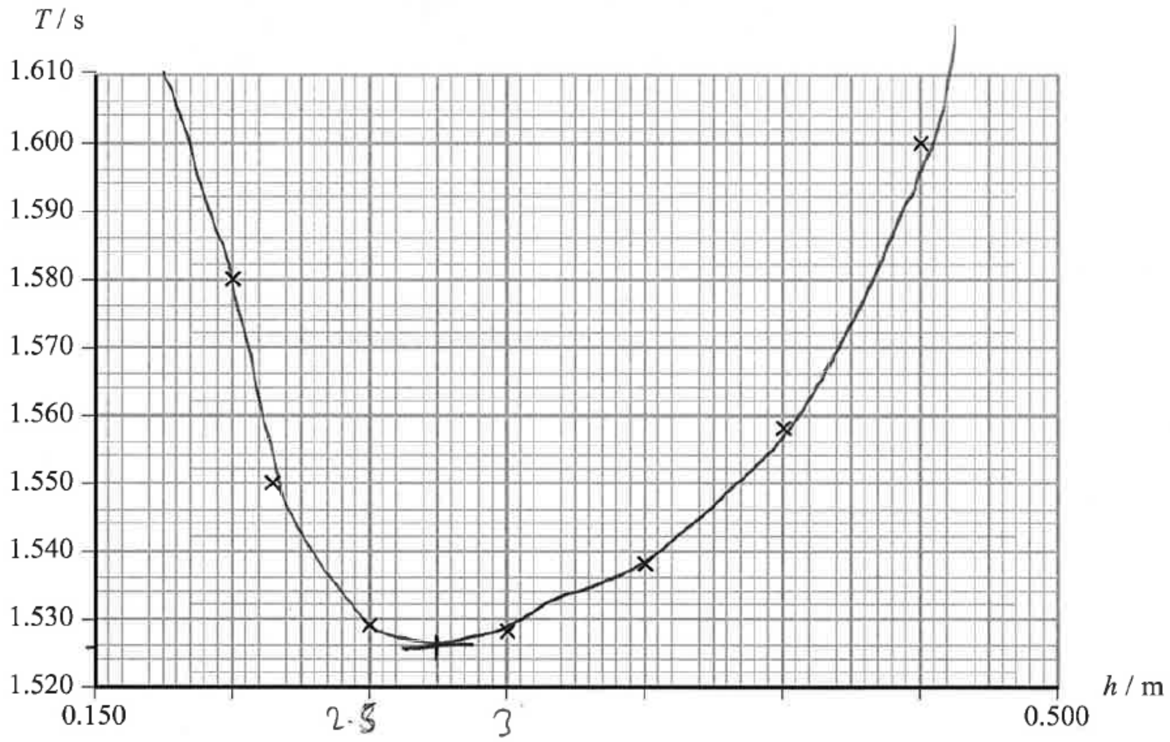
h = ...0.125.... T = ...0.526....

Examiner comments

(i) The line of best fit is poor as it misses a number of points, so scores 0.

(ii) The candidate has misread both values of their minimum. Their readings should be 1.526 s and 0.285 m. This student would have benefited from adding numbers to the x axis. Students should always read graphs to the maximum number of significant figures, in this case 4 on the y-axis and 3 on the x-axis.

Student answer C



(i) Draw a line of best fit on the graph.

(1)

T – 1.526

h – 2.75

(ii) Use your line to determine the value of *h* that would produce the smallest value of *T*.

Record these values.

(2)

h = 2.75 *T* = 1.526

Examiner comments

(i) The line is not smooth and the minimum point is unclear so scores 0.

(ii) The readings are correct and given to an appropriate number of significant figures so scores 2 marks. Because the units are show on the graph there is un unit error applied here.

Answers to part c)

Student answer A

(c) The graph of T against h does **not** produce a straight line.

The variables T and h are related by

$$T^2 h = 4\pi^2 h^2/g + C$$

where C is a constant.

Describe a graphical method to determine a value for C and state the unit for C.

(3)

Can plot a graph of T^2h against h^2,
C will be the intercept at $h^2=0$.
the unit of C will be ms^2.

Examiner comments

This example scores all 3 marks. The intercept at $h^2 = 0$ is an acceptable alternative for the second marking point.

Student answer B

(c) The graph of T against h does **not** produce a straight line.

The variables T and h are related by

$$T^2 h = 4\pi^2 h^2/g + C$$

where C is a constant.

Describe a graphical method to determine a value for C and state the unit for C.

(3)

Unit for C is s^2m

~~Plo~~ Plot a graph of $T^2h = 4\pi^2h^2/g$. From there a curve will be obtained. Compare the graph of $T^2h = 4\pi^2h^2/g$ with the graph of $T^2h = 4\pi^2h^2/g + C$. The difference in ~~height~~ y-axis will be the value of C.

Examiner comments

This response scores the final marking point, for the correct unit, only.

Student answer C

(c) The graph of T against h does **not** produce a straight line.

The variables T and h are related by

$$T^2 h = 4\pi^2 h^2/g + C$$

where C is a constant.

Describe a graphical method to determine a value for C and state the unit for C.

(3)

- Plot graph of T^2h against h^2
- linear graph should be produced with gradient $\frac{4\pi^2}{g}$ and y intercept C.

Examiner comments

The student correctly identifies the graph to plot and the "Y intercept" is taken to mean the intercept on the T^2h axis so the first two marks are awarded. There is no reference to the unit so the third mark is not given.

Exemplar question 3

A physicist investigates how light intensity varies with distance from a light bulb. She sets up the apparatus as shown.

(a) Explain why the resistance R of the LDR will increase as it gets further away from the bulb.

(2)

(b) The relationship between R and d is given by

$$R = \mathrm{k}\, d^{\,\mathrm{p}}$$

where k and p are constants.

Explain why a graph of ln R against ln d should give a straight line.

(2)

(c) She measures R for different values of d and records the following results.

d / **m**	***R*** / **kΩ**		
1.00	1.79		
1.20	2.24		
1.60	3.32		
2.00	4.04		
2.60	5.50		

(i) Plot a graph of ln R against ln d. Use the columns provided to show any processed data.

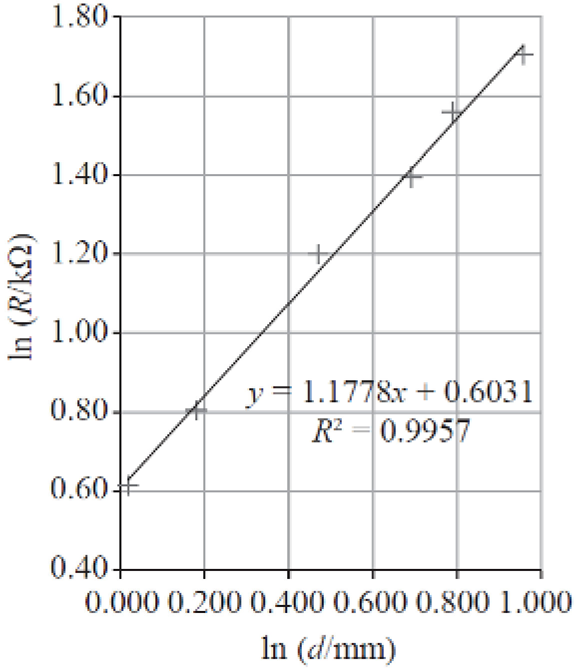
(5)

(ii) Determine the mathematical relationship between R and d.

(4)

Mark scheme

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>3 (a)</td><td>An explanation that makes reference to the following points:
• Resistance increases with decreasing intensity (1)
• As distance increases light intensity decreases so resistance increases (1)</td><td></td><td>2</td></tr>
<tr><td>3 (b)</td><td>An explanation that makes reference to the following points:
• Shows expansion ln R = p ln(d) + ln(k) (1)
• Compares with y = mx+ c and states that the gradient is p which is constant (1)</td><td></td><td>2</td></tr>
<tr><td>3 (c)(i)</td><td>• Ln values correct and to 3 or 4 SF (1)
<table><tr><th>d/m</th><th>R/kΩ</th><th>ln (d/m)</th><th>ln (R/kΩ)</th></tr><tr><td>1.00</td><td>1.79</td><td>0.000</td><td>0.582</td></tr><tr><td>1.20</td><td>2.24</td><td>0.182</td><td>0.806</td></tr><tr><td>1.60</td><td>3.32</td><td>0.470</td><td>1.200</td></tr><tr><td>2.00</td><td>4.04</td><td>0.693</td><td>1.396</td></tr><tr><td>2.20</td><td>4.70</td><td>0.788</td><td>1.548</td></tr><tr><td>2.60</td><td>5.50</td><td>0.956</td><td>1.705</td></tr></table>• Labels and unit (1)
• Scales (1)
• Plots (1)
• Line of best fit (1)</td><td>See marking guidance for graph plotting</td><td>5</td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
3 (c)(i) (continued)			
3 (c) (ii)	• Finds gradient with large triangle – at least half the plotted length **(1)** • $1.13 < p < 1.23$ to 2/3 SF and no units **(1)** • Obtains $k = 1.8$ **(1)** • States relationship between R and d **(1)**		**4**

Answers to part a)

Student answer A

(a) Explain why the resistance R of the LDR will increase as it gets further away from the bulb.

(2)

More light means less resistance. So as the bulb moves further ~~t~~ away the intensity of the light hitting the LDR will be reduced, thus increasing the resistance.

Examiner comments

The first sentence is the converse of the mark scheme which is acceptable. This answer scores both marks.

Student answer B

(a) Explain why the resistance R of the LDR will increase as it gets further away from the bulb.

(2)

the ~~luminosity~~ power output of the bulb spreads out radially outwards apparent light intensity around the whole surface of the bulb, following the equation $I = \frac{L}{4\pi d^2}$. As the distance d from the bulb increases, the perceived / apparent light intensity I decreases, since they are inversely proportional: ~~like the~~ (4π and L are constants, so) $I \propto \frac{1}{d^2}$

Examiner comments

This is a very good explanation of the inverse square law but it does not answer the question since there is no mention of resistance and so scores 0.

Student answer C

(a) Explain why the resistance R of the LDR will increase as it gets further away from the bulb.

(2)

When light energy decreases as light source gets away from LDR, the particles in resistor gets less excited and hence, causing more resistance.

> **Examiner comments**
> This student refers to light energy rather than light intensity and so does not score any marks.

Answers to part b)

Student answer A

(b) The relationship between R and d is given by

$$R = k\,d^{p}$$

where k and p are constants.

Explain why a graph of ln R against ln d should give a straight line.

(2)

If you log both sides: $\ln R = \ln k + \ln d^{p}$

$$\underbrace{\ln R}_{y\text{-axis}} = \underbrace{\ln k}_{\text{constant}} + \underbrace{p}_{\text{gradient!}}\underbrace{\ln d}_{x\text{-axis}}.$$

$$y = c + mx$$

> **Examiner comments**
> A clear answer that scores both marks. The equation for a straight line has been written in the correct order for the ln equation and the terms have all been clearly identified.

Student answer B

(b) The relationship between R and d is given by

$$R = \mathrm{k}\, d^{\,\mathrm{p}}$$

where k and p are constants.

Explain why a graph of $\ln R$ against $\ln d$ should give a straight line.

(2)

$R = kd^p$

$\ln R = \ln k + p \ln d$ is related by straight line equation

$Y = mX + C.$

Examiner comments

This scores the first mark for the correct equation but the links to y = mx + c have not been clearly made, nor is there a reference to the gradient being p.

Student answer C

(b) The relationship between R and d is given by

$$R = \mathrm{k}\, d^{\,\mathrm{p}}$$

where k and p are constants.

Explain why a graph of $\ln R$ against $\ln d$ should give a straight line.

(2)

$R = kd^p$

$\ln(R) = \ln(kd^p)$

$= \ln k + \ln d^p$ → Straight line eqn.

$\ln R = \ln k + p \ln d$

$\ln(R) = p \ln(d) + \ln(k)$

$y = m x + c$

Examiner comments

First mark again. The links to the equation are made by the way the ln equation is written but the specific statement that the gradient is p is not made.

Answers to part c)

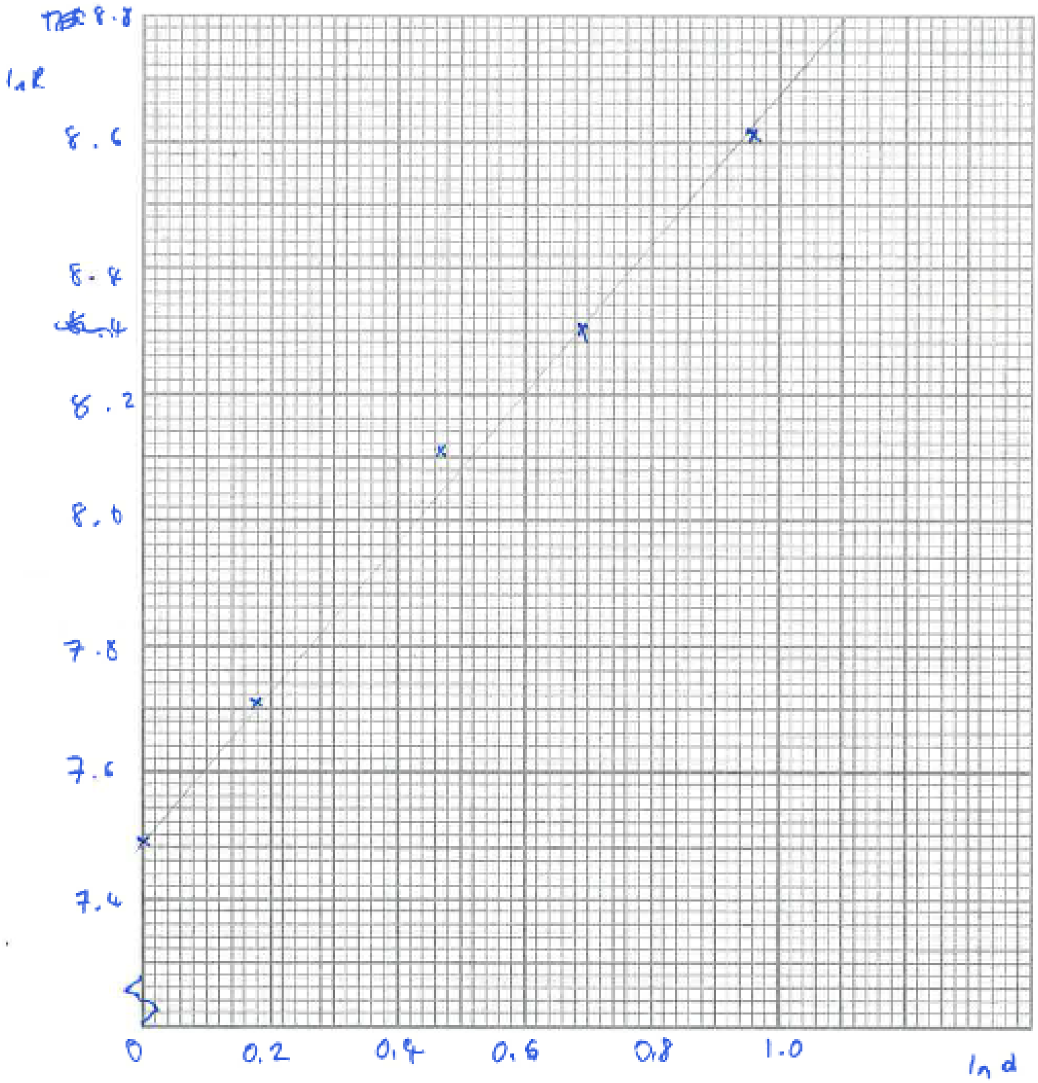
Student answer A

(c) She measures R for different values of d and records the following results.

d/m	R/kΩ	ln R	ln d
1.00	1.79	7.49	0
1.20	2.24	~~6~~7.71	0.18
1.60	3.32	8.11	0.47
2.00	4.04	8.30	0.69
2.60	5.50	8.61	0.95

(i) Plot a graph of ln R against ln d. Use the columns provided to show any processed data.

(5)



(ii) Determine the mathematical relationship between R and d.

(4)

$\frac{8.67 - 7.49}{1} = 1.18$

$\ln R = 1.18 \ln d + 7.49$

$R = d^{1.18} + e^{7.49}$

Examiner comments

(i) The number of significant figures in the table is only 2 instead of 3 for ln d

The units on the axes are wrong, they should be ln (R/Ω) and ln (d/m)
The scales, plots and line of best fit score the marks, giving 3 for this section.

(ii)Values used to finds the gradient show that a large triangle has been used but no antilog from intercept was worked out so this scores the 2 gradient marks.

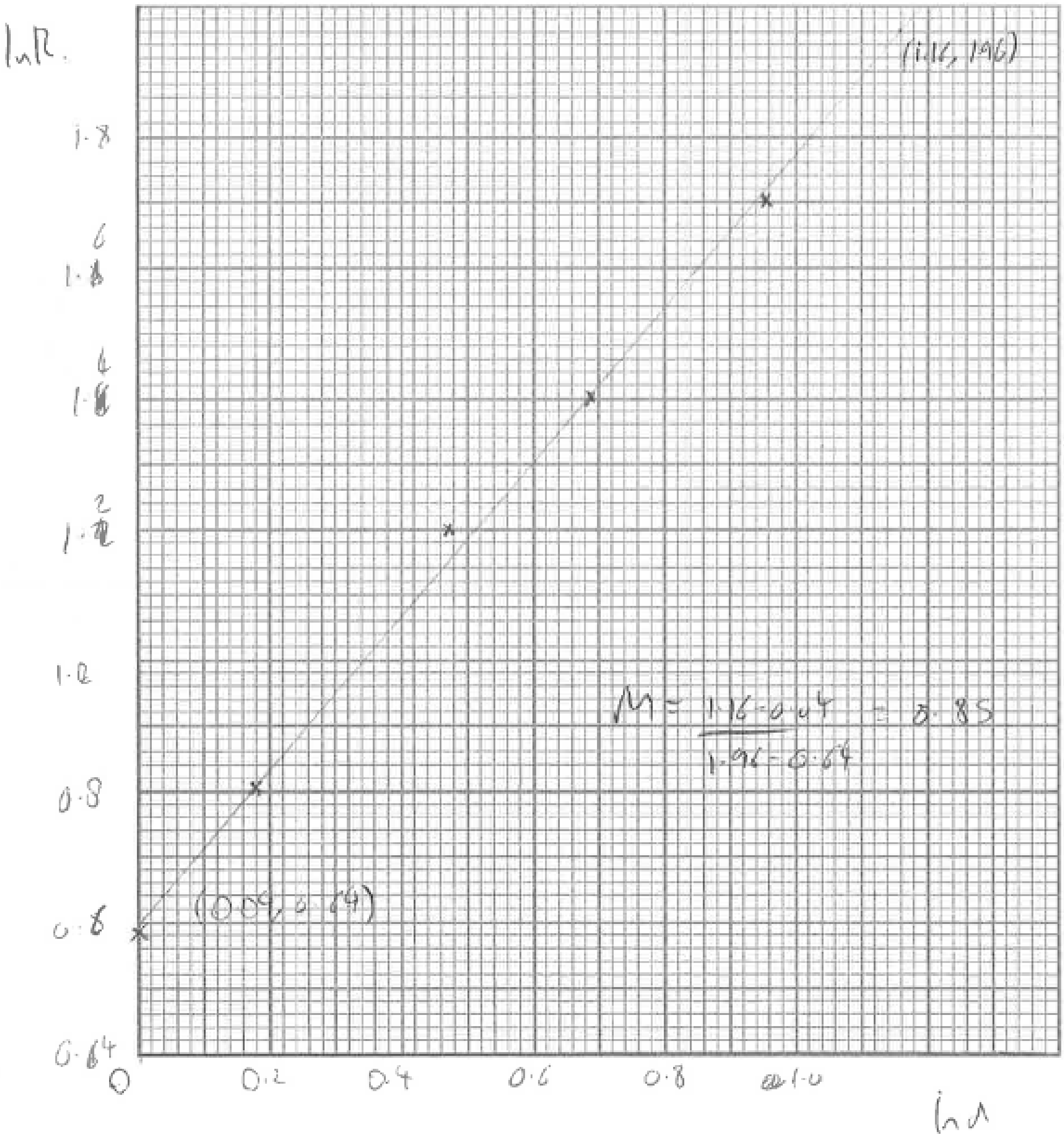
Student answer B

(c) She measures R for different values of d and records the following results.

d / m	R / kΩ	ln d	ln R
1.00	1.79	0	0.5822
1.20	2.24	0.182	0.806
1.60	3.32	0.470	1.200
2.00	4.04	0.693	1.400
2.60	5.50	0.956	1.705

(i) Plot a graph of ln R against ln d. Use the columns provided to show any processed data.

(5)



(ii) Determine the mathematical relationship between R and d.

(4)

$\ln R = p \ln d + \ln k$.

$\ln k = 0.6$ $\quad k = 1.82$

$p = m = 0.85$. $\therefore$ $R = 1.82 \times d^{0.85}$

Examiner comments

(i) There are no units on the graph but this scores the other 4 marks.

(ii) The student misreads values for gradient calculation so does not get the first 2 marks. Antilogs are taken so k is found but the last mark is for the correct relationship only. This scores 1 mark.

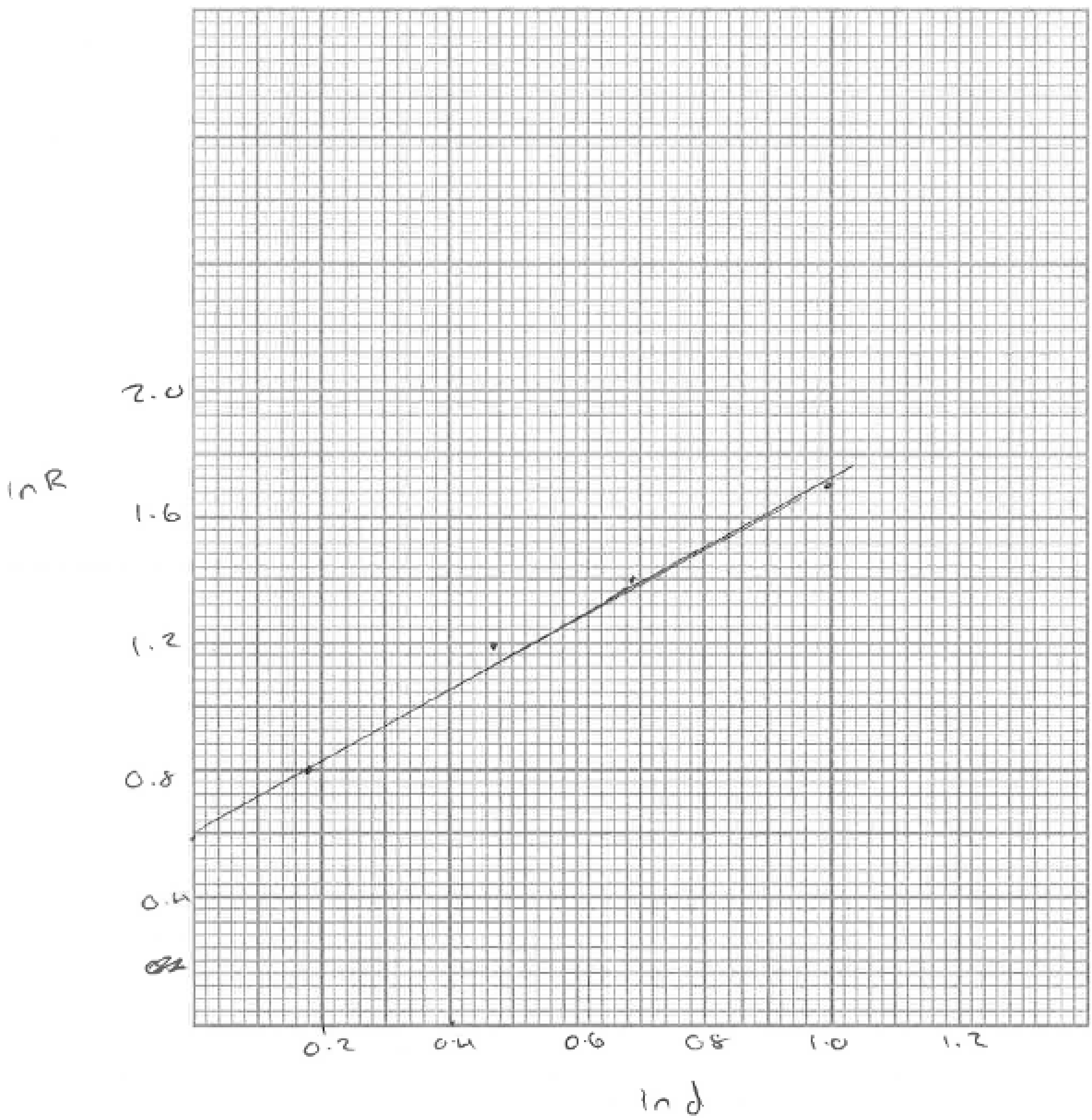
Student answer C

(c) She measures R for different values of d and records the following results.

d/m	R/kΩ	ln d	ln R
1.00	1.79	0	0.58
1.20	2.24	0.18	0.8
1.60	3.32	0.47	1.20
2.00	4.04	0.69	1.40
2.60	5.50	0.96	1.70

(i) Plot a graph of ln R against ln d. Use the columns provided to show any processed data.

(5)



(ii) Determine the mathematical relationship between R and d.

(4)

$\ln R = p \ln d + \ln k$

as p and k constant and constant gradient,

$\therefore R \propto d$ (R directly proportional to d)

Examiner comments

This scores no marks. (i)The number of significant figures is wrong, there are no units on the graph, the plotted points cover less than half of the graph paper, only 5 points have been plotted and it is not the line of best fit.(ii) no mathematical work so zero marks.

Exemplar question 4

The photograph shows a tea cup on a saucer.

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A student notices that walking with this sort of tea cup when it is filled with tea is particularly difficult to do without spilling it.

While walking, the tea starts to oscillate from side to side in the cup, rapidly increasing in amplitude and spilling over the edge.

The student develops the hypothesis that spillage occurs most when the frequency of the steps taken by a person matches the natural frequency of oscillation of tea in the cup.

(a) Explain whether the student's hypothesis is supported by relevant physics.

(4)

*(b) (i) Devise an experiment to investigate the hypothesis.

(6)

(ii) Describe how the measurements taken will be used to come to a conclusion.

(3)

Mark scheme

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>4 (a)</td><td>An explanation that makes reference to the following points:
Resonance is occurring… (1)
…when the driving frequency/forced vibration (at walking frequency) matches the natural frequency … (1)
…energy transfer is maximum (1)
Supporting the observation that the amplitude rapidly increases (1)</td><td></td><td>4</td></tr>
<tr><td>4 (b)(i)*</td><td>This question assesses a student’s ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.

<table><tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr><tr><td>6</td><td>4</td></tr><tr><td>5–4</td><td>3</td></tr><tr><td>3–2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table></td><td>Guidance on how the mark scheme should be applied:

The mark for indicative content should be added to the mark for lines of reasoning. For example an answer with five indicative marking points which is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</td><td>6</td></tr>
</table>

<table>
<tr><th>Question number</th><th>Acceptable answers</th><th>Additional guidance</th><th>Mark</th></tr>
<tr><td>4 (b)(i)*
(continued)</td><td>The following table shows how the marks should be awarded for structure and lines of reasoning.
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr>
<tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td></td><td></td></tr>
</table>

Question number	Acceptable answers	Additional guidance	Mark
4 (b)(i)* (continued)	**Indicative content** • Determine the natural frequency by displacing the tea in the cup and measuring the time for oscillations • Time (5 to 10 or 'suitable number' if test run mentioned) full oscillations and divide by the number • Carry the tea for a known volume of tea for fixed number of steps at a steady pace • Determine the frequency of the gait • Measure the quantity of tea remaining • Repeat for other walking paces		
4 (b)(ii)	A description that makes reference to the following points: • Plot volume of remaining tea against walking frequency **(1)** • Determine whether there is a relationship between step frequency and spillage **(1)** • If there is, determine whether maximum spillage occurs at or near the natural frequency **(1)**		**3**

Answers to part a)

Student answer A

(a) Explain whether the student's hypothesis is supported by relevant physics.

(4)

The student's hypothesis is supported by relevant physics which is the resonance frequency. When the frequency of steps is equal to the natural frequency of oscillation, the tea ~~to~~ in the cup will receive maximum energy produced by the steps and hence spilling out from cup.

Examiner comments

This scores the first three marking points but there is no link between the maximum energy and amplitude.

Student answer B

(a) Explain whether the student's hypothesis is supported by relevant physics.

(4)

~~At~~ When the driving force (the persons steps) matches the natural frequency, the amplitude increases dramatically ~~k~~ due to resonance.

~~The students~~ Hence at the ~~reson~~ natural frequency the tea will oscillate will larger amplitudes, spilling over the edge.

Examiner comments

No reference to maximum energy transfer (marking point 3) but scores the other 3 marks.

Student answer C

(a) Explain whether the student's hypothesis is supported by relevant physics.

(4)

Resonance occurs when the ~~natural~~ applied frequency (frequency of steps) is equal to the natural frequency of the system (tea in cup). ~~Resona~~ The amplitude increases as the ~~natural~~ applied frequency gets closer to the ~~system~~ ~~..~~ natural frequency. Maximum amplitude of the system is reached when ~~the site~~ resonance occurs.

Examiner comments

The first sentence scores marking points 1 & 2. There is no reference to maximum energy transfer or the student's hypothesis.

Answers to part b)

Student answer A

*(b) (i) Devise an experiment to investigate the hypothesis.

(6)

Allow the cup to oscillate naturally on the saucer and record the oscillations over a certain period of time. Use this to calculate the number of oscillations per second ~~and~~ which is the natural frequency. Then, apply a range of frequencies to the cup on the saucer by changing the rate, frequency of the ~~ft~~ steps taken by the person holding it, using applied frequencies equal to and above and below the natural frequency.

(ii) Describe how the measurements taken will be used to come to a conclusion.

(3)

If the amplitude of vibration reaches a maximum when the frequency of the steps taken is equal to the measured natural frequency of the cup, then the hypothesis can be considered correct.

Examiner comments

(i)This scores marking points 1 and 6 for the idea of measuring the natural frequency and repeating over a range of other frequencies. This answer lacks any practical details such as how to measure the frequency and how to measure the amount of tea spilt. Although much detail is missed, what is written is clear and logical so scores 1 mark for linkage. This means 2 marks for content + 1 mark for linkage = 3marks.
(ii)There is nothing of merit in the answer.

Student answer B

*(b) (i) Devise an experiment to investigate the hypothesis.

(6)

• Mark the inside of a cup at 0.5cm intervals

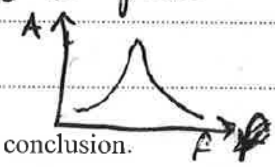
• Have someone walk with a tea cup at a low speed.

~~Mark~~ • Record which mark the tea reached (the mark will represent its amplitude).

• Repeat with ~~differe~~ person walking at different speeds: medium low, medium, medium high and high. Low speed means low frequency, medium low speed means medium low frequency and so on.

• Plot ~~the~~ graph of amplitude against frequency/ ~~speed~~

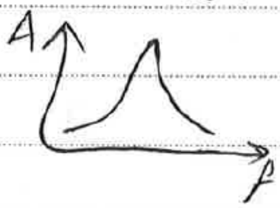
• Graph should have a ~~res~~: ~~peak shows if resonance occur~~. peak to prove resonance occurred.



(ii) Describe how the measurements taken will be used to come to a conclusion.

(3)

~~to~~ peak in ~~A-f~~ A against frequency means maximum amplitude was reached due to resonance. Shape of graph must be



Examiner comments

(i) This is awarded marking points 5 and 6, Although the markscheme refers to measuring the quantity of tea remaining, this student has attempted to measure amplitude which is an acceptable alternative. There is again some linkage so two content points means 2 marks and 1makr for linkage gives this answer 3 marks.

(ii) Nothing of merit.

Student answer C

*(b) (i) Devise an experiment to investigate the hypothesis.

(6)

Displace the tea in the cup ~~and~~ time 5 oscillations, ÷5 to get ~~tos~~ time for 1 = natural frequency. Measure volume of tea and walk at steady speed. Work out frequency of walking (steps per minute) and measure how much tea is in the cup. Put same ~~f~~ volume of tea in the cup and repeat for different speeds of walking.

(ii) Describe how the measurements taken will be used to come to a conclusion.

(3)

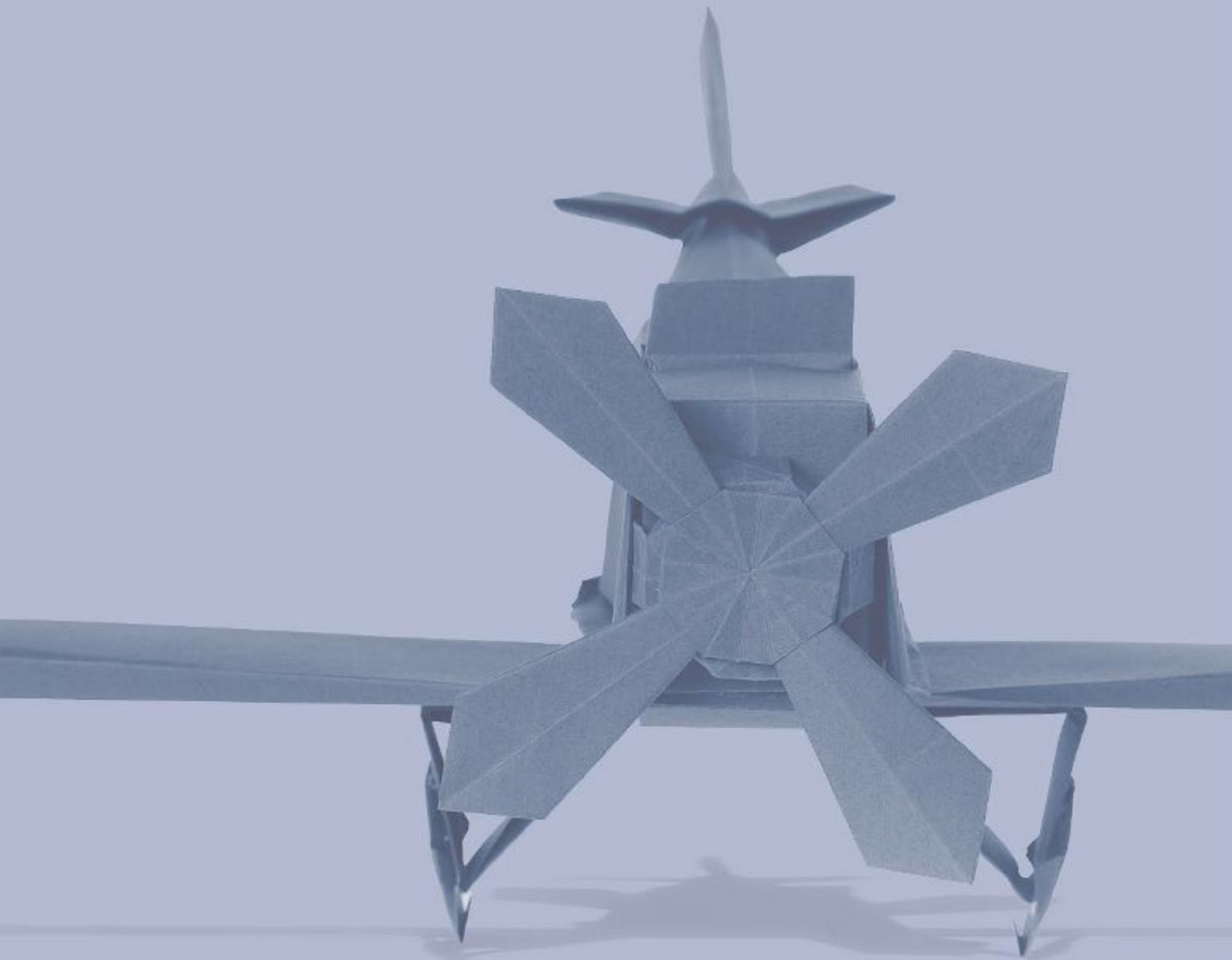
Plot a graph of volume of tea left against frequency of walking. Expect graph to have a peak at natural frequency if hypothesis correct

Examiner comments

This is an example of a good answer which has been written in terms of specific measurements to be taken.

(i) All of the physics points are covered so this gets the maximum 4 marks for content. The method is clear and logical so 2 linkage marks are also awarded giving a mark of 6

(ii) This gains marking points 1 and 3 but does not allow for the fact that there might not be any relationship between the frequency and volume of tea.



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