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AS LEVEL

Examiners' report

PHYSICS A

H[redacted]56
For first teaching in 2015

H156/01 Summer 2019 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates. The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report. A full copy of the question paper can be downloaded from OCR.

Paper 1 series overview

H156/01 is one of the two assessed components of AS Physics A. The component is worth 70 marks and is split into two sections. Section A contains 20 multiple choice questions (MCQs) and allows the breadth coverage of the specification. Section B includes short-answer style questions, problem solving, calculations and practical. The assessment of practical skills, as outlined in Module 1 (Development of practical skills in physics) and Module 2 (Foundations of physics), forms an integral part of the assessment. The Data, Formulae and Relationships booklet forms a valuable resource in examination and allows candidates to demonstrate their application of physics without the need to rote learn physical data, equations and mathematical relationships. The weighting of this component is 50% and duration of the exam paper is 1 hour 30 minutes.

H156/02 component is characterised by its in-depth questions and includes two level of response (LoR) questions.

Overview of performance in Paper 1

The positive attributes of the candidates in this component were:

- Answering most of the multiple choice questions and making good use of the spaces provided to do any rough analysis or calculations.
- Good use of calculators, especially handling powers of ten.
- Well-structured solutions with clear manipulation of equations, good substitution and expressing the final answers to appropriate significant figures.
- Good comprehension of command terms such as *describe*, *explain*, *show*, etc.

There were some missed opportunities in this component. Candidates are reminded that they can maximise marks in future examinations by following some of the procedures below:

- Underline or circle key data within a question to help with the calculations.
- Do not round up, or down, numbers in the middle of long calculations. Try to retain all the digits on your calculator for subsequent stages of a calculation. Truncating numbers in the middle of calculations may result in the loss of marks.
- Make good use of technical and scientific vocabulary in descriptions and explanations. Using words like *photons*, *acceleration*, etc. can help you to succinctly get your physics across.
- Do not to just use labels (e.g. ϕ, f, etc.) in explanations and descriptions. It is good practice to either define the labels or, better still, just use the correct terms (e.g. *work function*, *frequency*, etc).
- Finally, be aware of the information available on the Data, Formulae and Relationship Booklet. In some questions, you need data from this booklet. For example, in the multiple choice question **5**, you need the value of the elementary charge 1.60×10^{-19} C and in Question **25(b)(i)** you need the mass of the electron 9.11×10^{-31} kg. There is no need to remember these values.

Note

From this series students have been provided with a fixed number of answer lines and an additional answer space. The additional answer space will be clearly labelled as additional, and is only to be used when required. Teachers are encouraged to keep reminding students about the importance of conciseness in their answers. Please follow this link to our SIU https://www.ocr.org.uk/administration/support-and-tools/siu/alevel-science-538595/

Section A overview

Section A contains 20 multiple choice questions (MCQs) from topics across the four modules of the specification. This section is worth 20 marks and you are expected to spend about 25 minutes.

Space is provided on the exam paper for any analysis or scribbling. It is important for candidates to insert their correct response in the square box provided.

All questions showed a positive discrimination, and the less able candidates could access the easier questions. MCQs require careful inspection. Candidates are allowed to annotate text and diagrams if it helps to get to the correct answer. No detailed calculations are expected on the pages, so any shortcuts, or intuitiveness, can be employed to get to the correct answers.

Questions **1**, **2**, **3**, **4, 6**, **7**, **12** and **18** proved to be particularly straightforward, allowing most of the candidates to demonstrate their knowledge and understanding of physics. At the opposite end, Questions **5**, **9** and **13**, proved to be more challenging, and as such, were only accessible to the top-end candidates.

Question 1

1 The table below shows four physical quantities and their units.

Which row is correct?

	Physical quantity	Unit
A	strain	pascal
B	charge	coulomb
C	power	joule
D	force constant	newton

Your answer ☐ **[1]**

This was an easy starting question for all the candidates. It was testing knowledge of S.I. units used in a range of topics. The majority of the candidates got the correct answer B. The most popular distractor was D, followed closely by A.

Question 2

2 Four students each carry out an experiment to determine the acceleration of free fall *g*.

Which is the **least** accurate value?

A $(9.0 \pm 1.0)\,\mathrm{m\,s^{-2}}$

B $(9.5 \pm 0.1)\,\mathrm{m\,s^{-2}}$

C $(9.6 \pm 0.4)\,\mathrm{m\,s^{-2}}$

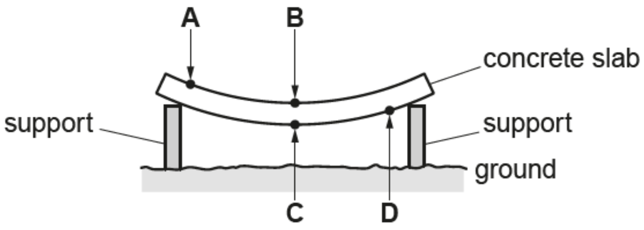
D $(9.7 \pm 0.2)\,\mathrm{m\,s^{-2}}$

Your answer ☐ **[1]**

This question was based on understanding the term accuracy; a key concept in practical skills. The majority of the candidates got the correct answer A. The difference between the accepted value for *g* and the experimental value was greatest for A. The most popular distractor was B, where candidates took 'least accurate' to mean the value with the least percentage uncertainty. Some candidates even had the percentage uncertainties calculated for each of the options.

Question 3

3 A uniform concrete slab is placed on two supports. The slab sags due to its own weight.



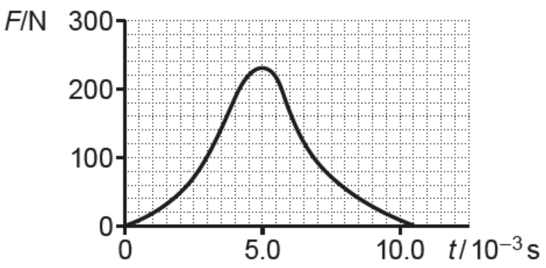
Which point, **A**, **B**, **C** or **D**, of the slab is under maximum compression?

Your answer ☐ **[1]**

This question was based on the simple understanding of compression of material in the form of a concrete slab. About two thirds of the candidates opted for the correct answer B. The majority of the remaining candidates opted for C. Point C of the slab would be under maximum tension. Only a very small number of candidates, mainly from the lower quartile, went for either A or D.

Question 4

4 The variation with time t of the force F acting on a ball is shown below.



Which statement is **not** correct?

A The area under the graph is equal to the work done by the force F.

B The ball has maximum acceleration at $t = 5.0 \times 10^{-3}$ s.

C The area under the graph is equal to impulse.

D The area under the graph has units kg m s^{-1}.

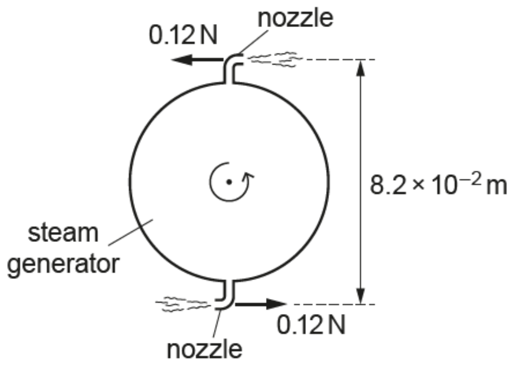
Your answer ☐ **[1]**

This question was based on a force-time graph for a ball. All the information that can be extracted from the graph. The majority of the candidates inserted A in the answer box, and secured 1 mark. All the other statements are correct. The statement B is correct, because the maximum acceleration of the ball is proportional to the maximum force. The area under a force-time graph is impulse, so statement C is correct. The area under the graph is also equal to change in momentum, therefore the area under the graph does have the unit's kg m s^{-1}. So, statement D is also correct.

Statement A is incorrect. Work done is the area under a force-distance graph, but here the horizontal axis has **time**, and not **distance**.

Question 5

5 The diagram below shows a rotating steam generator.



The steam ejected from the nozzles provides a couple. The force at each nozzle is 0.12 N. The perpendicular distance between the nozzles is 8.2×10^{-2} m.

What is the work done by the forces as the steam generator completes one revolution?

A 0 J

B 9.8×10^{-3} J

C 3.1×10^{-2} J

D 6.2×10^{-2} J

Your answer ☐ **[1]**

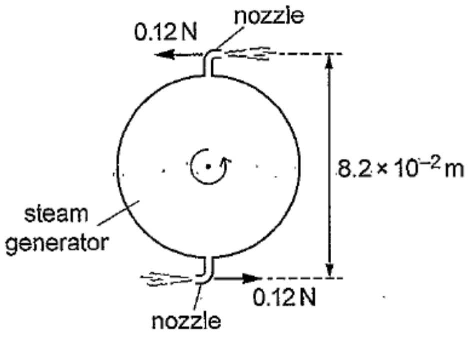
This question was based on work done by a couple, and as such proved to be quite challenging. The work done by the couple is given by the expression below:

$$\text{work done} = 2 \times \text{work done by each force} = 2 \times [0.12 \times \pi \times 8.2 \times 10^{-2}] = 6.2 \times 10^{-2}\ \text{J}$$

The most popular answers turned out to be either A or C. The answer C was for the work done by one of the forces. This question was only accessible to the very top-end candidates. The exemplar 1 below shows an incorrect analysis that led to B being inserted into the answer box.

Exemplar 1

The diagram below shows a rotating steam generator.



The steam ejected from the nozzles provides a couple. The force at each nozzle is 0.12 N. The perpendicular distance between the nozzles is 8.2×10^{-2} m.

What is the work done by the forces as the steam generator completes one revolution?

A 0 J ✗

B 9.8×10^{-3} J

C 3.1×10^{-2} J

D 6.2×10^{-2} J

$W = F \times d$

$0.12 \times 8.2 \times 10^{-2}$

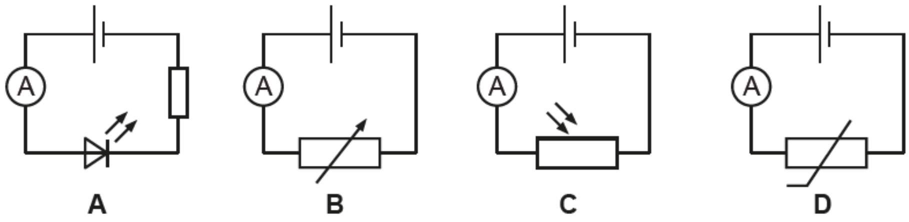
$= 9.8 \times 10^{-3}$

Your answer: B **[1]**

The candidate has either written the equation for work done, or torque of a couple. Substitution shows that the torque has been calculated. Unfortunately, the response of 9.8×10^{-3} J was there as one of the options. This exemplar shows that if the starting point is incorrect, it can easily lead to what looks like a promising response.

Question 6

6 Which circuit below can be used to monitor the variation of light intensity in a room?



Your answer [1]

This question was based on recognising circuit symbols. This was successfully answered by the vast majority of the candidates who opted for C because of the light-dependent resistor in the circuit. The popular distractor was A. The light-emitting diode in circuit A was often mistaken for a light-dependent resistor.

Question 7

7 A household is planning to change all their 60 W filament bulbs to 12 W LED bulbs.
The household has a total of 10 bulbs.
Each bulb will be used for about 2000 hours in one year.
The cost of 1 kWh is 15.4 p.

What would the annual saving be?

A £7.39

B £36.96

C £147.84

D £184.80

Your answer [1]

This was a tough question on the kilowatt hour, but almost all candidates picked up a mark here. On most scripts there were not much evidence of number crunching; calculations must have been done on calculators – sensible time saving strategy. Some candidates did use elaborate routes to get to the correct answer of C. The annual saving in pounds (£) is calculated as follows:

$$\text{annual savings} = (0.060 - 0.012) \times 10 \times 2000 \times 0.154 = £147.84$$

It is worth pointing out the rationale behind the distractors. A was the answer when the 2000 had been omitted from the calculation above. B was the answer for just using 12 W and finally D was the answer for just using 60 W.

Question 9

9 The resistance of a wire of length L is 3.00 Ω.
The wire is extended so that its length becomes 1.50L. Its volume remains the same.

What is the resistance of the extended wire?

A 2.00 Ω

B 3.00 Ω

C 4.50 Ω

D 6.75 Ω

Your answer ☐ **[1]**

This question was about the resistance equation $R = \frac{\rho L}{A}$ which appears in the Data, Formulae and Relationship Booklet. This was a good discriminator for the top-end candidates. The majority of the candidates opted for the answer C, which was simply 1.50 times the original resistance of the wire. The crucial statement that the 'volume of the wire remains the same' was omitted by most candidates.

The volume of the wire remains constant. The cross-sectional area of the wire will decrease by a factor of 1.50 as its length increases by this same factor. Since resistance $R \propto \frac{L}{A}$, this implies that the resistance of the stretched wire will increase by a factor of 1.50^2. This makes the resistance of the extended wire equal to $1.50^2 \times 3.00 = 6.75\ \Omega$.

The analysis above shows how it is easy to follow incorrect logic when a single pivotal statement in the question is skimmed over.

Question 12

12 The table shows the refractive index n of four transparent materials **A**, **B**, **C** and **D**.

Which material has the **smallest** critical angle?

Material	**A**	**B**	**C**	**D**
n	2.01	1.87	1.60	1.33

Your answer ☐ **[1]**

This question was about the critical angle and refractive index equation $\sin C = 1/n$ which appears in the Data, Formulae and Relationship Booklet. The majority of the candidates realised that the largest value of the refractive index would give the smallest critical angle. The answer had to be A. It was good to see the equation above scribbled on many of the scripts.

Question 13

13 The frictional force acting on an object falling vertically through water is directly proportional to its speed squared.

What is the correct relationship between P, the rate of work done against the frictional force, and the speed v of the object?

A $P \propto v^{-1}$

B $P \propto v$

C $P \propto v^2$

D $P \propto v^3$

Your answer [ ] **[1]**

This question is based on the equation $P = Fv$, which also appears in the Data, Formulae and Relationship Booklet. In the question, information is given about the frictional force F, which is directly proportional to v^2. Therefore, the rate of work done P must be proportional to v^3; making D as the answer. Most candidates struggled with this question, with all the distractors being equally popular. Less than a quarter of the candidates, mainly from the upper quartile, scored a mark in this question. The exemplar 2 below the correct response from a candidate.

Exemplar 2

The frictional force acting on an object falling vertically through water is directly proportional to its speed squared.

What is the correct relationship between P, the rate of work done against the frictional force, and the speed v of the object?

A $P \propto v^{-1}$

B $P \propto v$

C $P \propto v^2$

D $P \propto v^3$

$F \propto v^2$

$F = kv^2$

$P = Fv$

$P = kv^3$

Your answer [D] **[1]**

This candidate demonstrates how this question can be tackled with minimal amount of work. The key equation is on the script, as is the relationship between F and v. The final answer appears in the box; a perfect technique.

Question 18

18 A ball of diameter 2.50 cm is held above the ground. The bottom of the ball is 10.2 cm above the ground. The ball is released from rest.
Air resistance has negligible effect on the motion of the ball.

What is the time taken for the ball to reach the ground?

A 0.021 s

B 0.144 s

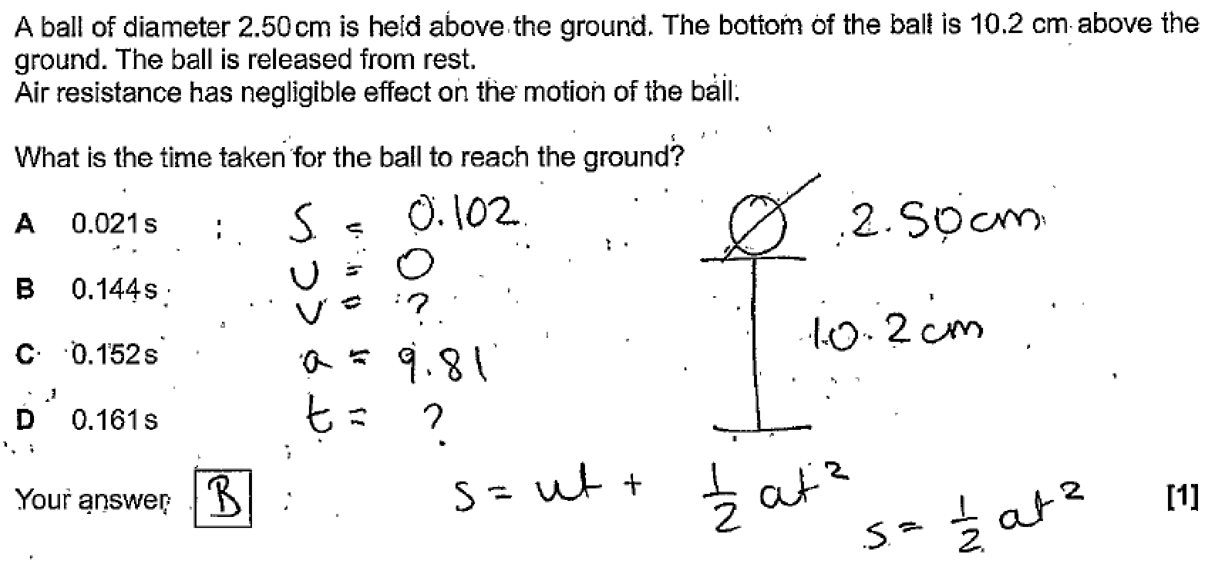
C 0.152 s

D 0.161 s

Your answer ☐ **[1]**

This question required knowledge and understanding of equations of motions. The simplest route to getting the correct answer was the equation $s = \frac{1}{2}at^2$ with the displacement $s = 0.102$ m. About two thirds of the candidates got the correct answer B. All the other distractors were based on using incorrect values for s. For example, the answer would have been D for $s = 12.7$ cm. The exemplar 3 below shows a typical working for a correct answer.

Exemplar 3


A ball of diameter 2.50 cm is held above the ground. The bottom of the ball is 10.2 cm above the ground. The ball is released from rest.
Air resistance has negligible effect on the motion of the ball.

What is the time taken for the ball to reach the ground?

A 0.021 s

B 0.144 s

C 0.152 s

D 0.161 s

Your answer B **[1]**

This exemplar illustrates relevant scribbling in a multiple choice answer can lead to the correct response. It is good to see that the candidate has focused on the correct distance of 0.102 m. The equation is there, as are the key numbers. The candidate had saved some time by finishing off the calculation on his/her calculator. A perfect technique from this candidate.

Section B overview

Section B includes short-answer style questions, problem solving, calculations and practical. This section is worth 50 marks and you are expected to spend about 1 hour 5 minutes.

Question 21 (a)

21 **(a)** For a system to be in equilibrium, the resultant force must be zero.

State another condition that must be satisfied for the system to be in equilibrium.

....

.... **[1]**

Most candidates struggled with this opening question. Only a third of the candidates picked up a mark for 'resultant moment = 0'. A small number of candidates spoilt their answers by mentioning momentum rather than moment. A statement for the principle of moments was allowed.

?	**Misconception**	The two most popular incorrect responses for the second condition for equilibrium were: • The system has no external forces acting. • The object must be travelling with constant speed.

Question 21 (b) (i)

(b) Fig. 21.1 shows a ball at **rest** on a horizontal table.

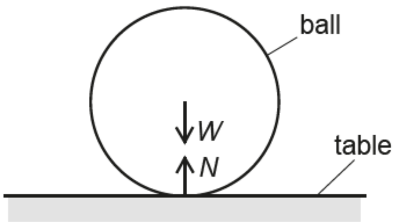


Fig. 21.1

The weight of the ball is W and the normal contact force on the ball is N.

(i) According to Newton's third law of motion, W is one of the forces in a pair of equal and opposite forces.

Name the object that experiences a force of magnitude W but in the opposite direction to W.

.... **[1]**

This question was poorly answered, with only the very top candidates realising that it was the Earth experiencing the force W in the opposite direction. 'Ground' instead of the Earth was allowed by examiners – but such answers were extremely rare. Newton's third law remains enigmatic to many candidates. The most popular incorrect answers were 'ball' and 'table'.

Question 21 (b) (ii)

(ii) According to a student, $W = N$ is a consequence of Newton's third law of motion.

State why this is incorrect.

.... **[1]**

Examiners were looking for the idea that in Newton's third law, the pair of forces were of the same type and had to act on two separate objects. The force W is a **gravitational** force and N is the normal contact force is an **electrostatic** force between the base of the ball and the top of the table. The variety of incorrect answers demonstrated the lack of comprehension of this law. The two exemplars below show answers from a top-end candidate and a candidate securing a middle-grade.

Exemplar 4

According to a student, $W = N$ is a consequence of Newton's third law of motion.

State why this is incorrect.

W and N are not the same type of forces and this is not a consequence of Newton's third law of motion. **[1]**

In this exemplar from a top-end candidate, the response is half of the total response, but it was given 1 mark by the examiners. Some candidates went a step further by mentioning that W is a gravitational force and N is an electrostatic force.

Exemplar 5

According to a student, $W = N$ is a consequence of Newton's third law of motion.

State why this is incorrect.

There was no force applied on the ball to cause a equal and opposite force. **[1]**

This illustrates a strange response from a low-grade candidate. It shows poor understanding of this important law. There is nothing worthy here for credit.

Question 21 (c) (i)

(c) Fig. 21.2 shows a model dolphin in a museum. The dolphin is held in equilibrium by two cables **A** and **B**.

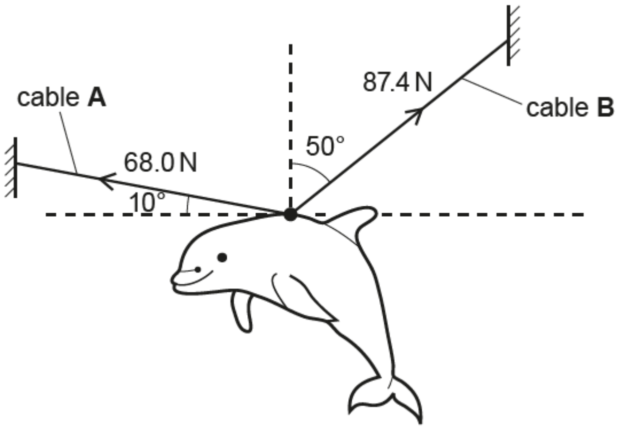


Fig. 21.2

The tension in cable **A** is 68.0 N and it makes an angle of 10° to the horizontal. The tension in cable **B** is 87.4 N and it makes an angle of 50° to the vertical.

(i) Calculate the **total** vertical force *F* supplied by cables **A** and **B** by resolving the tensions in cables **A** and **B**.

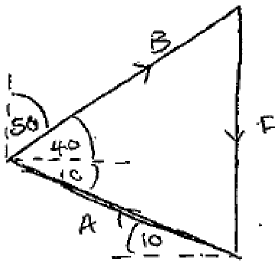
F = ... N **[2]**

The question has a clue for making a start on this question. Most candidates did resolve the two tensions in the cables vertically. The majority of the responses were well-structured and demonstrated excellent understanding of vectors. Although not straightforward, many candidates used the correct angle when determining the vertical components of the forces. The correct answer of 68.0 N appeared on most scripts. A small number of candidates got 1 mark for just getting one of the components correct.

A very small number of candidates got the correct answer by using trigonometry and triangle of forces. This is not what was expected, but full credit was given for this alternative approach. Correct responses will always score marks, even when the candidates choose not to go along the path designed by the examiners. This different approach is illustrated in the exemplar 6 below.

Exemplar 6

Calculate the **total** vertical force F supplied by cables **A** and **B** by resolving the tensions in cables **A** and **B**.



$F^2 = A^2 + B^2 - 2AB\cos\theta$

$F = \sqrt{68^2 + 87.4^2 - 2 \times 68 \times 87.4 \times \cos 50}$

$= \sqrt{4622.329\ldots}$

$= 67.98\ldots \text{ N}$

$\approx 68.0 \text{ N (3sf)}$

F = ...68.0..... N **[2]**

The candidate has used a triangle of forces and the cosine rule to determine the net downward. As it happens, the F in this calculation is the weight of the dolphin. However, it is numerically equal to the total upward vertical force. This concise and perfect alternative technique picked up the maximum marks.

Question 21 (c) (ii)

(ii) Use your answer from **(i)** to calculate the mass m of the dolphin.

m = ... kg **[2]**

Almost all candidates correctly used $W = mg$ to determine the mass of the dolphin. Full marks were frequently picked up because of error carried forward (ECF) from **(c)(i)**. There were very few cases of g = 10 m s^{-2} being used; this was penalised because g = 9.81 m s^{-2} is given in the Data, Formulae and Relationship Booklet.

Question 21 (c) (iii)

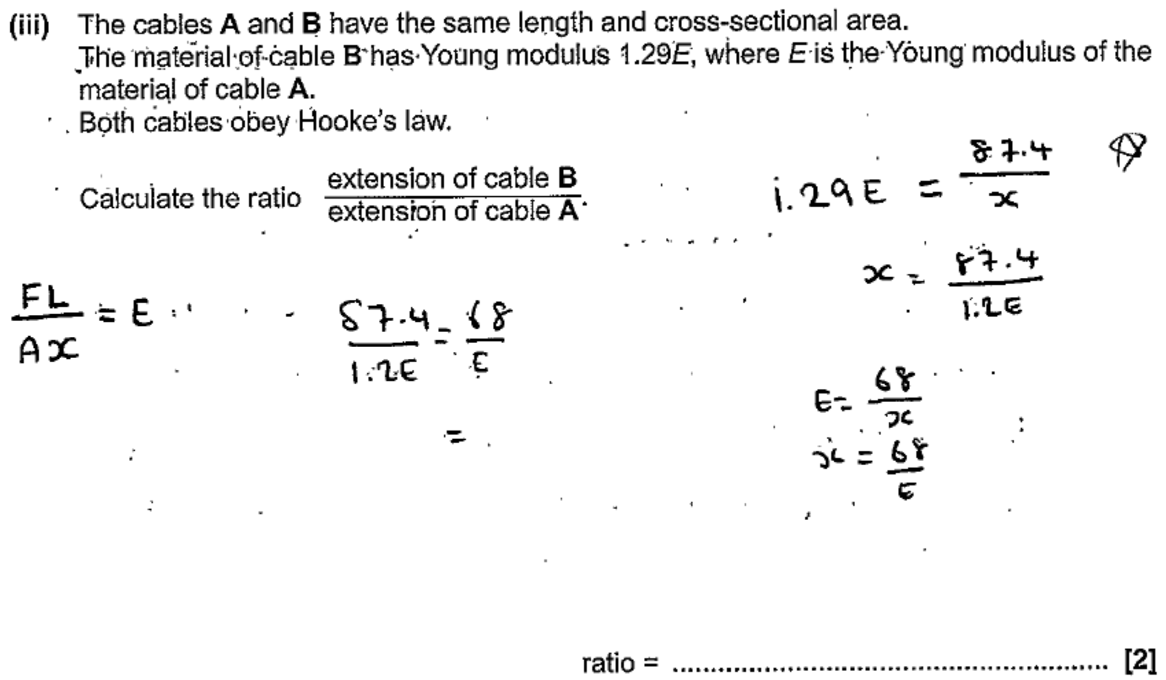
(iii) The cables **A** and **B** have the same length and cross-sectional area.
The material of cable **B** has Young modulus 1.29*E*, where *E* is the Young modulus of the material of cable **A**.
Both cables obey Hooke's law.

Calculate the ratio $\frac{\text{extension of cable } \mathbf{B}}{\text{extension of cable } \mathbf{A}}$.

ratio = ... **[2]**

This question on the equation for Young modulus *E* was well-answered with most candidates picking up one or more marks. The extension *x* of a wire is given by the expression $x = \frac{FL}{EA}$, where *F* is the tension in the wire, *L* its length and *A* its cross-sectional area. In this question, the extension $x \propto \frac{F}{E}$. Since both *F* and *E* increase by the same factor of 1.29, this meant that the ratio is 1.00. The most frequent incorrect answers were 1.29 and 1.29^{-1} or 0.78. The majority of the candidates in the upper quartile picked up 2 marks.

Exemplar 7


(iii) The cables **A** and **B** have the same length and cross-sectional area.
The material of cable **B** has Young modulus 1.29*E*, where *E* is the Young modulus of the material of cable **A**.
Both cables obey Hooke's law.

Calculate the ratio $\frac{\text{extension of cable } \mathbf{B}}{\text{extension of cable } \mathbf{A}}$.

ratio = ... **[2]**

This exemplar shows a response from a top-grade candidate. The solution is much more elaborate and the response of 0.996 is given to 3 significant figures. A perfect solution that earned this candidate 2 marks.

Question 22 (a)

22 A metal ball is released from rest. It falls vertically towards the ground. Fig. 22 shows the variation with time *t* of the displacement *s* of the ball.

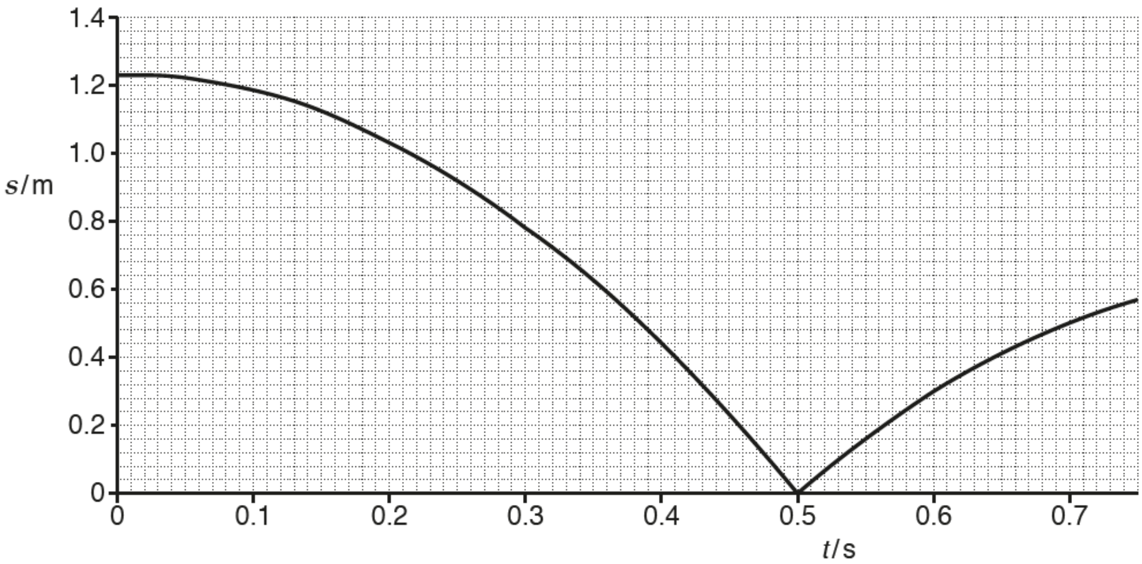


Fig. 22

Air resistance has negligible effect on the motion of the ball.

The ball hits the ground at $t = 0.50$ s.
During the collision, the ball is in contact with the ground for a time of 1.8 ms.
The mass of the ball is 56 g.

(a) Describe and explain the variation of the velocity of the ball from $t = 0.20$ s to $t = 0.70$ s.

No calculations are required.

....

....

....

....

....

.... **[4]**

This question on displacement-time graph required clear interpretation and exposition of the physics. The question discriminated well, with the top-end candidates describing the motion of the ball in clear scientific terms. Terms such as *acceleration* and *deceleration* were used appropriately. Up to time $t =$ 0.50 s, the ball was accelerating towards the ground – its velocity was increasing at a steady rate. The ball made impact with the ground at $t = 0.50$ s. The speed of the ball immediately after the impact was less than the speed just before the impact. This can be inferred from the gradient of the graph; the gradient being equal to velocity. The ball was moving away from the ground after $t = 0.50$ s and decelerating. It was only the very best candidate who mentioned that the gradient of the graph is equal to velocity of the ball. The two exemplars 8 and 9 show responses from top-end and low-end candidates.

Exemplar 8

Describe and explain the variation of the velocity of the ball from $t = 0.20$ s to $t = 0.70$ s.

No calculations are required.

From $t = 0.20$s to $t = 0.50$s, the ball is accelerating as it moves downwards. At $t = 0.50$s, the ball ~~th~~ collodes with the ground and bounce back upwards. From $t = 0.50$s, to $t = 0.70$s, the ball is ~~acc~~ decelerating as it moves upwards from the ground. Gradient of the graph equals to velocity. The change in gradient (velocity) equals to acceleration. **[4]**

This is a response from a top-end candidate. The description is flawless. The last statement about the 'change in gradient' being equal to acceleration was ignored. It should have been **rate** of change in the gradient being equal to acceleration, however, the statement from the candidate was not an essential requirement. This candidate had picked up an elusive mark for mentioning that the gradient of the graph is equal to velocity.

Exemplar 9

Describe and explain the variation of the velocity of the ball from $t = 0.20$ s to $t = 0.70$ s.

No calculations are required.

Between 0s - 0.5s, velocity of the ball is increasing as it is accelerating at $9.81 ms^{-2}$. At exactly 0.5s, the velocity of the ball is zero m/s. ~~But~~ Then from 0.5s - 0.7s, velocity increases but as time continues, the rate at which velocity is increasing ~~dec~~ slows down.

[4]

This is a response from a low-end candidate. It contains mistakes and misconceptions. The only mark obtained was for mentioning that the ball was accelerating before its impact with the ground.

?	**Misconception**	There were some missed opportunities, with some candidates using contradictory statements such as '*after t = 0.50 s, the ball is slowing down because it is acceleration upwards*'. The three most common misconceptions are summarised below: • The ball reaching **terminal velocity** just before the impact with the ground. • The ball was **accelerating** again after t = 0.50 s. • The displacement-time graph showed **projectile motion** of the ball.

Question 22 (b)

(b) Use an equation of motion to show that the speed of the ball is 4.9 $m\,s^{-1}$ just before it hits the ground.

[2]

This question was generally well-answered with candidates using a range of equations of motion to show the speed to be 4.9 $m\,s^{-1}$. The most popular route was:

$$v = 0 + (9.81 \times 0.50) = 4.905 \text{ m s}^{-1}.$$

Question 22 (c)

(c) Draw a suitable tangent to the curve in Fig. 22 and show that the **rebound** speed of the ball is about 3.5 $m\,s^{-1}$.

[3]

In this question, candidates had clear instructions on what to do. Most candidates drew adequate tangents at t = 0.50 s and did the correct analysis to determine the rebound speed of the ball. Most responses were in the range required (3.20 to 4.00 $m\,s^{-1}$) and most candidates scored 3 marks. About a quarter of the candidates drew tangents at times other than t = 0.50 s. This meant that they could only score a maximum of 1 mark for correctly calculating the gradient of their tangent.

Question 22 (d)

(d) Calculate the average resultant force acting on the ball during the collision.

force = ... N **[2]**

The correct answer of 260 N eluded even many of the top-end candidates. The vector nature of velocity, or momentum, was overlooked, with many candidates calculating the magnitude of the force as follows: force = $\frac{\Delta p}{\Delta t} = \frac{0.056\ (4.9-3.5)}{1.8 \times 10^{-3}}$ = 44 N   The magnitude of the change in the velocity of the ball 0.056(4.5 + 3.5), which would have given the correct answer of 260 N.

?	**Misconception**	Some examples of **incorrect** physics were: • force = weight of the ball = 0.056 × 9.81 • Using Δt = 0.50 s instead of 1.8 ms. • Using either 4.9 m s^{-1} or 3.5 m s^{-1} to calculate the force.

Question 23 (a) (i)

23 (a) A cell of electromotive force (e.m.f.) 1.4 V and internal resistance 0.62 Ω is connected to resistor **A** and wire **B** as shown in Fig. 23.1.

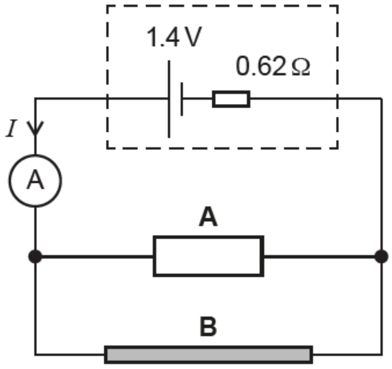


Fig. 23.1

The resistance of resistor **A** is 1.8 Ω and resistance per unit length of wire **B** is 9.5 Ω m^{-1}.
The length of wire **B** is 40 cm.

(i) Calculate the current I in the circuit. Write your value to an appropriate number of significant figures.

I = ... A **[4]**

This circuit question required multiple steps to calculate the current I in the circuit. Firstly, the candidates had to determine the resistance of wire B, then sort out the parallel combination of resistors A and wire B, and eventually deal with the whole circuit which included the internal resistance of 0.62 Ω. The question discriminated well, with almost half of the candidates securing full marks. The responses were often well-structured and demonstrated skilled use of calculators. Some responses were spoilt by premature rounding of numbers, but generally, candidates were sensible in retaining numbers on their calculators for subsequent stages of the calculation. Exemplar 10 below shows an immaculate response from a middle-grade candidate.

Exemplar 10

Calculate the current I in the circuit. Write your value to an appropriate number of significant figures.

resistance of wire B = 9.5 × (40 ÷ 100)
= 9.5 × 0.4
= 3.8 Ω

~~total resistance~~ resistance of the circuit, R_T = ~~3.8 + 1.~~ $\left(\frac{1}{1.8} + \frac{1}{3.8}\right)^{-1}$
= $\frac{171}{140}$
= 1.2214 Ω

$\varepsilon = I(R_T + r)$
1.4 = I(1.2214 + 0.62)
= 1.8414 I

$I = \frac{1.4}{1.8414}$
= 0.760283
= 0.76 A (2 s.f.)

I = 0.76 A [4]

All the stages of the calculations are easy to see in this well-structured response. This candidate has not rounded any of the numbers between stages – a very admirable strategy. The final response is quoted to 2 significant figures as required.

	Misconception	Some of the most common mistakes are summarised below: • Calculating the total resistance using either $(3.8^{-1} + 1.8^{-1} + 0.62^{-1})^{-1}$ or (3.8 + 1.8 + 0.62). • Forgetting to include the internal resistance when calculating the current.

Question 23 (a) (ii)

(ii) Calculate the ratio $\dfrac{\text{power dissipated in the internal resistance}}{\text{total power supplied by cell}}$.

ratio = ... **[2]**

Most candidates scored 1 mark for using an appropriate power equation. The main obstacle here for the candidates was what quantities to use for the total power supplied by the cell. Quite often, the internal resistance was omitted and $0.76^2 \times 1.22$ was used for calculating the total power. Top-end candidates used the easier alternative of 1.4×0.76.

Question 23 (b)

(b) This question is about two identical filament lamps. Fig. 23.2 shows the I-V characteristic of each lamp.

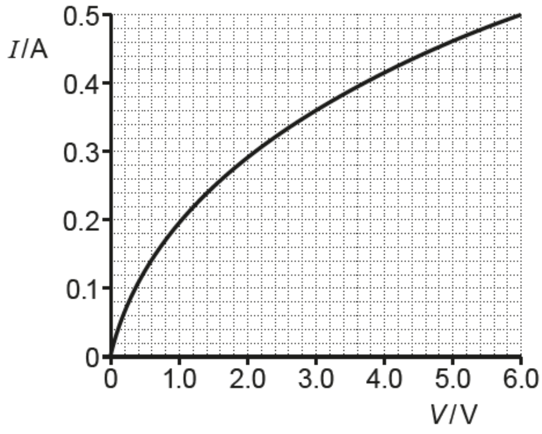


Fig. 23.2

The lamps are connected to a 6.0 V supply of negligible internal resistance in **series**, as shown in Fig. 23.3, and then in **parallel**, as shown in Fig. 23.4.

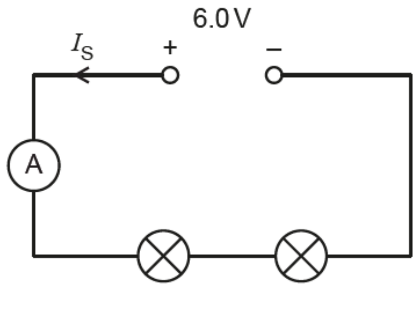


Fig. 23.3

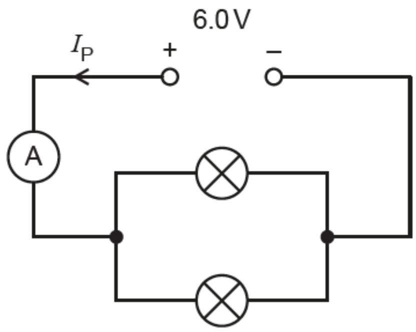


Fig. 23.4

The current from the supply in the series circuit is I_S and the current from the supply in the parallel circuit is I_P.
I_P is found to be almost 3 times greater than I_S.

Use Fig. 23.2 to explain why I_P is almost 3 times greater than I_S.
Show any calculations and your reasoning below.

Fig. 23.3	Fig. 23.4

[4]

This question produced a range of marks, with most candidates securing 2 or more marks. For the lamps in series, it was important to recognise that the potential difference across each lamp is 3.0 V. From the I-V graph, this meant a current I_S of about 0.36 A. For the lamps in parallel, the current in each lamp was 0.50 A because the potential difference across each lamp was 6.0 V. This meant that the current I_P was twice the current in each lamp; 1.00 A. The current I_P is about 2.8 times greater than current I_S. This final step of the analysis was often omitted by most of the candidates.

A significant number of candidates scored no marks here and about 10% of the candidates omitted this question altogether.

?	**Misconception**	The most common mistake made by candidates, across the ability spectrum, was to assume that each lamp had a constant resistance of 12 Ω in the series combination. A lamp is a non-ohmic component. At a potential difference of 3.0 V, the resistance of each lamp is about 8.3 Ω.

Question 24 (a)

24 (a) You are provided with a rectangular block of plastic.

Describe how you can use a ray-box (or a laser beam), together with other equipment available in the laboratory, to accurately determine the refractive index of the plastic block.

....

....

....

....

....

.... **[3]**

This question produced a wide spectrum of marks, with only the upper quartile of the candidates generally securing 2 or 3 marks. Candidates are reminded that if a diagram is drawn to support an answer, it must be adequately annotated. On many scripts, the normal was missed out and the angles of incidence and refraction were marked incorrectly (often between the light beam and the straight edge of the rectangular block). A significant number of candidates decided to change the block to a semi-circular one, and focused erroneously on determining the refractive index n using the critical angle equation $\sin C = 1/n$.

Question 24 (b) (i)

(b) The speed of sound in air can be determined by forming stationary waves in the laboratory. Fig. 24.1 shows an arrangement used by a student to determine the speed of sound *v*.

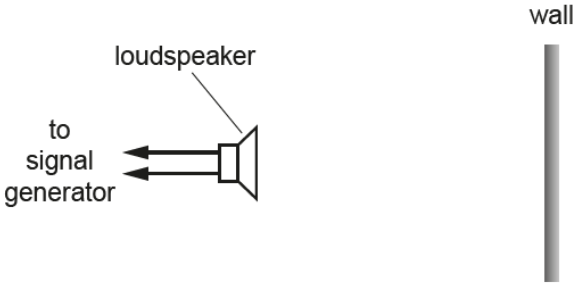


Fig. 24.1

A loudspeaker is placed in front of a smooth vertical wall in the laboratory. The loudspeaker is connected to a signal generator.
Stationary waves of frequency *f* are formed in the space between the wall and the loudspeaker.

A microphone is used to determine the mean separation *L* between adjacent nodes.

Fig. 24.2 shows the data plotted by the student.

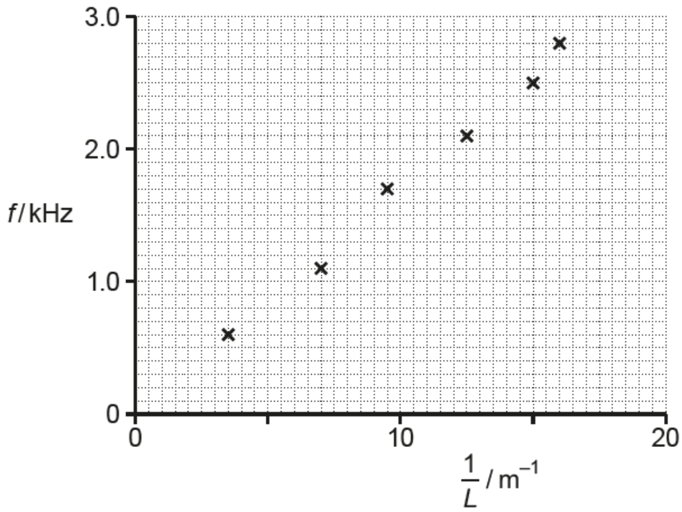


Fig. 24.2

(i) Draw a straight line of best fit and determine the gradient of this line.

gradient = ... Hz m **[2]**

The straight-lines of best fit were generally acceptable. A small number of candidates drew the lines using very thick or indistinct pencil leads. Large triangles were often used to determine the gradient of the lines. Only a very small number of candidates, mainly at the lower quartile, made errors with powers of ten and got an answer of 0.17 instead of 170.

Question 24 (b) (ii)

(ii) Explain why the gradient of the line is $\frac{v}{2}$, where v is the speed of sound.

....

.... **[2]**

Most candidates scored 1 mark for either quoting the wave equation $v = f\lambda$ or the wavelength being twice inter-nodal distance *L.* The analysis leading to the gradient = $v/2$ proved to be quite demanding for most of the candidates. The most frequent incorrect reasoning was that speed v was divided by 2 because the sound waves are reflected from the wall, and they had to travel twice the distance there and back. Only the most able of the candidates scored full marks.

Question 24 (b) (iii)

(iii) Use your answer in **(i)** and the information given in **(ii)** to determine v.

v = ... $m\,s^{-1}$ **[1]**

Almost all candidates picked up 1 mark for multiplying their answer from **(b)(i)** by 2. This included those who also got an answer such as 0.17 in **(b)(i)**. Error carried forward (ECF) rules were applied even when the speed of sound looked unrealistic.

Question 24 (b) (iv)

(iv) The smaller values of *L* are much more difficult to determine with the microphone in this experiment and this produces large percentage uncertainty in the values of $\frac{1}{L}$.

Suggest how this percentage uncertainty may be reduced in this experiment.

....

....

.... **[2]**

This was a low-scoring question, with many candidates focussing on *averaging* results. Only a small number of candidates appreciated that lower frequency would give longer inter-nodal distance *L*, and this resulted in smaller percentage uncertainty.

Question 25 (a)

25 (a) State **one** piece of evidence for the wave-like behaviour of electrons.

....

.... **[1]**

The majority of the candidates scored a mark for recalling that electron **diffraction** provided the key evidence for the wave-like behaviour of electrons. Two of the most frequent incorrect responses were *refraction* and the *photoelectric effect*.

Question 25 (b) (i)

(b) In an electron-gun, each electron is accelerated to a maximum kinetic energy of 210 eV.

(i) Show that the final speed of each electron is about $9 \times 10^6\,\mathrm{m\,s^{-1}}$.

[3]

This was not a straight forward question but most candidates demonstrated excellent knowledge and application of physics here. The conversion of 210 eV was often done correctly. The K.E. equation was used successfully to show the final speed of the electrons to be about 8.6×10^6 m s^{-1}.

The exemplar 11 below shows a model response from a top-end candidate.

Exemplar 11

In an electron-gun, each electron is accelerated to a maximum kinetic energy of 210 eV.

(i) Show that the final speed of each electron is about $9 \times 10^6\,\mathrm{m\,s^{-1}}$.

maximum kinetic energy: 210 eV

$= 210 \times$ ~~1.9 ×~~ 1.6×10^{-19}

$= 3.36 \times 10^{-17}$ J

$\frac{1}{2}mv^2 = 3.36 \times 10^{-17}$

~~$v^2 = 3.36 \times 10^{-17} \times 2 \div 9.11$~~

$v^2 = \dfrac{3.36 \times 10^{-17} \times 2}{9.11 \times 10^{-31}}$

$= 7.3765 \times 10^{13}$

$v = \sqrt{7.3765 \times 10^{13}} = 8.59 \times 10^6$

$\approx 9 \times 10^6$ m s^{-1} (1s.f.)

[3]

This exemplar shows a typical response produced by most of the candidates. The conversion from eV to J is very clear. The correct mass of the electron has been used to get the response of 8.6×10^6 m s^{-1}. It is good to report that very few candidates used 210 J to get the impossible response of 2.1×10^{16} m s^{-1}.

Question 25 (b) (ii)

(ii) Calculate the de Broglie wavelength λ of each electron.

λ = ... m **[2]**

The majority of the candidates effortlessly used the de Broglie equation and their answer from **(b)(i)**, or 9×10^6 m s^{-1}, to calculate the wavelength λ of the electron.

?	**Misconception**	The two common mistakes being made here were: • Using 3.0×10^8 m s^{-1} for the speed instead of 8.6×10^6 m s^{-1}. • Using the energy of the photon equation $E = \frac{hc}{\lambda}$ instead of $\lambda = \frac{h}{mv}$.

Question 25 (c)

(c) Electromagnetic waves interact with matter as photons.

Explain the photoelectric effect using ideas of **photons**, **conservation of energy** and **work function**.

....

....

....

....

....

.... **[4]**

This question on the photoelectric effect provided excellent discrimination with most candidates demonstrating good knowledge of the photoelectric effect. The work function was well defined and the key idea of the one-to-one interaction between a photon and an electron was communicated well. Some candidates took *work function* and *threshold frequency* to be synonymous, and the Einstein's photoelectric equation was quoted without much interpretation. Candidates are once again reminded that in descriptions it is important to define any terms used. Rather than just writing $hf = \phi + KE_{max}$ (which appears on the Data, Formulae and Relationship booklet), it would have would have been better to write

energy of photon = work function of the metal + maximum kinetic energy of the electron

as an alternative to annotating the formula with "where h is , f is , ϕ is, KE_{max} is "

Overall, the terms highlighted in the question helped candidates to provide focused responses. Many candidates continue to show knowledge of the quantum physics.

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