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Examiners' report

PHYSICS A

H156
For first teaching in 2015

H156/02 Summer 2018 series

Version 1

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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 H156/02 series overview

This is the third paper of the new AS specification. A good range of marks were achieved by candidates and it did not appear that candidates were short of time. There are several questions on the paper which test the practical skills that candidates should have experienced in their AS course.

The quality of written work was variable. A significant number of candidates could have gained more marks by stating definitions correctly and carefully answering the questions set. It is important for all candidates to understand key command terms such as state, describe, define, etc.

It is worth reminding candidates that their scripts are scanned and then electronically marked by examiners. It is therefore important that answers are not written outside the space provided for the answers. The legibility of some candidates' work remains a concern.

There were two Levels of Response (LoR) questions which gave candidates the opportunity of demonstrating their knowledge and understanding of physics. It is important that candidates answer the question set in a logical way with clear explanations. Candidates should also ensure that they answer the question set.

There were also several "show" questions on the paper. These types of questions prevent candidates who struggle with one part of a question being penalised on the next part – for example, candidates who could not do question 3 (d)(i) could still gain full marks in question 3 (d)(ii) and similarly candidates who could not do9 (b)(i) could still gain full credit for 9 (c).. These "show" questions do require candidates to clearly indicate their method. The unknown should be the subject of any equation – credit is not given for using the "show" value.

Candidate performance overview

Candidates who did well on this paper generally did the following:

- Demonstrated clear reasoning in explanation type questions.
- Performed calculations logically showing their working e.g. 4 (a) and (b), 6 (b), 6 (c) (ii) and (iii) and 9 (b)(i).
- Produced clear and concise responses for Level of Response questions: 2 and 7 (a).
- Applied knowledge and understanding to questions set in a novel context.
- Used technical terms correctly.

Candidates who did less well on this paper generally did the following:

- Found it difficult to apply what they had learnt to unfamiliar situations.
- Produced responses that lacked depth in questions requiring explanations.
- Did not plan their answers to Level of Response questions 2 and 7 (a).
- Were often unsure of dealing with powers of ten and unit prefixes.
- Showed poor setting out of unstructured calculations, e.g. 4 (a), (b), 6 (b), 6 (c)(ii) and (iii) and 9 (b)(i).
- Did not provide complete reasoning in show type questions.
- Were often confused with cross-sectional area – questions 4 (b) and 6 (c) (ii).

There were some very good scripts with clearly laid out physics and well-presented calculations. The comments that follow tend to relate mainly to the opportunities that were missed by the candidates.

Question 1 (a)

1 Fig. 1 shows how the velocity v of a car varies with time t as the car approaches a road junction.

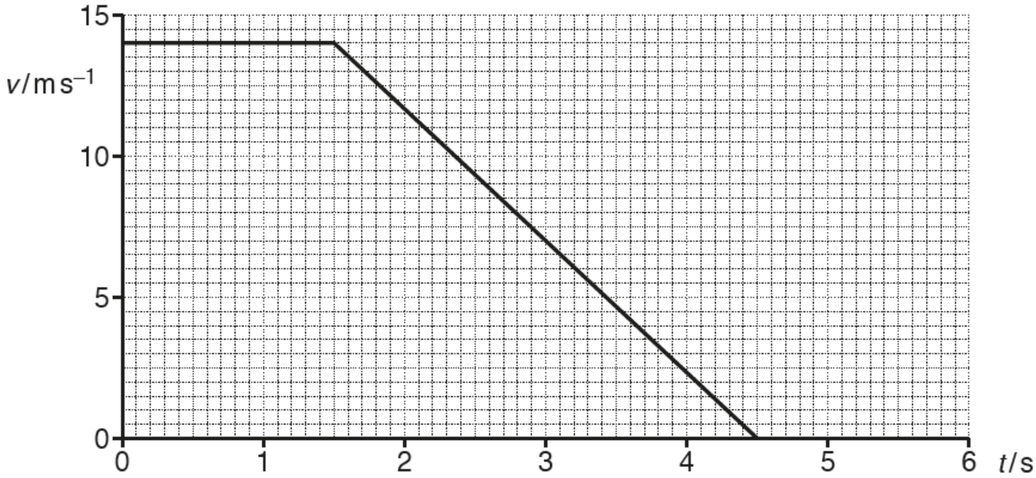


Fig. 1

(a) Explain what feature of the graph shows the deceleration of the car and that the deceleration is constant after 1.5 s.

....

....

.... **[2]**

This question was aimed to be a gentle introduction to the paper. It was expected that candidates would state that the **negative** gradient indicates the deceleration; many candidates simply referred to the gradient. The second part required candidates to refer to the straight line indicating that the deceleration is constant.

Candidates may find it helpful to underline the key terms in the stem of the question, for example 'deceleration' and 'deceleration is constant'.

Question 1 (b)

(b) The driver of the car applies the brakes at a distance of 20 m from the 'stop line' at the junction.

Calculate the distance *s* of the car relative to the stop line when the car comes to a stop.

s = ... m **[3]**

Candidates needed to understand that the car started decelerating when the brakes were applied. When answering this type question, candidates should be encouraged to show all their working. It was hoped that candidates would have written for the first mark that the area under the graph would be equal to the displacement. Then a clear calculation of the displacement was expected and then 21 m – 20 m to give the answer of 1 m.

Other candidates correctly used $s = \frac{(u+v)}{2}t$

Some candidates attempted to use $s = ut + ½at^2$. To do this correctly candidates needed to determine the deceleration of the car and used this in the equation.

Question 2

2* A student wishes to determine experimentally the efficiency of a small low-voltage DC motor. The motor is used to lift light loads.

Describe with the aid of a suitable diagram how an experiment to determine the efficiency of the electric motor can be safely conducted, and how the data can be analysed.

....

....

....

....

.... **[6]**

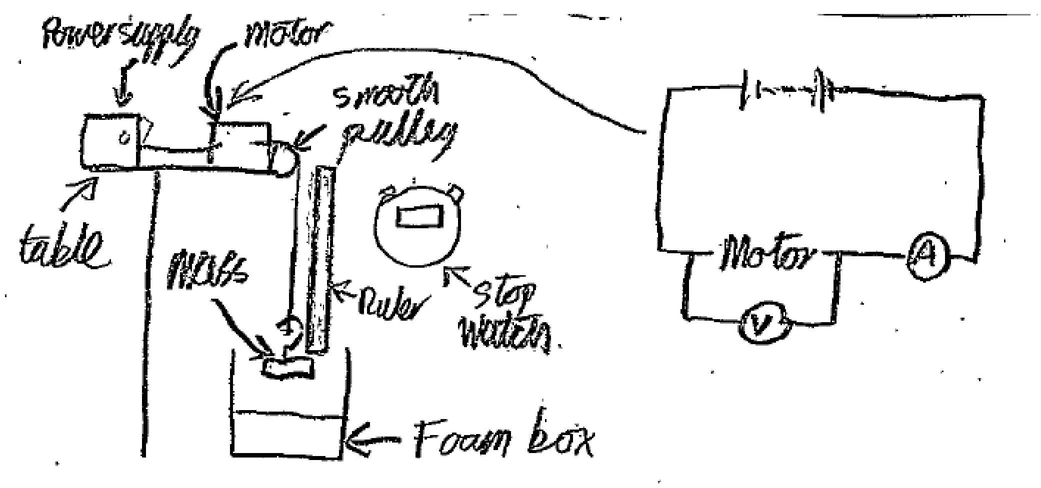
This question is assessing candidates' abilities to plan an investigation. The question is set to help candidates e.g. "lift light loads" should have given the hint of gravitational potential energy.

The stem of the question indicates that a suitable diagram should be drawn. Many candidates did not label their diagrams, or the diagrams were not workable. It was expected that there would be a workable circuit diagram with appropriate measuring instruments to determine the input power or energy; correct circuit symbols should be used. There also needed to be a diagram indicting how the useful power or energy could be determined. See Exemplar 1.

When answering planning questions, candidates should identify the measurements that need to be taken and indicate appropriate measuring instruments.

Candidates also needed to explain how the data would be analysed. This required them to give the appropriate equations using their measurements to determine the input power/energy, the output power/energy and the efficiency. Good candidates suggested the plotting of an appropriate graph and explained how the efficiency could be determined from the gradient.

Exemplar 1



This candidate has drawn two diagrams – one diagram indicating clearly how the motor is connected to a cell with an ammeter and voltmeter which could be used to determine the input power. The left-hand diagram is an arrangement of the apparatus which indicates the basic set up and included a foam box for the mass to fall into if the experiment does not work properly.

This candidate has also underlined key words from the question.

Question 3 (a)

3 A student is carrying out an experiment in the laboratory to determine the acceleration of free fall *g*. The student drops a small steel ball from rest and records the time *t* taken for the ball to fall through a vertical distance *h*.

The results for different vertical distances are shown in the table below.

h / m	t / s	t^2 / s^2
0.660	0.365	0.133
0.720	0.385	0.148
0.780	0.400	0.160
0.840	0.415	0.172
0.900	0.430	
0.960	0.445	0.198

(a) Describe and explain how the student could use standard laboratory equipment to make accurate measurements of *h* and *t*.

....

....

....

....

....

.... **[4]**

This question assessed candidates' knowledge and understanding of the techniques and procedures used to determine the acceleration of freefall. Most candidates were able to explain how the vertical distance could be measured using a metre rule. To measure the time, to the nearest 0.001 s, it was expected that candidates would describe either a method using an electromagnet and trap door or the use of light gates with a timer. Many candidates did not realise that the times were recorded to the nearest 0.001 s.

Many candidates were vague in their responses, e.g. "use light gates" without an explanation. It was expected that candidates would state that the light gates would be connected to a timer or datalogger or computer and that the timer would start when the ball interrupts the first light beam and stops when the second light beam is crossed.

Candidates should experience and be able to describe the techniques to determine velocity and acceleration using light gates

Question 3 (b)

(b) Complete the table for the missing value of t^2. **[1]**

This question was well answered. Since the raw data was given to three significant figures the calculated data should also have been given to three significant figures. Candidates did not score the mark for writing 0.1849 (four significant figures or 0.184 (truncating the data).

Question 3 (c) (i)

(c) Fig. 3 shows the graph of t^2 (y-axis) against h (x-axis).

(i) Plot the missing data point and draw the straight line of best fit. **[2]**

This question was again well answered with the majority of the candidates plotting the data point correctly. Sometimes the straight line of best fit did not have the points balanced.

Candidates should be encouraged to plot graphs using a sharp pencil. It is helpful to use a clear 30 cm rule to draw the straight line of best fit. Thick plots and/or lines do not score marks.

Question 3 (c) (ii)

(ii) Determine the gradient of the straight line of best fit.

gradient = ... $s^2 m^{-1}$ **[1]**

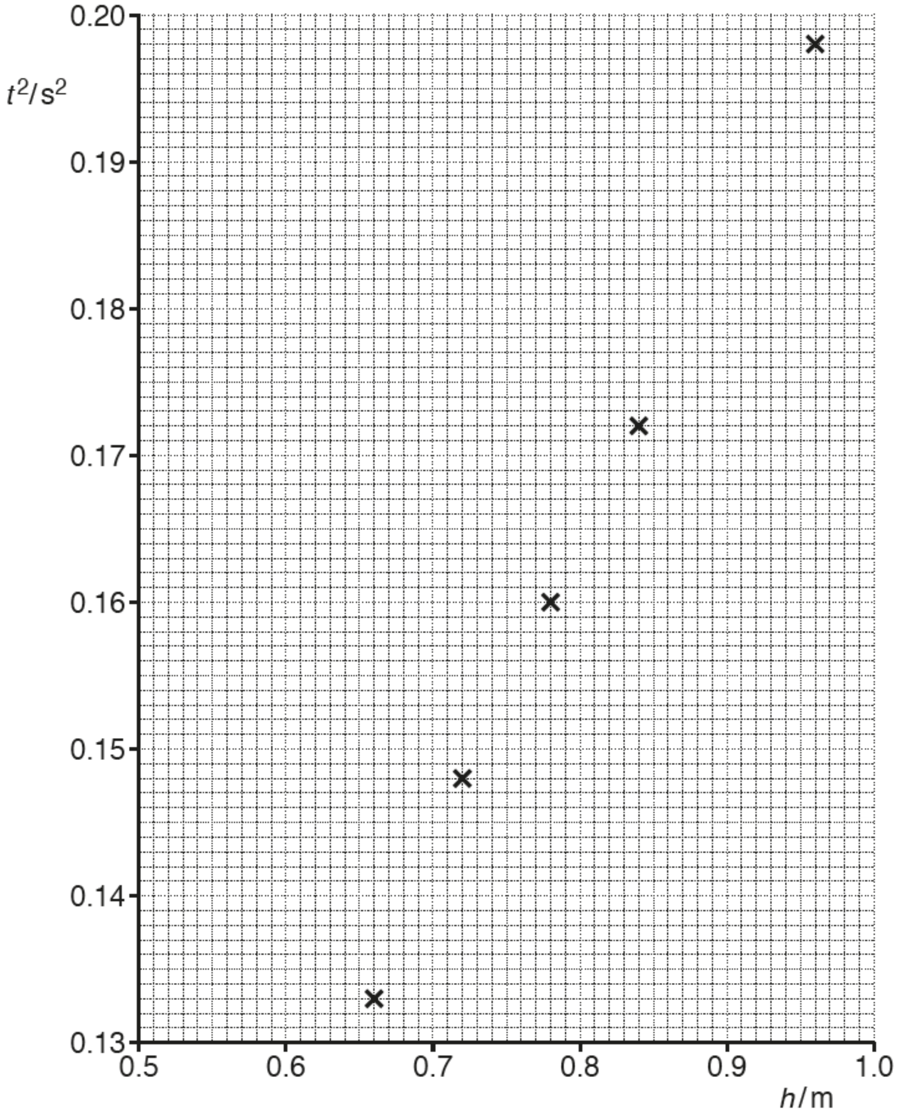


Fig. 3

To determine the gradient of the straight line of best fit candidates are expected to identify two points (x_1, y_1) and (x_2, y_2) which are on the line and substitute them into

$$\text{gradient} = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x}$$

The two points should be at least half the length of the drawn line apart. The advantage of this method is that it automatically allows for negative gradients.

Common errors included the use data points from the table which are not on the line or just using one data point and assuming that the line passed through the origin.

Question 3 (d) (i)

(d) **(i)** Use the equations of motion for constant acceleration to show that the relationship between *t* and *h* is

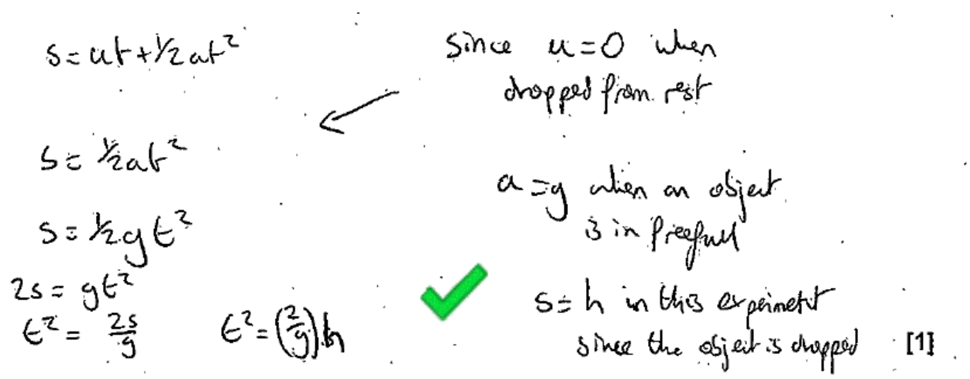
$$t^2 = \left(\frac{2}{g}\right)h$$

where *g* is the acceleration of free fall.

[1]

For this type of question, candidates should start the answer by quoting the relevant equation of motion. It was then expected that candidates would state that *u* (or *ut*) = 0, that *a* = *g* and *s* = *h*. Some lower ability candidates did not clearly rearrange the equation correctly.

Exemplar 2



This shows a reasoned answer with the relevant terms defined and clear working to demonstrate the rearrangement.

Question 3 (d) (ii)

(ii) Use your answer to **(c)(ii)** to determine the experimental value for *g*.

g = ... m s^{-2} **[1]**

Candidates were required to identify from the equation given at the beginning of 3 (d) (i) that the gradient was equal to 2/*g*. Candidates then needed to use the gradient value they calculated in 2 (c) (ii) to determine *g*. Some candidates incorrectly substituted data points from the table of results.

To improve this skill candidates should practise comparing the *x* and *y* values from graphs with the equation of a straight line and then identifying the gradient and *y*-intercept values.

Question 4 (a)

4 An engineer is investigating the tension in a steel cable supporting a uniform wooden plank as shown in Fig. 4.

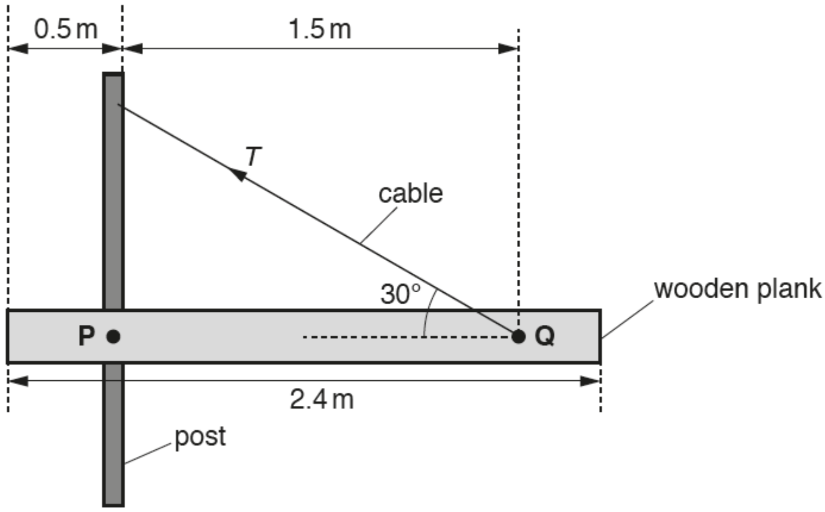


Fig. 4 (not to scale)

The plank is 2.4 m long and has a mass of 50 kg. It is pivoted at point **P** to a vertical post. The cable is fixed to the plank at point **Q** and to the vertical post as shown in Fig. 4. The cable is at an angle of 30° to the plank. The plank is in equilibrium and resting in a horizontal position.

(a) Show that the tension T in the cable is about 460 N.

[4]

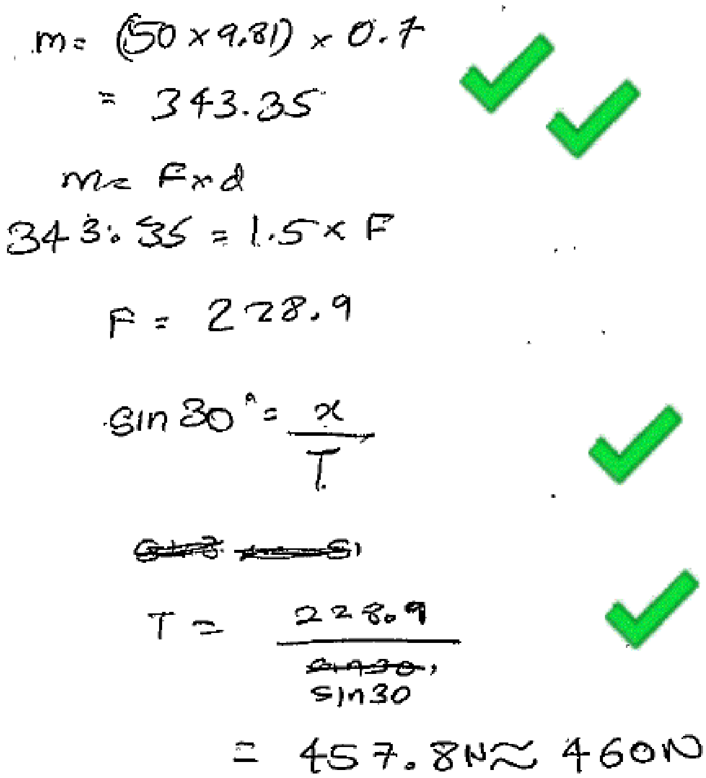
This question was a "show" type question where candidates needed to show that the tension in the cable was about 460 N. Ideally in these type of questions, candidates should have shown their working logically and gained answer of 457.8 (N).

Most candidates scored a mark for determining the weight of the beam. Good candidates clearly showed their working.

Good candidates stated the principle of moments, indicated how the clockwise moment would be determined, indicated how the anticlockwise moment would be determined and gave an answer of 457.8 (N).

To determine the anticlockwise moment candidates needed to resolve the tension T into its vertical component – both $T\sin30°$ and $T\cos60°$ were acceptable.

Exemplar 3



In this exemplar the candidate has clearly shown the working to answer the question. Initially the candidate has calculated the clockwise moment by multiplying the force (mass of 50 (kg) by 9.81) by 0.7 (m). This gains two marks. The candidate’s answer could have better if the candidate had written on the left-hand side “clockwise moment” rather than “m”, however, it is implicit from the candidate’s working the meaning of “m”.

The candidate has then clearly shown that the anticlockwise moment is equal to the clockwise moment and determined correctly the perpendicular force or vertical force.

The candidate then correctly relates the force *T* to sin 30° and the vertical force and evaluates the answer as 457.8 N before indicating that this is approximately 460 N. Including the 457.8 is appropriate in these type of show questions.

Question 4 (b)

(b) The original length of the steel cable is 1.73 m and it has a cross-sectional area of 11.0 mm^2.
The Young modulus of steel is 210 GPa.
Calculate the extension *x* of the cable shown in Fig. 4.

x = ... m **[3]**

This question required candidates to carry out several calculations. Good candidates would start by combining the definitions of stress and strain with the definition of Young modulus to give

$$x = \frac{TL}{EA}$$

A significant number of candidates made a power of ten (POT) error either with 210 GPa or with the area of 11.0 mm^2. Many candidates wrote the latter as 11 x 10^{-3} m^2. Other lower ability candidates tried calculating the area from this value.

Some candidates correctly determined the stress, then the strain and then the extension.

Question 5 (a)

5 (a) State *Newton's second law of motion.*

....

....

.... **[1]**

Less than half of the candidates could state Newton's second law correctly. A significant number of candidates wrote force = mass x acceleration. Another common error was stating the principle of conservation of momentum. Some candidates were confused by the term impulse and incorrectly gave the answer as change of momentum as opposed to stating that the resultant force is directly proportional to the rate of change of momentum. Examiners allowed "equal" for proportional.

For these type of questions, if a candidate gives an equation, then all the symbols must be defined.

Question 5 (b) (i)

(b) Fig. 5.1 shows a tennis ball before and after bouncing on the ground.

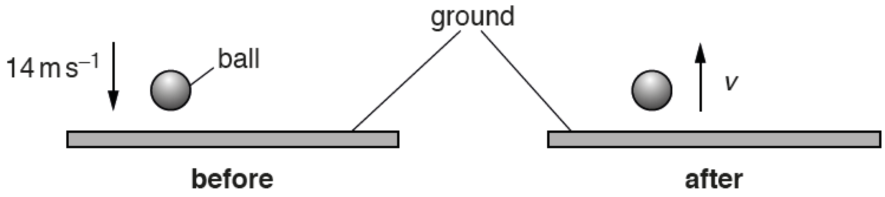


Fig. 5.1

The mass of the tennis ball is 0.062 kg. The tennis ball is slightly warmer after its collision with the ground.

(i) The tennis ball hits the ground at a speed of $14\,m\,s^{-1}$.
Calculate the momentum p of the tennis ball as it hits the ground.

p = ... N s **[1]**

This question was well answered. Many candidates helpfully showed their working.

Question 5 (b) (ii)

The force acting on the ball during collision with the ground is *F*.
Fig. 5.2 shows a graph of force *F* acting on the tennis ball against time *t*.

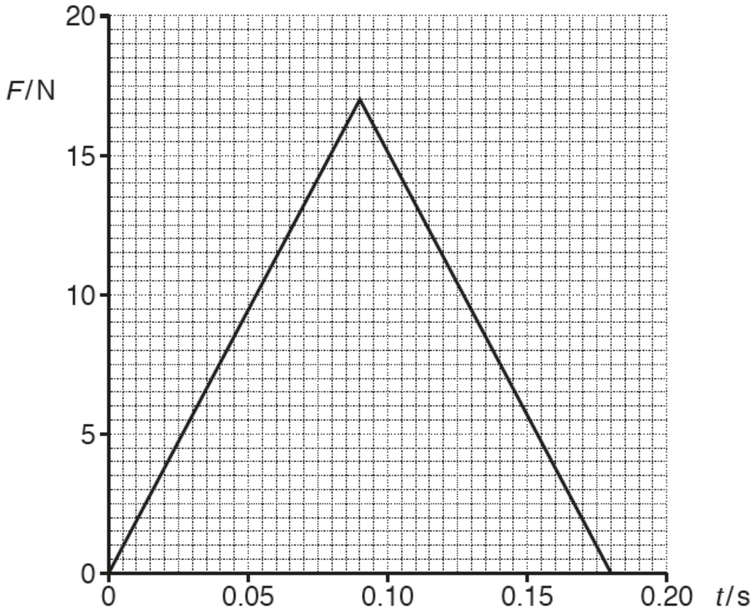


Fig. 5.2

The tennis ball is in contact with the ground for 0.18 s.

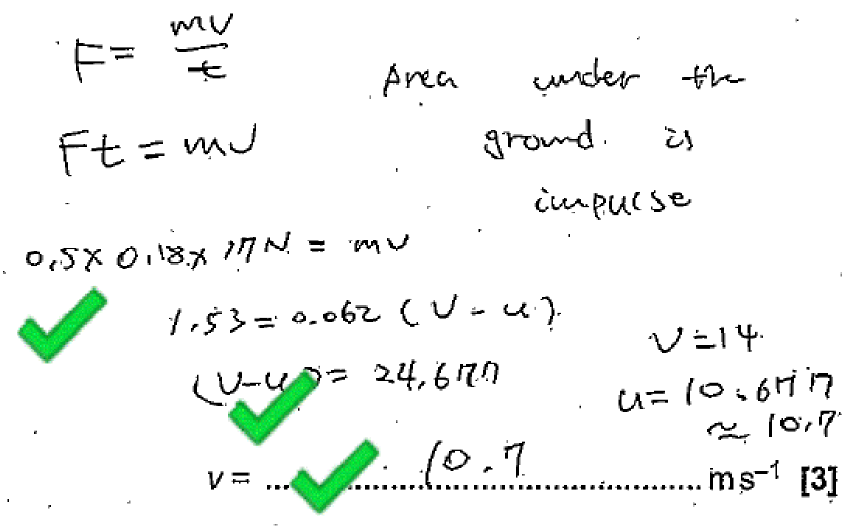
(ii) Determine the speed *v* of the tennis ball as it leaves the ground.

v = ... m s^{-1} **[3]**

Candidates found this question difficult. Candidates needed to realise the importance of Fig. 5.2 and understand that the area under the graph was equal to the change of momentum of the ball. It is important that candidates show their working so that if the graph is misread they may still obtain credit later.

Having determined the change in momentum correctly, candidates then needed to determine the momentum of the ball leaves the ground.

Exemplar 4


$F = \frac{mv}{t}$ Area under the ground is impulse

$Ft = mv$

$0.5 \times 0.18 \times 17N = mv$

$1.53 = 0.062 (v - u)$ $v = 14$

$(v - u) = 24.677$ $u = 10.677$ ≈ 10.7

v = ... 10.7 ...... ms^{-1} **[3]**

This exemplar demonstrates that the candidate understands that the area under the graph is the impulse. The method to calculate the area is shown and although the candidate has not used the answer to (b)(i), the method in terms of the change of velocity is correct and clearly indicated.

Question 5 (b) (iii)

(iii) State what is meant by an elastic collision and explain how your answer to **(ii)** shows that this collision is **not** elastic.

....

....

.... **[2]**

Many candidates did not state that the kinetic energy is conserved – often there were general statements about energy being conserved. Some candidates did not relate their answer to part (ii) as required by the question.

Some candidates determined the kinetic energy before and after the ball left the ground – candidates could gain full marks with this approach.

Question 6 (a)

6 Fig. 6.1 shows the *I*–*V* characteristics for two electrical components **X** and **Y**.

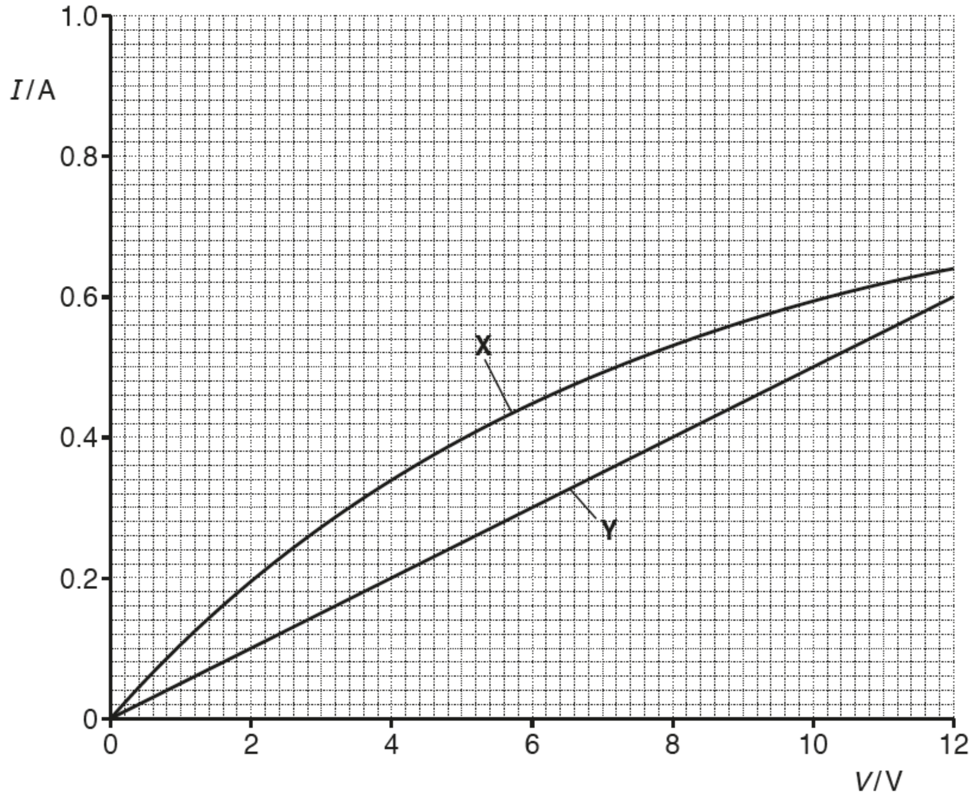


Fig. 6.1

(a) Suggest the two components **X** and **Y** that were used.

Name of component **X** ....

Name of component **Y** .... **[1]**

Many candidates did not appear to recognise the *I-V* characteristics for a filament lamp or an ohmic resistor. Incorrect answers that were often seen included diodes and LDRs. X could have been a thermistor with a positive temperature coefficient (ptc) although the specification only makes reference to thermistors with negative temperature coefficients

Question 6 (b)

(b) Fig. 6.2 shows components **X** and **Y** connected in parallel to a battery of e.m.f. 9.6 V and internal resistance *r*.

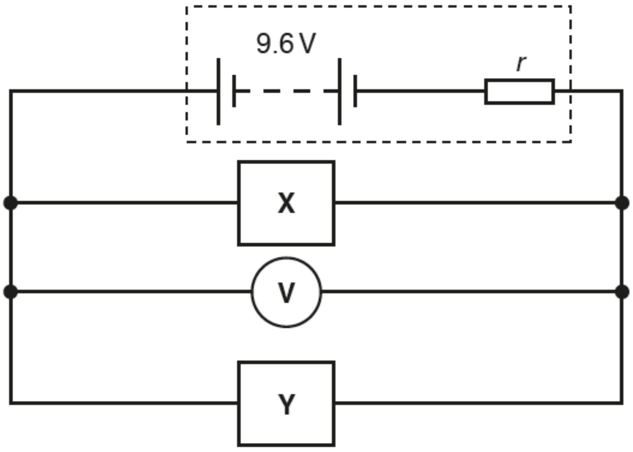


Fig. 6.2

The voltmeter reading is 7.2 V. Determine *r*.

r = ... Ω **[3]**

This question assessed candidates' knowledge of internal resistance as well as their understanding of series and parallel circuits. Many candidates correctly determined that the 'lost volts' was 2.4 V. Unfortunately, the total current in the circuit was more difficult for candidates to determine. Candidates needed to identify that the potential difference across each component was 7.2 V and use the graphs to determine the two current values.

Again, good candidates clearly show their working. The advantage would be in that an error in reading information from the graph would still allow further credit.

Exemplar 5

The voltmeter reading is 7.2 V. Determine *r*.

e.m.f = terminal p.d + lost Volt (Ir) ∴ Ir = 9.6 − 7.2 = 2.4 V ∴ r = 2.4/I = 2.4/0.86 = 2.8 Ω (2sf)

p.d across X and Y are the same according to Kirchhoff's 2nd law.

At 7.2V, I_X = 0.50 A, I_Y = 0.36 A

Total I = 0.50 + 0.36 = 0.86 A

r = ...2.8.......... Ω [3]

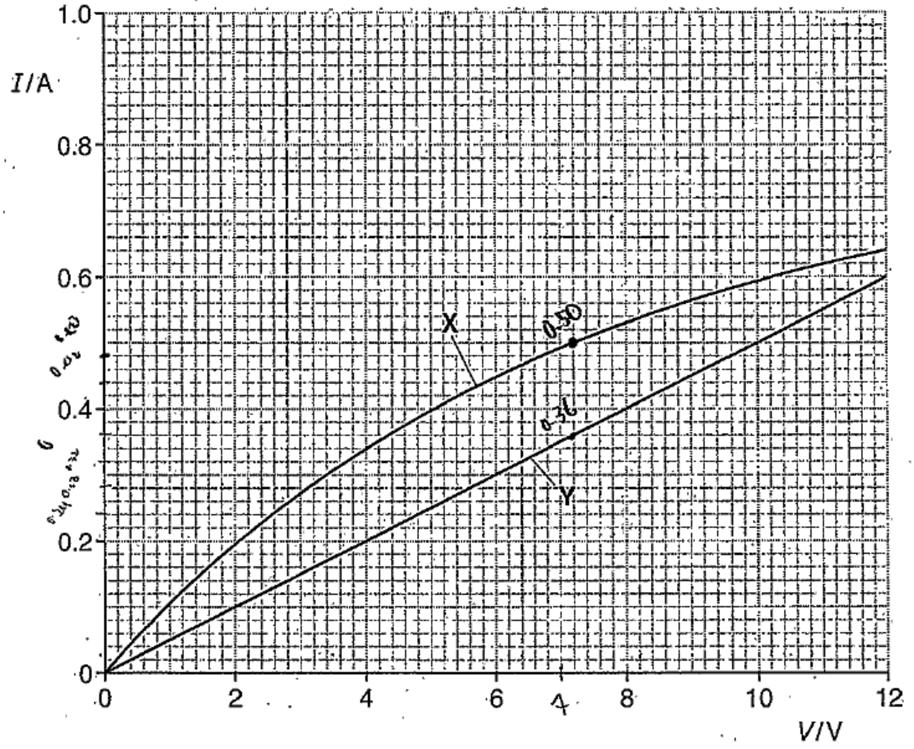


Fig. 6.1

The candidate has clearly state the method and at the top stated that *Ir* = 2.4 V.

The candidate has then clearly read the currents for each component at a potential difference of 7.2 V to then determine the total current. There is then a correct calculation to determine the internal resistance *r*.

Question 6 (c) (i)

(c) A cable consists of 17 tightly packed copper wires, see Fig. 6.3.

Fig. 6.3 (not to scale)

The student measures the diameter *d* of one of the copper wires as 0.12 ± 0.01 mm.

(i) Explain how the student should measure precisely the diameter of the wire.

....

....

.... **[2]**

Most candidates were able to identify a suitable measuring instrument such as a micrometer. To score the second mark candidates were expected to explain the purpose of repeating readings that the reading would be repeated in different directions or along the wire and the mean or average diameter would be determined. to assure that the outcome is precise.

Question 6 (c) (ii)

The student measures the resistance *R* of the whole **cable** as 1.86 ± 0.02 Ω.
The length *L* of the cable is 21.0 ± 0.1 m.

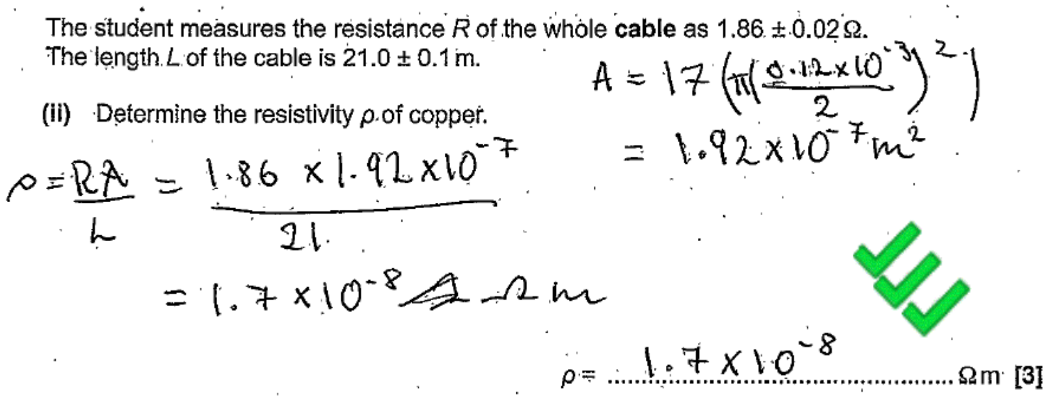
(ii) Determine the resistivity *ρ* of copper.

ρ = ... Ω m **[3]**

A very large number candidates did not take into account that the resistance of the cable was the resistance of 17 wires in parallel. Many candidates did not clearly show their working. Good candidates calculated the cross-sectional area of one wire and then correctly rearranged the resistivity equation from the data booklet.

Some lower ability candidates had difficulty in calculating the cross-sectional area of the wire and there were often power of ten errors.

Exemplar 6


The student measures the resistance R of the whole **cable** as $1.86 \pm 0.02\,\Omega$.
The length L of the cable is 21.0 ± 0.1 m.

(ii) Determine the resistivity ρ of copper.

$A = 17\left(\pi\left(\frac{0.12\times10^{-3}}{2}\right)^2\right)$

$= 1.92\times10^{-7}\,m^2$

$\rho = \frac{RA}{L} = \frac{1.86\times1.92\times10^{-7}}{21}$

$= 1.7\times10^{-8}\,\Omega m$

$\rho =$ 1.7×10^{-8} Ωm **[3]**

This candidate has correctly approached the question by determining the total area of the copper in the cable and then correctly used the equation.

Again, the equations used are clearly demonstrated.

Question 6 (c) (iii)

(iii) Determine the percentage uncertainty in ρ.

percentage uncertainty = ... % **[2]**

Many candidates clearly determined the percentage uncertainties on L, R and d which gained the first mark. A common final answer (which scored one mark) was 9.88% because candidates did not multiply the percentage uncertainty in d by two to allow for d^2.

Some candidates attempted a maximum or minimum method – this was a long method and it was easy to make an error. When working out the maximum value, the maximum value of R and d needed to be used with the minimum value of L.

Question 7 (a)

7 (a)* In an experiment to investigate microwaves, a microwave detector **D** is placed between a microwave transmitter **T** and a flat metal sheet.

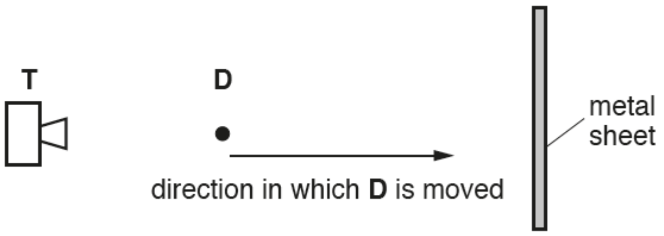


Fig. 7.1

The detected signal at **D** shows regions of maximum and minimum intensity as **D** is moved towards the metal sheet as shown in Fig. 7.1. The distance between **adjacent** regions of maximum and minimum intensities is 72 mm.

Explain the presence of the regions of maximum and minimum intensity **and** determine the frequency of the microwaves.
The speed of microwaves in air is $3.0 \times 10^8\,m\,s^{-1}$. **[6]**

....

....

....

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....

....

....

This was the second Level of Response question; a good range of marks was achieved. It required candidates to explain a standing wave pattern formed by microwaves. Many good candidates explained the pattern produced in terms of the metal sheet reflecting the microwaves, causing superposition with an explanation of nodes and antinodes. It was hoped that their understanding that the distance between successive maxima/minima is *λ/2* would assist them in the calculation of the frequency.

Good candidates wrote the equation and indicated that the wavelength of the microwaves was 0.288 m.

Candidates should practise writing explanations to physics phenomenon. It is expected that the answers to these Level of Response questions will have a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Exemplar 7

A stationary wave is formed when the incident and reflected microwaves superpose to form a resultant wave ~~consts consist~~ The resultant wave has maximum and minumum The maximum represents an antinode. An antinode is formed when constructive interference takes place and similarly ~~da~~ a minimum (nodes) (node) is formed when destructive interference takes place. ~~w~~ The distance between an antinode and a node is 0.072 m, which is quarter of the wave length The full wavelength is 0.288 m long (0.072×4).

∴ $v = f\lambda$

∴ ~~velocity~~ frequency = $\frac{\text{velocity}}{\text{wavelength}}$

$f = \frac{3 \times 10^8}{0.288} = 1.0416 \times 10^9 \text{ Hz}$

$f = 1.04 \times 10^9 \text{ Hz}$

L3

This is an example of a Level of Response answer.

The question gives a practical demonstration which candidates may have seen during the AS course. The question gives candidates the opportunity to describe the observations using their knowledge and understanding as well as determining the frequency of the microwaves. Candidates should use appropriate physics terms.

In this case the candidate begins by implying that the microwaves are reflected by the barrier to superimpose a resultant wave. The candidate states that maxima are antinodes and formed by constructive interference. The candidate then explains the formation of nodes in terms of destructive interference. Appropriate physics terms have been used.

The candidate has then correctly realised that the distance between the node and an anti-node is a quarter of a wavelength. The candidate could have stated that the distance between successive nodes is half a wavelength, but this is implied in the previous statement.

Finally, the candidate clearly shows the method of determining the wavelength by quoting the wave equation, rearranging the equation and substituting values. The candidate finishes the determination of the frequency by calculating the frequency and then rounding to an appropriate number of significant figures two or three) and gives a correct unit (Hz).

Question 7 (b)

(b) In another experiment using microwaves, a metal grille **G** consisting of a series of long metal rods is placed between the transmitter **T** and the detector **D** as shown in Fig. 7.2.

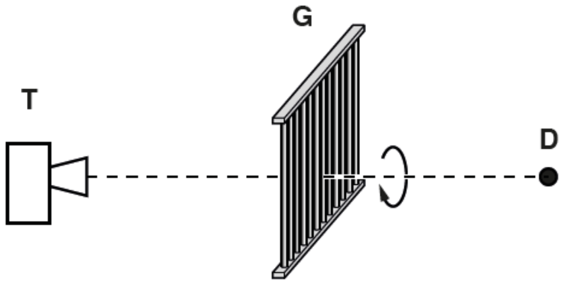


Fig. 7.2

The grille is slowly rotated through 180° about the line joining **T** and **D**. The detected signal at **D** varies from zero to maximum and back to zero again.

Explain why the detected signal behaves in this way.

....

....

....

....

....

.... **[2]**

Candidates found this question difficult. Candidates often did not state that the microwaves were polarised or mistakenly thought that the grille caused the microwaves to become polarised.

Candidates also did not appear to read the question carefully often thinking that the detected signal varied from a maximum initially. Some candidates quoted $I = I_0\cos^2\theta$ to help explain their answer.

Question 8 (a) (i)

8 A student investigates the path of a light ray through ethanol. Fig. 8.1 shows ethanol in a rectangular glass container. Light of wavelength 5.2×10^{-7} m is incident on the container as shown.

Fig. 8.1 (not to scale)

(a) The table below shows the refractive indices *n* and speeds of light *v* in various transparent media.

medium	***n***	***v* / m s^{-1}**
air	1.00	3.00×10^8
ethanol		2.20×10^8
glass	1.52	
vacuum	1.00	3.00×10^8

(i) Complete the table by calculating the missing values of *n* and *v*. **[2]**

This question was generally well answered. Some lower ability candidates were careless in the calculation of the speed of light in glass and gave their answers as either 1.9 or 2.0 as opposed to 1.97. There were also some candidates who gave an answer of 4.56×10^8 m s^{-1} – this is where candidates should check the pattern in the table.

Question 8 (a) (ii)

(ii) Determine the wavelength λ of the light in glass.

λ = ... m **[1]**

Surprisingly, this question did not score highly – many candidates did not realise that the wavelength of light in the glass would be the wavelength of light in air divided by the refractive index of glass.

Question 8 (b) (i)

(b) Fig. 8.2 shows an enlarged version of a section of the left hand side of the glass container.

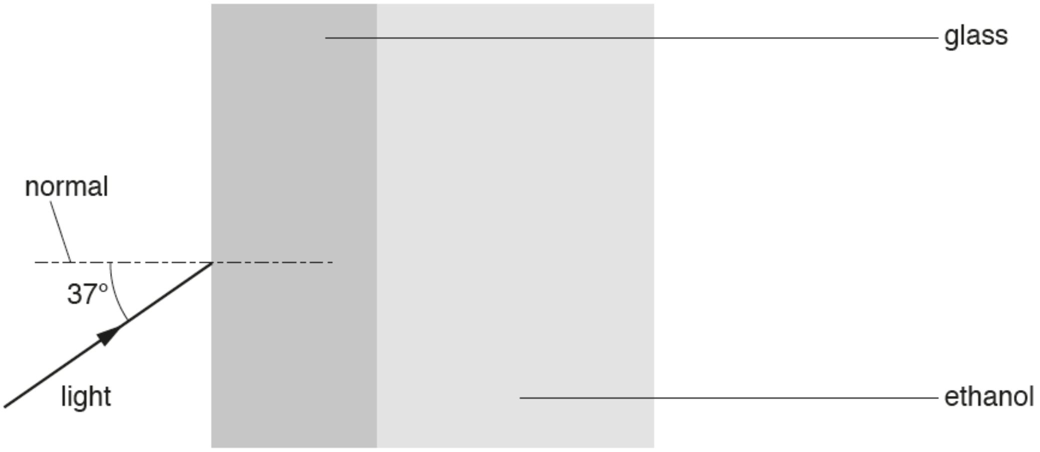


Fig. 8.2 (not to scale)

(i) The light is incident on the glass at an angle of 37°.
Determine the angle of refraction θ in the glass.

θ = ...° **[2]**

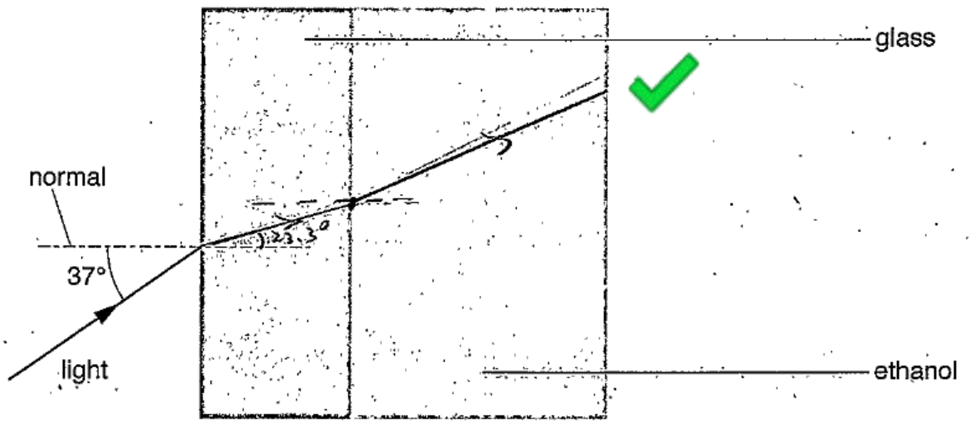
Many candidates correctly applied Snell's law. Common mistakes were either using the wrong refractive index or inverting the answer.

Question 8 (b) (ii)

(ii) Without any further calculation, sketch the ray of light as it passes through the glass into the ethanol. **[1]**

This question required candidates to apply the previous answers to this question to draw an appropriate ray diagram. Candidates do need to use a ruler. A common error was for the emergent ray in the ethanol to be parallel to the incident ray in the air. This question required candidates to think through their diagram stage by stage using information from the previous part and the table given earlier in the question.

Exemplar 8



This candidate has used a ruler and drawn straight rays. The candidate has marked on the normal and indicated the angle of refraction in the glass. It is clear that the ray in the ethanol is not parallel to the original ray.

Question 9 (a) (i)

9 Einstein derived the following equation to explain the photoelectric effect:

$$hf = \phi + KE_{max}$$

(a) Define the following terms from the equation

(i) *hf*

....

.... **[1]**

Many candidates simply defined the symbols as opposed to the term. It was expected that candidates would state that *hf* was the energy of a *photon*.

Question 9 (a) (ii)

(ii) ϕ

....

.... **[1]**

Again, a common answer was to state that ϕ represented the work function rather than defining what is meant by work function. Good candidates stated that the work function was the minimum energy needed to remove an electron from a metal surface.

Question 9 (b) (i)

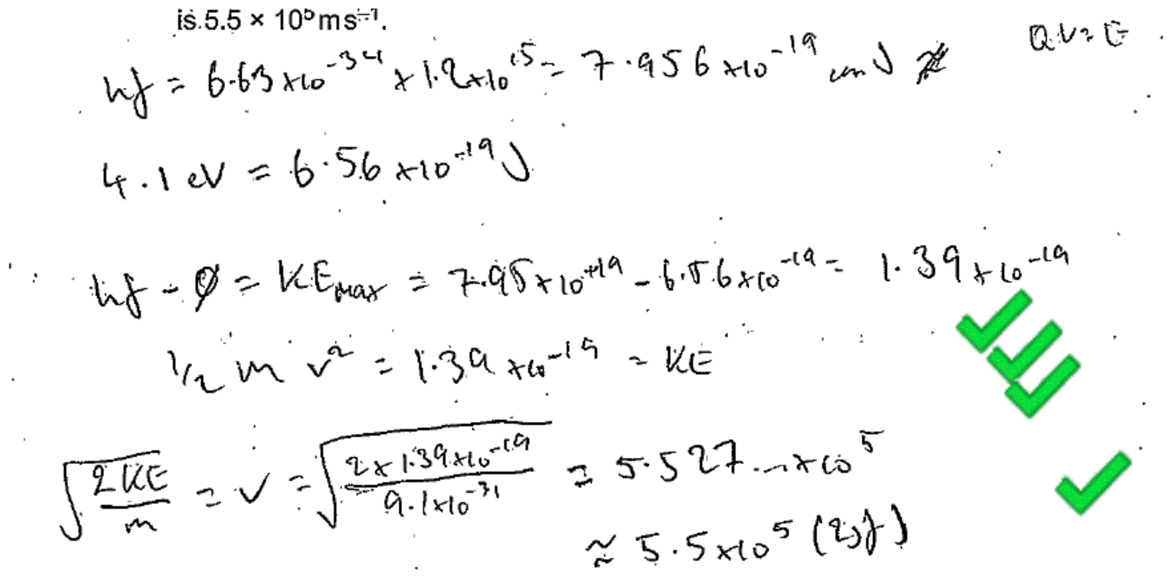
(b) Electromagnetic radiation of frequency 1.2×10^{15} Hz is incident on the surface of a negatively charged aluminium plate. The work function of aluminium is 4.1 eV.

(i) Show that the maximum speed of the electrons emitted from the surface of the aluminium is $5.5 \times 10^5\, m\, s^{-1}$.

[4]

Good candidates clearly showed the individual steps in this calculation, e.g. the conversion of electron-volt to joule for the work function, the energy of the photon calculated. It was important that candidates demonstrated that they had substituted the mass of the electron from the data booklet and correctly evaluated the square root term. Examiners expected to see 5.536×10^5 ($m\, s^{-1}$) for full credit so that it was clear that candidates had correctly calculated the powers of ten.

Exemplar 9


is 5.5 × 10⁵ ms⁻¹.

$hf = 6.63\times10^{-34} \times 1.2\times10^{15} = 7.956\times10^{-19}$ J

$4.1\,eV = 6.56\times10^{-19}$ J

$hf - \phi = KE_{max} = 7.95\times10^{-19} - 6.56\times10^{-19} = 1.39\times10^{-19}$

$\frac{1}{2}mv^2 = 1.39\times10^{-19} = KE$

$\sqrt{\frac{2KE}{m}} = v = \sqrt{\frac{2\times1.39\times10^{-19}}{9.1\times10^{-31}}} = 5.527...\times10^5$

$\approx 5.5\times10^5$ (2sf)

In line 3 of the candidate's working, there is a rearrangement of the equation given at the beginning of the question. There is then clear substitution of the energy of a photon which was calculated in line 1 and the work function which had been converted from electron volt to joule in line 2 to give a value for the maximum kinetic energy of the electrons. This scores three marks.

In the final part the candidate correctly shows the rearrangement of the kinetic energy equation to give *v* as the subject and then correctly substitutes in the values including the mass of the electron from the data and formulae sheet.

The final answer is given as 5.527 x 10^5 which is then shown to be approximately equal to 5.5 x 10^5 (ms^{-1}). This last part is essential in these show type questions.

Question 9 (b) (ii)

(ii) State and explain what change, if any, occurs to the maximum speed of the emitted electrons when the intensity of the electromagnetic radiation is increased.

....

....

....

.... **[2]**

For this type of question, a clear explanation is needed before the mark for stating the change, if any. Candidates' descriptions were often vague, and few stated that the maximum energy was independent of intensity.

Question 9 (c)

(c) Moving electrons have wave-like properties.
Calculate the de Broglie wavelength λ for electrons travelling at $5.5 \times 10^5\,\mathrm{m\,s^{-1}}$.

λ = ... m **[2]**

The final question was either answered very well or candidates chose an incorrect equation, often $E = \frac{hc}{\lambda}$.

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