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Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H157
For first teaching in 2015

H157/02 Summer 2018 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 examination paper can be downloaded from OCR.

Paper H157/02 series overview

H157/02 is the second of two examination units for AS Physic B (Advancing Physics): H157/01 is the 'Foundations of physics' or 'breadth' paper, and this paper is 'Physics in depth.' Accordingly, this paper contains longer questions which explore the chosen contexts in more detail than would be done on the 'breadth' paper. This paper also features extended response questions, and more emphasis on the evaluation of practical skills.

Candidates who are successful in this paper are those who have mathematical fluency, using algebraic analysis with consistency in the use of significant figures and standard scientific notation where appropriate. These candidates are able to scan each question to determine the way in which it is structured, so that division of a question into (for example) (a)(i), (a)(ii), (a)(iii), (b)(i) and (b)(ii) suggests that it contains two 'stories', one in three linked parts followed by one in two parts.

Less successful candidates had difficulty with re-arranging algebraic equations, made errors involving powers of 10 when converting between SI prefixes and base units (e.g. nm to m). They often fail to see the development of a theme between consecutive sub-parts of a question, attempting (for example) to answer part (g)(ii) on the way to answering (g)(i), when they should be asking themselves, 'How does the answer to (g)(i) lead on to (g)(ii)?' which may suggest the approach that's necessary for (g)(i) as well – examiners do attempt to make the earlier parts of these structured questions more straightforward than the subsequent ones.

In this paper, candidates were not penalised for excessive use of significant figures except in 7(a)(ii) and 8(a)(i) but very many chose always to write down all the figures displayed on the calculator. Candidates should be encouraged to note the number of significant figures in the data and to round accordingly in their final answer.

Section A

Question 1(a)

1 A book is held 25 cm from an eye. This is the smallest distance from an object for which a normal eye can form a clear image.
Light is refracted by the cornea and the lens together, and a clear image is formed on the sensitive retina, 2.1 cm behind the lens.
The ray diagram for this arrangement is shown in Fig. 1.

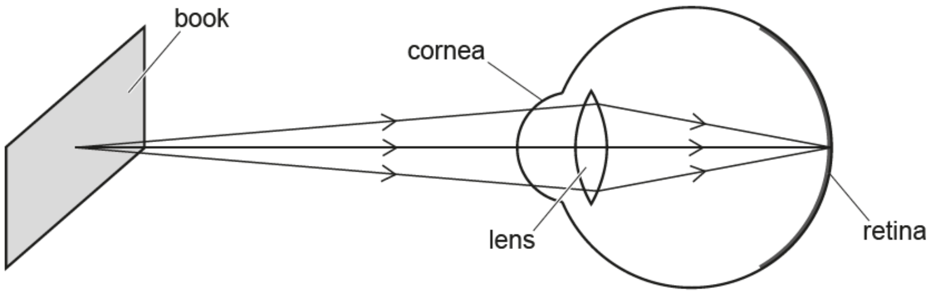

Fig. 1

(a) Calculate the power *P* of the combination of the cornea and the lens.

P = ... D **[2]**

Question 1(b)

(b) The sensitive cells at the centre of the retina are separated by 2.5 μm.
Calculate the distance *d* on the book that would correspond to this separation in the image on the retina.

d = ... m **[2]**

Question 1(c)

(c) A long-sighted person cannot focus on an object 25 cm from the eye. Carol is long-sighted and the closest object that forms a sharp image on her retina is 1.5 m from the eye.
Explain why Carol has difficulty reading small print in a book when she is not using her glasses.

....

....

.... **[2]**

Candidates who realised, in (a), that the value of *u* to use in the lens equation was – 0.021 (m) rather than – 21 (cm) or + 21 (cm) generally got both marks: those who made one of these two slips could still get 1 mark e.c.f. (error carried forward), and many did.

In part (b) the magnification (0.084, or 1/12) had to be found first, and this then used to find the minimum size of an object that, subject to this magnification, would result in an image 2.5 μm in size. Some lower ability candidates calculated the magnification correctly but then made the object 12 × smaller instead of bigger, so clearly could not envisage the physical situation.

In part (c), it was intended that candidates realise that the book had to be placed 6 × further away than the standard 25 cm for Carol to see the print clearly, reducing the resolution six-fold. Very few candidates attempted any calculation, and a single mark was credited for a purely qualitative explanation, of which the commonest acceptable responses were 'the lens and cornea of Carol's eye are not powerful enough to focus and image on the retina' or the equivalent 'In Carol's eye, the image would be formed behind the retina.'

Question 2(a)

2 A modern digital television has a screen measuring 1280 pixels by 720 pixels (Fig. 2).

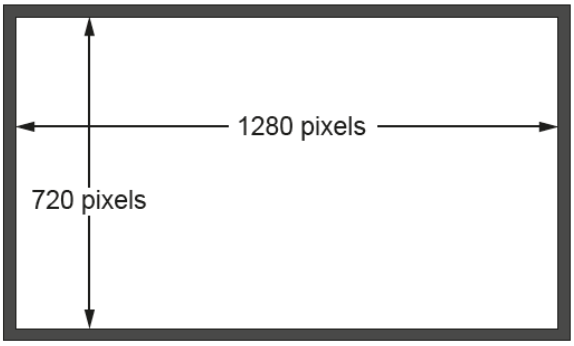

Fig. 2

(a) Each pixel is encoded by 3 bytes, one for each of the colours red, green and blue. A new image is displayed on the screen 30 times each second.

Calculate the number of gigabytes needed to encode a high-definition video lasting for one hour. You can assume that every pixel must be encoded every time a new image appears on the screen.

number = ... GB **[2]**

Question 2(b)

(b) When this one-hour high-definition video is downloaded, it takes up 13 GB on the digital storage. This value is much smaller than the value calculated in **(a)**.

Suggest and explain **one** reason for this.

....

....

....

.... **[2]**

Most were able to calculate the file size in GB for (a), although there were a number of common errors: some did not read the question with enough care and omitted the '3 bytes per pixel' while others converted from bytes to bits, which was not needed here.

In part (b), most realised that the file had been compressed and many made reasonable suggestions as to which data could be omitted, and why: some suggested that the compression involved a significant drop in the picture quality, which contravened the 'high-definition video' referred to in the question stem.

Question 3(a)

3 Fig. 3 shows a lift designed for a very tall building.

It consists of a 'cage' that can hold up to eight passengers. The total mass of the cage and passengers must not exceed 1200 kg. The cage is supported by a steel cable of cross-sectional area $2.8 \times 10^{-3}\,m^2$ and density $7800\,kg\,m^{-3}$.

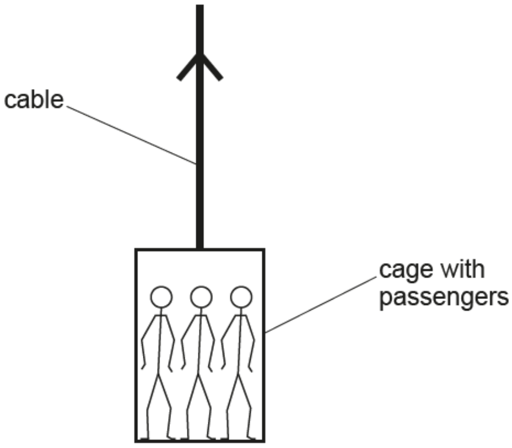

Fig. 3

(a) The lift cable is 420 m long when completely unwound.
Calculate the tensile stress at the **top** of the cable, when it is completely unwound and supporting a fully-loaded cage.

$g = 9.8\,m\,s^{-2}$

density $\rho = \dfrac{\text{mass}}{\text{volume}}$

stress = ... Pa **[3]**

Question 3(b)

(b) Explain why it is incorrect to use the value of the stress calculated in **(a)** and the equation $E = \frac{\text{stress}}{\text{strain}}$ to calculate the extension of the cable.

....

....

....

.... **[2]**

In (a), many showed the ability to work out the cable mass, and then to find the total weight of cable plus cage, but in this second stage a significant number omitted the weight of either the cable or the cage. Relatively few candidates confused mass and weight here. Calculation of stress was well done, even if this was often e.c.f from the wrong weight.

In (b), only the best identified that the stress at the top included the effect of weight of the cable as well as the cage, but very few realised that the extension of the entire cable needed to be calculated from the mean stress. Most attempted to explain the problem by stating, for example, 'You would need to have the strain or the Young modulus to work out the extension.'

Question 4(a)

4 A small rocket of mass 0.27 kg is mounted vertically on the ground. Exhaust gases emerge at high speed from the rocket, as shown in Fig. 4.

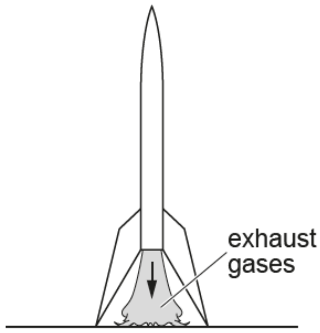

Fig. 4

(a) At the start, the gases are ejected at a rate of $47\,\text{g s}^{-1}$ with a speed of $110\,\text{m s}^{-1}$ relative to the rocket and the ground.
Show that the rocket exerts a downwards force of about 5 N on the exhaust gases.

[2]

Question 4(b)

(b) Calculate the initial upward acceleration of the rocket.
$g = 9.8\,\mathrm{m\,s^{-2}}$

acceleration = ... $\mathrm{m\,s^{-2}}$ **[2]**

Question 4(c)

(c) Explain why this acceleration is correct only at the instant when the rocket engine starts.

....

....

....

.... **[2]**

To get two marks in (a) it was important that candidates made it clear that $\Delta p/\Delta t$ was force, and that this was $\Delta m/\Delta t \times v$. A number seemed just to have multiplied the two number in the question stem, converting from to kg, and spotting that this was close to 5, and this gained no credit unless there was a clear link to momentum change.

In (b), two acceptable approaches were seen: calculating the resultant upward force and thence obtaining *a*, or finding the acceleration that would have been obtained by the 5 N force alone, and then vectorially adding *g* to this.

In (c), many candidates reasonably argued that air resistance would apply once the rocket started to move, and that this effect would reduce the acceleration more and more as the velocity increased. A smaller number realised that the mass of the rocket fell continually as exhaust gases were ejected, and that (assuming a constant thrust) the acceleration would increase, either because of the increasing value of F/m or because the rocket weight was reducing, both of which apply in this case. A number gained credit for ascribing the changing acceleration to a changing rate of ejection of exhaust.

Question 5(a)

5 A simple model of a gas atom consists of separate energy levels, as shown in Fig. 5.

In this model, there are three levels, **A**, **B** and **C**. The vertical separation between levels is proportional to the energy differences between the levels, showing that these energy differences are not uniform.

The electrons of the atom, shown as black dots, can have any of these three energies, but cannot have any other energy.

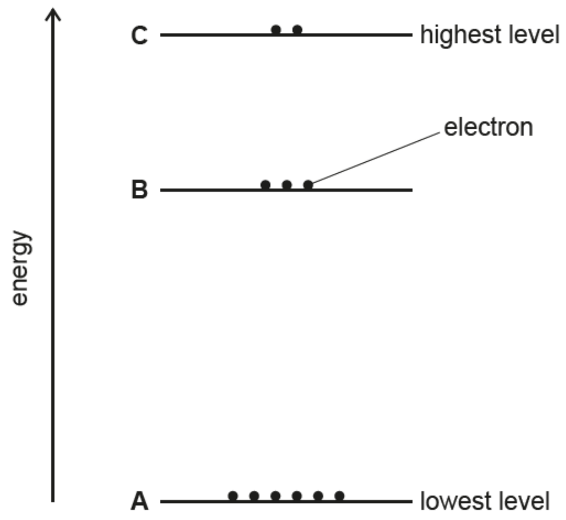

Fig. 5

When one atom absorbs exactly the right amount of energy, an electron can 'jump up' from one level to a higher level.
When an electron "falls" from a higher level to a lower level a photon will be emitted. The energy of this photon will be the energy difference between those two levels.

(a) State why the spectrum of light emitted by excited atoms of this gas will contain exactly three different frequencies.

....

.... **[2]**

Question 5(b)

(b) In the spectrum of this gas, the longest wavelength of light emitted is 650 nm. Calculate the energy released by a falling electron and state the two levels between which the electron has fallen.

speed of light, $c = 3.0 \times 10^{8}\,\text{m s}^{-1}$
the Planck constant, $h = 6.6 \times 10^{-34}\,\text{J s}$

energy = ... J

the electron fell from level .... to level .... **[3]**

In (a), candidates tended to get one mark, either for relating an energy transition to a frequency, e.g. by quoting $E = hf$, or by listing the three possible transitions. Many seemed to think that three levels meant three photon energies as if the electron were to fall from or to some other level.

Many who didn't seem in (a) to understand that a photon was emitted by a transition successfully identified the correct transition (C → B) in part (b). The calculation in part (b) was usually done well, either via $c = f\lambda$ and $E = hf$ or directly via $E = hc/\lambda$.

Section B

Question 6(a)*

6 Fig. 6.1 represents a cell of e.m.f. ε and internal resistance r. **A** and **B** are the positive and negative terminals of the cell.

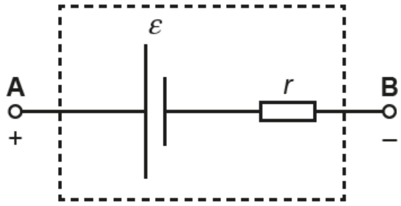

Fig. 6.1

(a)* Complete the circuit diagram of Fig. 6.1, adding appropriate meters and a variable resistor, to show how you could determine values of ε and r. Describe and explain the procedure you would use to determine accurate values of ε and r and their uncertainties.

....

....

.... **[6]**

6(a) was the first of the two extended response questions in this paper. Although not a 'Section C' Practical question, it was related to a practical activity expected to have been done by the candidates: *determining the internal resistance of a chemical cell or other source of e.m.f.*

On the positive side, well-prepared candidates knew that using a variable resistor to obtain a range of values of current and terminal p.d. would allow a V-I graph to be drawn, and that the best-fit straight line would allow both the e.m.f. ε and internal resistance r to be determined from the V-axis intercept and gradient respectively. Level 3 answers to this question (gaining 5 or 6 marks) did this confidently, also suggesting that drawing more than one straight line would allow uncertainties in ε and r to be determined by obtaining extreme values of those constants.

On the negative side, few candidates seemed to be familiar with the circuit symbol for a variable resistor, with most preferring to use a thermistor symbol. Many candidates did indeed refer to the use of a thermistor in this experiment, with variation in current and terminal p.d. obtained by changing the temperature which, though possible, is somewhat eccentric. The very weakest answers seemed more in place in a foundation-tier GCSE answer, with ammeter and voltmeter incorrectly connected, and sometimes no external resistance at all.

Question 6(b)(i)

(b) A battery-powered appliance has a rechargeable battery consisting of two lithium-ion cells in series. Each cell has an e.m.f. ε = 3.6 V and an internal resistance r = 0.32 Ω.

The capacity of this battery is 1200 mAh, meaning that a fully-charged battery can deliver an average current of 1200 mA for an hour before it is completely discharged.

A fully-charged battery of this type is connected to an external load of resistance 5.2 Ω until it is completely discharged. You can assume that the e.m.f. ε is constant throughout the discharge.

(i) Show that a charge of about 4 kC flows during this discharge.

[1]

Question 6(b)(ii)

(ii) Calculate the time taken for the discharge.

time = ... s **[3]**

Most candidates correctly determined that the charge in (i) was 4320 C, but in (ii) only the best correctly used the e.m.f. and internal resistance of the two-cell battery to find the current, and then to use that current with 4320 C or 4000 C to obtain the time. A large number plucked 1.2 A from the question stem ('The capacity of this battery is 1200 mAh') without understanding what that statement meant, even though it was explained in the stem ('..meaning that...').

Question 6(b)(iii)

(iii) Show that the percentage efficiency of energy transfer to the load resistance *R* is given by

$$\text{percentage efficiency} = 100 \times \frac{R}{R + 2r}$$

where *r* is the internal resistance of one of the battery cells.

[3]

Part (b)(iii) proved had a high level of demand: few candidates related energy or power efficiency to I^2R, although a number correctly asserted that the current through this series circuit was the same everywhere.

Question 6(c)

(c) Lithium-ion rechargeable batteries are used for a large number of charge-discharge cycles.

Fig. 6.2 shows how the energy stored in such a battery changes with the number of charge-discharge cycles. This is shown for two discharge currents: 2A and 15A. In this graph, a relative capacity of 100% refers to the energy stored when the battery is first charged.

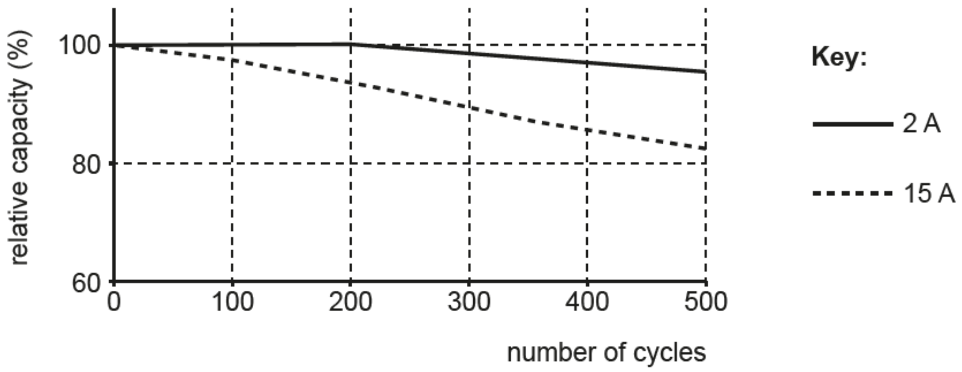

Fig. 6.2

Use the information in Fig. 6.2 to discuss the suitability of this type of battery for a mobile phone and for an electric car.

....

....

....

....

.... **[3]**

Good responses to this question quickly picked up the trends in the data – the capacity loss on repeated charging and discharging, and the greater loss at higher currents – as well as the fact that 2A would approximate better to a mobile phone charging and 15A would be more like the current drawn by an electric car.

Question 7(a)

7 This question is about the standing waves that produce the musical notes in string instruments.

(a) A double bass is a large musical instrument with four strings of the same vibrating length *L* but different thicknesses. Notes are produced by moving a bow perpendicular to the string (Fig. 7.1).

This question considers only the thickest string of the double bass, which produces the lowest notes.

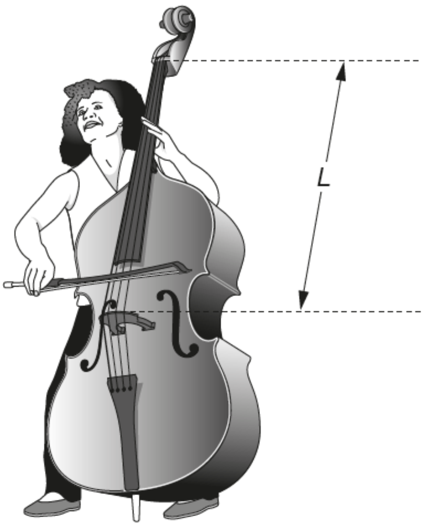

Fig. 7.1

(i) The length L = 0.980 m and the frequency f_0 of the fundamental note produced by the thickest string is 41.2 Hz.
Show that the waves travelling along the string have a speed of less than 100 m s^{-1}.

[2]

Most candidates correctly applied $v = c\lambda$, although a large number thought that the inter-nodal distance (the string length) was λ instead of $\frac{1}{2}\lambda$ and so obtained 1 mark e.c.f.

Question 7(a)(ii)

(ii) A player can produce a harmonic (a note of higher frequency) by touching the string **lightly** at a certain point to make the string vibrate with zero amplitude at that point. This point must be a whole fraction of *L* from one end of the string, e.g. one-half, one-third, etc. of the way along.

The player produces a note of frequency *f* about 200 Hz on this thickest string by touching it at a distance *x* of about 20 cm from one end.

Using appropriate scientific terms, explain why this higher frequency is produced, and calculate the values of *x* and *f* to an appropriate number of significant figures.

....

....

....

....

....

x = ... cm *f* = ... Hz **[4]**

The best candidates were able to describe the formation of a higher-harmonic standing wave, with a node where the string was lightly touched, but many did not score the two marks for 'Using appropriate scientific terms, explain why…' As regards the actual values for *x* and *f*, for which 3 significant figures (as in the data) were expected, only the best candidates seemed aware that *x* should be an exact fraction of the string length and that *f* should be that same ratio of the fundamental frequency, only this time a multiple. From the data presented, the factor should have been 5 (0.980 m/5 = 19.6 cm), although 4 was also accepted as 0.980 m/4 = 24.5 cm could be considered to be 'about 20 cm.' As the end being measured from was not specified, 0.980 m – *x* was also allowed.

Question 7(a)(iii)

(iii) The fundamental frequency f_0 of the note produced by a vibrating string of length L is given by the equation

$$f_0 = \frac{1}{2L}\sqrt{\frac{T}{\rho A}}$$

where T is the tension of the string, A its cross-sectional area and ρ the density of the material of which it is made.
Calculate the diameter of the thickest string, which has a tension of 290 N and a mean density of 8100 kg m^{-3}.

diameter = ... m **[3]**

This question was quite testing in terms of algebraic rearrangement. Many candidates prefer to substitute in all values at the start, and then to rearrange to obtain the unknown *A*. This is quite acceptable. It is important, however, to be painstakingly precise in each stage of the rearrangement, whether arithmetic or algebraic, as it is extremely easy to misplace a square or square-root sign.

Most candidates realised that the required answer was not cross-sectional area nor radius, but diameter. However, in the rush of the examination, many omitted a calculation stage. Candidates sometimes ended up with a double bass string of an unreasonable diameter ranging from 5 μm to 10 m, without any comment added.

Question 7(b)(i)

(b) A bass guitar (Fig. 7.2) has four strings that produce notes of the same frequencies as the four strings of the double bass. The strings are not played with a bow like a double bass. They are pulled perpendicular to the string and released (plucked) just as on an ordinary guitar.

As in part **(a)**, part **(b)** considers only the thickest string of the instrument.

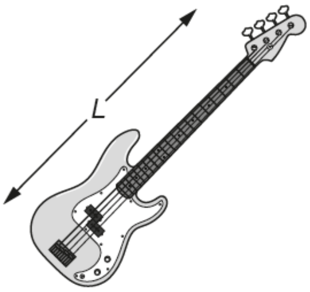

Fig. 7.2

(i) Use the equation given in **(a)(iii)** to show that, for strings producing the same fundamental frequency f_0,

$$\rho A \propto \frac{T}{L^2}.$$

Show your working clearly and explain your reasoning.

[2]

Only the very best candidates were able to tackle this question, so it is as well to lay out the steps which a candidate should take, as this sort of analysis is not uncommon in Physics examination. Unlike (a)(iii), this is not a case where values can be substituted first, as this is a purely algebraic rearrangement.

Step 1: Rearrange the given equation so that the expression on the left of the proportionality sign is the subject of the equation. Take two or three steps to do this, if necessary.

This gives $\rho A = \frac{T}{4L^2 {f_0}^2}$

Step 2. Group the quantities on the right-hand side of the expression so that the required right-hand-side of the proportionality is separated from the other quantities. Put these other quantities next to the equals sign.

This gives $\rho A = \frac{1}{4{f_0}^2} \times \frac{T}{L^2}$

Step 3. State that the term after the equals sign consists only of quantities which do not change, and so replace them with a single constant, for example, k.

This gives $\rho A = k \times \frac{T}{L^2}$.

Step 4:

At this stage you can assert that the direct proportionality ($\propto$) means = k ×, which is what you had been asked to demonstrate.

Question 7(b)(ii)

(ii) The thickest string on the bass guitar is 0.86 m long and is at a tension of 190 N.

You can assume that this string has the same mean density as a double bass string, which is 0.98 m long and is at a tension of 290 N.

By considering the ratio $\frac{T}{L^2}$ for the thickest strings on each instrument, discuss how the two strings will differ, and how plucking a double bass string would feel different from plucking a bass guitar string of the same fundamental frequency. You may include calculations in your answer.

....

....

....

....

.... **[3]**

Many were well able to show that the ratio is greater (302 N m $^{-2}$) for the double bass than for the bass guitar (257 N m $^{-2}$), but only the best went on to state that, as this ratio is proportional to ρA, where the density is the same for both, it meant that the double bass string was thicker.

For the last mark, many referred to the lower tension in the guitar bass as making it easier to pluck, which was acceptable, and some also commented on the thicker double bass string being harder to pluck.

Section C

Question 8(a)(i)

8 Two students, Alice and Bob, are using a diffraction grating to determine the wavelength of light emitted by a light-emitting diode (LED).

Bob places a ruler a distance x behind the grating and Alice observes the positions on the ruler corresponding to the straight-through beam (**A**) and the first-order diffracted beams (**B** and **C**), as shown in Fig. 8.1.

y_1 and y_2 are the observed values of y, the displacement on the ruler of **C** and **B** from **A**.

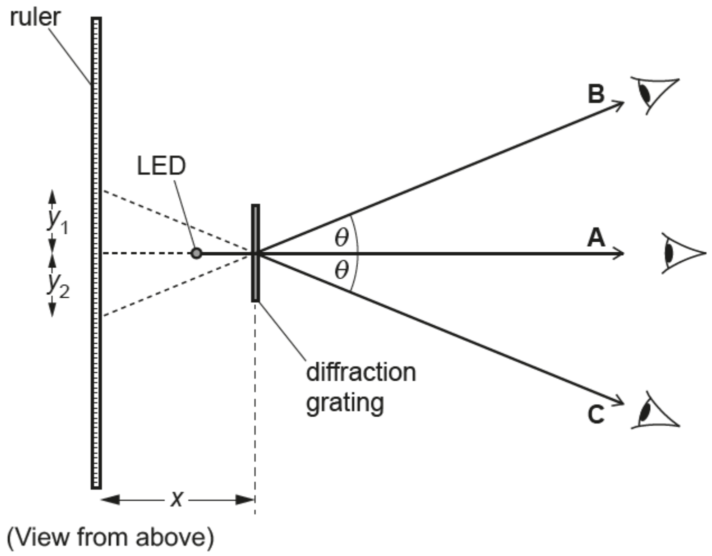

Fig. 8.1

(a) By measuring the distances y_1 and y_2, Alice and Bob intend to find the angle θ of first-order diffraction maximum.

(i) For this LED, Alice and Bob obtain the following data for the first-order maximum.

	reading 1	reading 2	reading 3
y_1/cm	5.9	6.2	6.1
y_2/cm	6.1	5.9	6.3

Use the table to calculate the mean value of y and its uncertainty.

mean = ... cm

uncertainty = ... cm **[3]**

Most candidates managed this very fluently, but there were enough wrong answers to make it worthwhile clarifying.

There are no obvious outliers, so the procedure here is to calculate the mean value of y, which is 6.083 cm, then to define the uncertainty as the spread = half the range = (6.3 – 5.9)/2 = 0.2, and then to reduce to uncertainty to 1 significant figure – in this case there are no extra figures to round, so the uncertainty = 0.2 cm. The last point is to round the mean value to agree with the precision of the uncertainty (i.e. the same number of figures after the decimal point), so y = 6.1 ± 0.2 cm.

Question 8(a)(ii)

(ii) Explain why repeating the measurements at least three times is good experimental practice.

....

....

.... **[2]**

Some answers were too routine, e.g. 'can calculate an average' rather than 'to give an average which is a better representation of the true value.' 'To identify outliers' was an acceptable response, but several explained clearly that three values was the minimum that you would need to identify an outlier.

Question 8(a)(iii)

(iii) Describe how Alice and Bob could use the values obtained in part **(a)(i)** to find the mean frequency of the light from the LED. You do not need to do any calculations.

....

....

....

....

.... **[3]**

This question was designed to tackle a shortcoming noted in AS candidates, that of failing to see the big picture and of focussing on detail. Many responses were too brief for all three marks, e.g. Use $n\lambda = d \sin \theta$ to find λ and then $c = f\lambda$ to find f, without stating how θ can be found. Better candidates wrote of y being the mean of the two displacements, and how it gives θ.

Question 8(b)*

(b)* Repeating the experiment for different LEDs, Bob used their data to plot the graph of Fig. 8.2.

The values of *E*, the minimum energy needed to emit a photon, were obtained by measuring the minimum p.d. that would allow the LED in question to emit light. The gradient of the best-fit straight line should be the Planck constant, *h*.

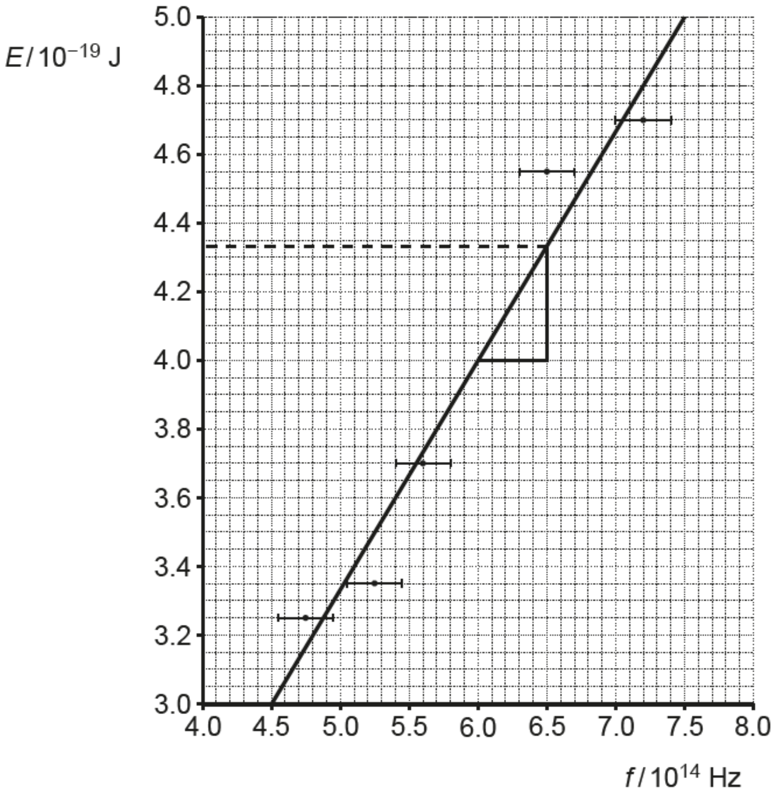

Fig. 8.2

Bob's analysis is shown on the graph of Fig. 8.2 and in the box following.

$$h = \text{gradient} = \frac{4.33 \times 10^{-19} - 4.0 \times 10^{-19}}{0.5 \times 10^{14}} = 6.6 \times 10^{-34}\ \text{J s}.$$

This is exactly the same as the data book, so the experiment worked well.

Evaluate his analysis of the data from the experiment.

....

....

.... **[6]**

8(b) was the second of the two extended response questions in this paper and was entirely based on one of the practical activities listed in the Specification in the sections headed *Demonstrate and apply knowledge and understanding of the following practical activities*. In the entire Specification for AS there are 19 such activities listed, and candidates are expected to have an understanding of the apparatus and techniques involved. This one was: *determining the Planck constant using different coloured LEDs*, which is one of the available Practical Activities contributing to the Practical Endorsement.

Weaker (Level 1) responses here were happy to take Bob's statement at face value, but most candidates spotted shortcomings in the analysis, such as the inadequate triangle drawn to calculate the gradient, the considerable spread in the data (suggesting that the uncertainties in f and/or E had been grossly underestimated, or else that some mistaken reading, probably the one at $E = 4.55 \times 10^{-19}$ J, had been made). Level 3 answers were more complete in detailing these shortcomings and also often suggested how the uncertainty for h could be found by drawing other lines, as mentioned in the commentary for 6(a).

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General qualifications
Telephone 01223 553998
Facsimile 01223 552627
Email general.qualifications@ocr.org.uk