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Examiners' report

PHYSICS A

H556

For first teaching in 2015

H556/03 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.

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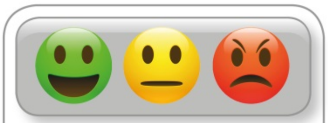

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Paper 3 series overview

H556/03, 'Unified Physics', is the last of the three examination components for the new revised A Level examination for GCE Physics A.

Compared to papers H556/01 and H556/02, a larger proportion of the questions in H556/03 target the higher assessment objectives (AO2 and AO3). This means that candidates should expect more problem-solving questions and less simple recall. For example, they can be asked to apply their knowledge and understanding to unfamiliar contexts, as in Question 1, to analyse and interpret experimental data, as in Question 2(b), or to design an experiment in order to test a conclusion, as in Question 3(c).

There are 10 examples of candidates' answers included below to illustrate points made in the report.

Candidate performance overview

Candidates who did well on this paper generally

- performed their calculations in a logical manner, showing clear working
- provided clear and structured answers to the Level of Response Questions 3(c) and 5(a)
- showed a good depth of understanding in their answers to the extended writing Questions 1(d) and 4(b)(ii)
- were confident in using their knowledge in unfamiliar contexts. For example, in Question 6(c), they were able to take their understanding of the Doppler shift from cosmology and apply it to sound waves.

Candidates who did less well on this paper generally

- found it difficult to choose the correct formula to use in an unfamiliar context. For example, they did not realise that Questions 1(a) and (b) involved a trapped volume of a gas under pressure, and so did not use the equation of state for an ideal gas.
- made arithmetic and/or power of ten (POT) errors in simple calculations.
- found it difficult to interpret and use all the information given in the text of the question.
- demonstrated poor application of physics principles in their answers to the extended writing Questions 1(d) and 4(b)(ii). In particular, they did not seem to have the skills required to respond to Question 4bii about circular motion.

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/

Question 1 (a) and (b)

1 A toy rocket is made from a 1.5 litre plastic bottle with fins attached for stability.

The bottle initially contains 0.30 litres of water, leaving 1.2 litres of trapped air at a temperature of 17 °C.
A pump is used to increase the pressure of the air within the plastic bottle to 2.4×10^5 Pa at the start of lift-off.

Fig. 1.1 shows the rocket at the start of lift-off.

1 litre = 10^{-3} m^3

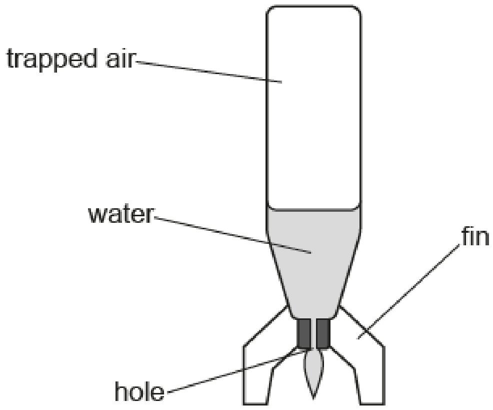


Fig. 1.1

(a) Calculate, in moles, the amount of trapped air in the bottle at the start of lift-off.

amount of air = ... mol **[2]**

(b) The trapped air pushes the water downwards out of the hole, causing the rocket to rise.
The temperature of this air remains constant.

Calculate the final pressure of the trapped air just before all the water has been released.

final pressure = ... Pa **[3]**

Questions 1(a) and 1(b) took the ideal gas equation and applied it to an unfamiliar situation, that of a toy rocket. Most candidates answered these questions well, remembering to convert the temperature from 17°C to 290K.

Common problems in 1(a) and 1(b)

- confusing *N* (number of molecules) with *n* (number of moles)
- using an incorrect power of ten (POT) value for the volume, by either failing to convert litres correctly or simply omitting the 10^{-3}.

Question 1 (c) (i)

(c) Here is some data on the toy rocket.

mass of empty bottle and fins = 0.050 kg
area of cross-section of hole = $1.1 \times 10^{-4}\,m^2$
initial pressure of trapped air = $2.4 \times 10^5\,Pa$
atmospheric pressure = $1.0 \times 10^5\,Pa$
density of water = $1.0 \times 10^3\,kg\,m^{-3}$

(i) Use the data above to show that the **upwards** force on the rocket at the start of lift-off is about 15 N.

[2]

Most candidates realised that a difference in air pressure between the inside and outside of the bottle would force the water downwards, producing an upwards force on the bottle which could be calculated using p = F/A.

Common problems in 1(c)(i)

- ignoring the pressure of the atmosphere to give an upwards force of 26N
- thinking that the upwards force was caused by upthrust and attempting to use the formula *p = hρg.*

Question 1 (c) (ii)

(ii) Hence calculate the initial vertical acceleration of the rocket.

initial acceleration = ... $m s^{-2}$ **[3]**

This question, although a simple F = ma problem, challenged many candidates.

Common problems in 1(c)(ii)

- using incorrect mass (either mass of bottle alone = 0.05kg, or mass of water alone = 0.3kg, or POT errors)
- using upwards force from 1(c)(i) rather than *resultant* force in the formula F = ma.

Exemplar 1

(ii) Hence calculate the initial vertical acceleration of the rocket.

$$\rho = \frac{m}{V} =$$

$$m = \rho V = 1 \times 10^3 \times 0.3 \times 10^{-3}$$
$$= 0.3$$

$$F = ma$$
$$a = F/m = \frac{15.4}{0.3 + 0.05} = 44 \text{ ms}^{-2}$$

initial acceleration = 44 ms^{-2} **[3]**

Exemplar 1 shows the most common incorrect response. The correct value for mass (m = 0.35kg) has been used, but the value for the upwards force (15.4N) rather than the resultant force (15.4 – mg) has been used for F.

Question 1 (d)

(d) Discuss whether adding more water initially would enable the rocket to reach a greater height.

....

....

....

.... **[3]**

This question involved several factors and a conclusion was not required; hence the word 'discuss'. Candidates who performed well on this question realised that the weight of the rocket would increase, reducing the resultant force, and m would increase in the formula F = ma. These would both give a reduced initial acceleration and imply a smaller height. However, the time taken to expel the water would increase, meaning that the rocket would accelerate for longer.

One common misconception was that the larger volume of water in the bottle would increase the pressure of the trapped air. However, as a pump was used to determine the pressure before lift-off, this argument was not given credit.

Question 2 (a)

2 $^{60}_{27}Co$ is produced by irradiating the stable isotope $^{59}_{27}Co$ with neutrons.

Each nucleus of $^{60}_{27}Co$ then decays into a nucleus of nickel (Ni) by the emission of a low energy beta-minus particle, one other particle and two gamma photons.

(a) Complete the nuclear equations for these two processes.

$$^{59}_{27}Co \; + \; ^{\cdots\cdots}_{\cdots\cdots}n \; \longrightarrow \; ^{60}_{27}Co \; \longrightarrow \; ^{\cdots\cdots}_{\cdots\cdots}Ni \; + \; ^{\cdots\cdots}_{\cdots\cdots}e \; + \; \cdots\cdots\cdots \; + \; 2\gamma$$

[3]

The correct symbol for the 'one other particle' in this question was ($\bar{\nu}$),($\bar{\nu}_e$) or ($^0_0\bar{\nu}$), all being acceptable.

Common problems in 2(a)

- some attempts for the symbol 'nu' could not be given because they were indecipherable or looked more like 'gamma'
- balancing the bottom row proved more troublesome than balancing the top row, presumably because of the '-1' for the electron

Exemplar 2

$$^{59}_{27}Co \; + \; ^{1}_{0}n \; \longrightarrow \; ^{60}_{27}Co \; \longrightarrow \; ^{60}_{28}Ni \; + \; ^{0}_{-1}e \; + \; \bar{\gamma}_e \; + \; 2\gamma$$

[3]

Exemplar 2 illustrates the two most common problems that were encountered in this response.

	AfL	Centres should give candidates plenty of practice in balancing equations that involve beta minus decay.

Question 2 (b) (i)

(b) Students want to carry out an investigation into gamma photon absorption using a source of ${}^{60}_{27}\text{Co}$.

They add sheets of lead between the source **S** and a radiation detector **T**, to give a total thickness *d* of lead. **S** and **T** remain in fixed positions, as shown in Fig. 2.1.

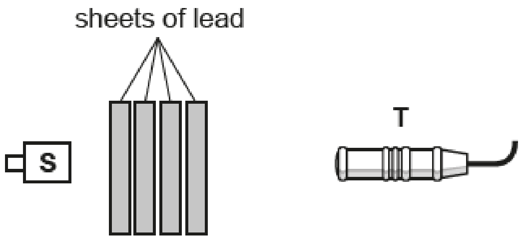


Fig. 2.1

(i) The ${}^{60}_{27}\text{Co}$ source emits beta radiation as well as gamma radiation.

Explain why this would not affect the experiment.

....

.... **[1]**

Candidates were clearly familiar with the penetrative powers of beta and gamma radiation.

Common problems in 2(b)(i)

- saying that beta would be absorbed by air/paper/aluminium, but not mentioning the lead
- saying that gamma would also be absorbed by the lead.

Question 2 (b) (ii) (1)

(ii) The students record the number N of gamma photons detected by **T** in 10 minutes for each different thickness d of lead. The background count is negligible.

The results are shown in a table. The table includes values of ln N, including the absolute uncertainties.

N	d/mm	ln N
4300 ± 440	0	8.37 ± 0.10
2500 ± 250	10	7.82 ± 0.10
1400 ± 150	20	7.24 ± 0.11
800 ± 90	30	6.68 ± 0.11
500 ± 60	40	6.21 ± 0.12
300 ± 40	50	

N and d are related by the equation $N = N_0 e^{-\mu d}$ where N_0 and μ are constants.

1. The students decide to plot a graph of ln N against d.

Show that this should give a straight line with gradient = – μ and y-intercept = ln N_0.

[1]

Most candidates were obviously very familiar with this and gave a clear response. Credit was given for either

Gradient of best fit line:

- a clear comparison of $\ln N = -\mu d + \ln N_0$ with y = mx + c
- using log rules to give $\ln(N_0 e^{-\mu d}) = -\mu d + \ln N_0$

Question 2 (b) (ii) (2)

2. Complete the missing value of ln N in the table, including the absolute uncertainty.

Show your calculation of the absolute uncertainty in the space below.

[2]

Candidates who gained the uncertainty mark mostly used the standard method of finding half the range i.e. (ln340– ln260)/2.

However, a very common response was to calculate the fractional uncertainty in N (i.e. 40/300) rather than the absolute uncertainty in lnN. This was not given without mathematical justification e.g. $\Delta(\ln N) \approx (\Delta N)/N$.

Question 2 (b) (ii) (3) and (4)

3. In Fig. 2.2, five of the data points have been plotted, including error bars for ln *N*.

- Plot the missing data point and error bar.
- Draw a straight line of best fit and one of worst fit. **[2]**

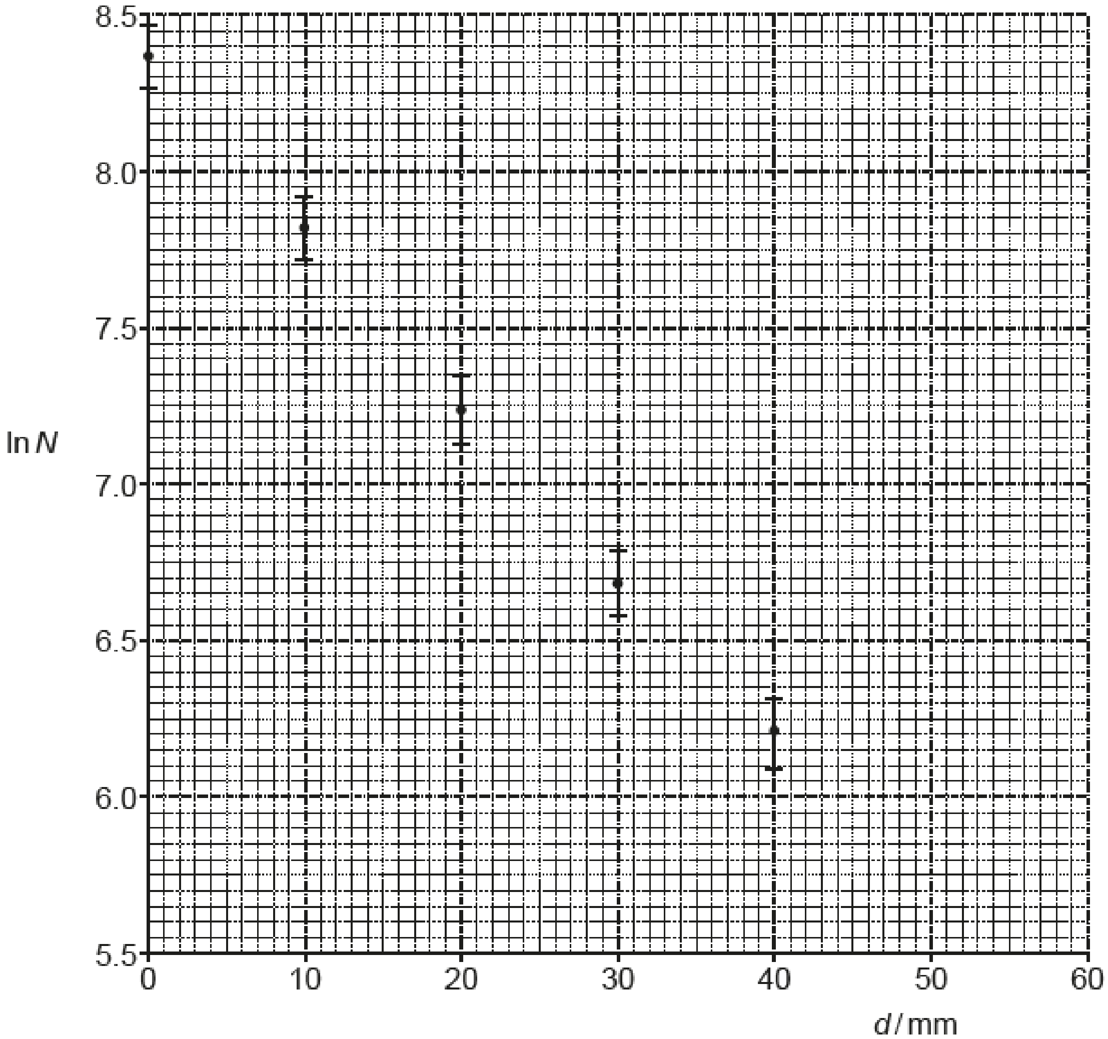


Fig. 2.2

4. Use Fig. 2.2 to determine the value of μ in m^{-1}, including the absolute uncertainty.

μ = ... ± .... m^{-1} **[4]**

The majority of candidates had no difficulty in plotting the point (50, 5.70) correctly. Both best and worst fit lines were usually drawn well enough, although some had very thick pencil lines and a surprising number had not been extended to the lnN axis. Almost all candidates gained the mark for using a sufficiently large triangle (Δd > 25mm) for calculating the gradient of their best fit line.

Common problems in 2(b)(ii)4

Gradient of best fit line

- Power of ten (POT) errors due to not converting mm to m
- Failure to notice the false origin of the ln*N* axis
- Taking the natural logarithm of the ln*N* axis data
- *Calculation of absolute uncertainty*
- Calculating the *fractional* or *percentage* uncertainty in *μ* instead of its *absolute* uncertainty
- Not giving the values of the gradient and its absolute uncertainty to the same number of d.p.

Question 2 (b) (ii) 5

5. Determine the thickness, $d_{½}$, of lead which halves the number of gamma photons reaching **T**.

$d_{½}$ = ... m **[2]**

Most mathematically able candidates quickly obtained the result μd1/2 = ln2 and then used it with their value of μ. Other candidates used a variety of (usually correct) graphical methods with Fig. 2.2.

Question 3 (a)

3 Fig. 3.1 shows the design of a 'mechanical' torch.

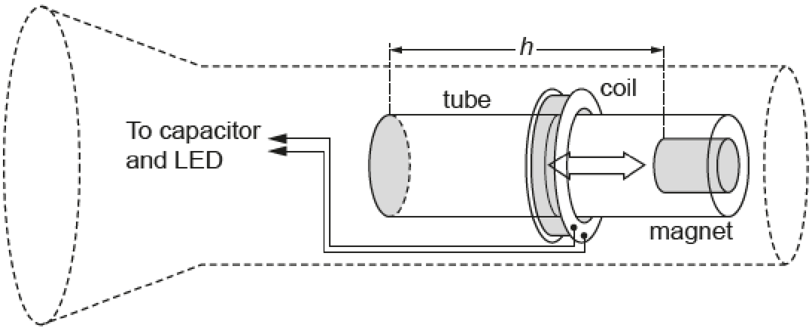


Fig. 3.1

There is no battery in the torch. Instead, when the torch is inverted, the magnet falls a short vertical distance h through the coil of wire, as shown in Fig. 3.2. This induces an electromotive force (e.m.f.) across the ends of the coil. The e.m.f. is used to store charge in a capacitor, which lights a light-emitting diode (LED) when it discharges.

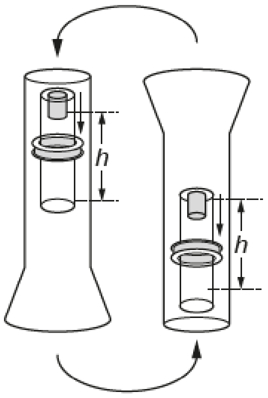


Fig. 3.2

Fig. 3.3 shows the variation with time of the e.m.f. generated as the magnet falls the distance h.

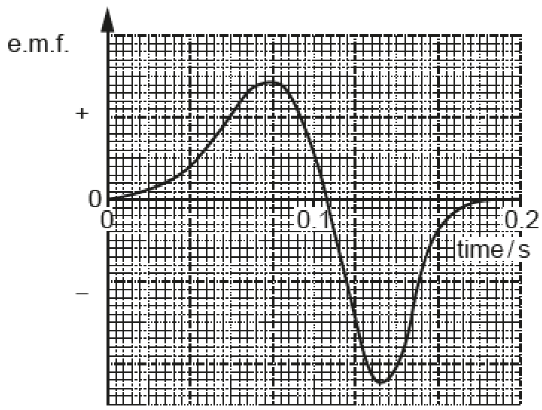


Fig. 3.3

(a) Explain the shape of the curve in Fig. 3.3.

....

....

.... **[3]**

Candidates need to remember to look at the command word in the question. Here it was 'explain'; not 'describe'.

The key features to be explained were:

- why is an e.m.f generated?
- why does the e.m.f change sign?
- why does the e.m.f fall to zero halfway through the fall?
- why is the maximum negative e.m.f greater than the maximum positive e.m.f / why is the width of the second peak smaller than that of the first peak?

The strongest responses were those where candidates stated at the outset what gave rise to the e.m.f. Some candidates clearly recognised the need to state Faraday's law, but simply quoted the formula without defining any terms and so could not receive credit. Weaker responses were characterised by describing the shape of the graph in terms of the position of the magnet - often incorrectly – rather than in terms of flux linkage. A common misconception was stating that the negative peak was caused by the magnet returning after an inversion, with the zero e.m.f. just after 0.1s being caused by the magnet being temporarily stationary. However, the question clearly states that 'Fig.3.3 shows … the e.m.f. generated … as the magnet falls the distance h'.

Exemplar 3 below demonstrates clearly this common misconception.

Exemplar 3

The first part of the curve the 'Emf' is increasesing as the magnet gets closer to the coil. The peak is when the magnet is in the middle of the coil as the magnet moves away so does the curve decrease. ~~and now~~ As the magnet is now moving in the opposite direction the emf is negative. It takes less time on the way back as The electric field repels it. [3]

Question 3 (b) (i)

(b) When the torch is inverted, the pulses of e.m.f. shown in Fig. 3.3 cause a capacitor of capacitance 0.12 F to become charged.
Each positive **and** each negative pulse adds 9.0×10^{-3} C to the charge stored in the capacitor.

(i) The torch is inverted 80 times.

Calculate the total energy stored in the capacitor.

total energy = ... J **[3]**

The strongest answers were those where candidates set out their response in steps; first calculating the total charge and then using a correct formula to calculate the total energy stored. Many candidates performed the steps of their calculation randomly across the answer space, making it hard to determine their method.

Common problems in 3(b)(i)

- ignoring the information that *each* pulse added charge
- ignoring the information that the torch was inverted 80 times
- applying the x 80 factor at the wrong stage in the calculation
- using the formula $W = QV$ rather than $W = ½QV$ to calculate the energy stored on the capacitor
- incorrectly substituting values stated in the question.

Question 3 (b) (ii)

(ii) When the torch is switched on, the energy stored in the capacitor lights a 50 mW LED.

Estimate the time for which the LED lights.

time = ... s **[1]**

Almost all candidates gained the mark for 3(b)(ii), as any incorrect answer to 3(b)(i) was accepted with error carried forward (ECF).

Question 3 (c)

***(c)** In the torch, the gravitational potential energy of the magnet is converted into electrical energy supplied to the 50 mW LED.

You are asked to investigate whether the efficiency of this energy conversion depends on the number of inversions of the torch.

- Describe how you will make accurate measurements to collect your data. Assume that both the torch and the tube can be opened.
- Explain how you will use the data to reach a conclusion. **[6]**

....

....

....

In level of response questions like 3(c), candidates must remember to refer closely to the stem of the question when planning their extended answer to make sure that they are addressing the question asked.

The challenge in this question was to design an experiment that would yield results leading to a valid conclusion. Candidates could gain full credit for investigating the efficiency of gravitational potential energy (GPE) to either:

- energy conversion in the LED (power x time) or
- energy stored in the capacitor (½CV^2 or ½Q^2/C)

Candidates were then expected to describe how the efficiency would be calculated, and how they could tell whether the efficiency depended on the number of times the torch is turned or inverted, n.

Many candidates were able to describe a valid graphical method, usually plotting efficiency against n, or output energy against input energy. Some candidates plotted time against number of inversions, which was able to score maximum credit provided that they clearly explained that t and n were proportional to output and input energy respectively.

The best responses were those where candidates had not just stated what to plot but had gone on to describe and explain the expected shape of the graph and what its gradient would show.

Common problems in 3c

- investigating the energy conversion ½Q^2/C to Pt
- assuming the number of inversions was varied without stating it explicitly
- using *mgh* for input energy rather than *nmgh, accounting for the number of inversions*
- assuming that the torch would gain the same amount of charge at every inversion rather than attempting to measure the final charge after *n* inversions
- using the formula efficiency = energy loss/input energy
- making an assumption about the outcome (e.g. I would expect to get a straight line through the origin)
- wrongly interpreting the graphical results they expected to get

Exemplar 4

Determine the length h using a ruler at eye level to reduce parallax. Measure the mass of the magnet using a digital mass balance and use the formula E = mgh to find the gravitational potential energy. ~~Make a circuit across the capacitor with a voltmeter and data logger to~~ For different intervals of number of turns, time how long the LED is lit up for and use Pt = W to find the work done by the LED. Find the efficiency of the torch using $\frac{\text{output}}{\text{input}} \times 100$ for each interval and plot a graph of efficiency against number of turns and draw a line of best fit. If it goes through the origin and is straight, then ~~energy~~ efficiency ~~and to~~ ∝ number of turns.

Exemplar 4 shows a typical Level 2 response. The candidate is correctly trying to find the efficiency of GPE converted to electrical energy in the torch, but their response lacks the clarity and detail needed for a Level 3 response. Also, their method will not yield correct results because they have

- not realised that GPE increases with the number of turns, so they need to use the formula GPE = nmgh.
- not specified that the length h is the distance that the magnet falls, rather than the length of the tube.
- not made clear which is the input and which the output energy in the (correct) efficiency formula.
- used incorrect graphical analysis for their graph of efficiency against n. We want to discover whether efficiency depends on n, not demonstrate that efficiency increases proportionally to n, which is impossible.

Question 4 (a)

4 At an airport, the conveyor belt for suitcases moves at a constant speed of $1.5\,\mathrm{m\,s^{-1}}$.
In Fig. 4.1, a suitcase of mass 8.0 kg has reached the line labelled **XX'**.

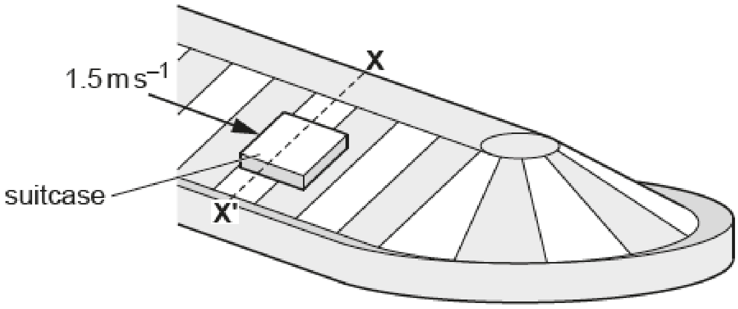


Fig. 4.1

Fig. 4.2 shows the situation in vertical cross-section.
The frictional force *F* prevents the suitcase of weight *W* from sliding to the bottom of the belt.
The normal contact force on the suitcase is *R*.
The belt is inclined at an angle of 30° to the horizontal.

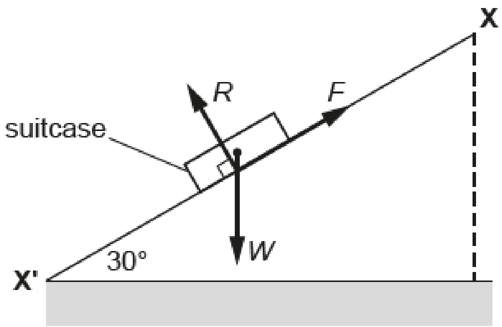


Fig. 4.2 (not to scale)

(a) By using a vector triangle, or by resolving forces, calculate the magnitude of forces *F* and *R*.

F = ... N

R = ... N
[3]

Most candidates were able to answer this question easily, although a few got their answers for F and R the wrong way around.

Question 4 (b) (ii)

(ii) When the suitcase is at line **YY'**, the magnitude of force *F* is larger and the magnitude of force *R* is smaller than at **XX'**.

Explain why this is so.

....

....

....

.... **[4]**

Question 4(b)(ii) proved very difficult and highlighted poor understanding of circular motion. Almost all candidates described the centripetal force as an additional force that had appeared out of nowhere. This centripetal force 'pulled the suitcase inwards' (or, in some cases, outwards) or 'balanced the frictional force' or 'added to the frictional force' and so on.

Exemplar 5

At YY' the bag is moving in an arc, meaning that centripetal force is acting on it as well as weight, friction and the normal. In order to keep the bag in equilibrium, friction has to increase and R has to decrease, as this centrifital force works against friction (F) and with R.

The candidate who gave the response in Exemplar 5 clearly thinks that an additional force, called the centripetal force, now acts on the suitcase. The forces F and R have to adjust in order to keep the suitcase in equilibrium. They have not realised that the suitcase is no longer in equilibrium horizontally but is accelerating. This means that the available forces have to adjust in order to provide a resultant force towards the centre of the circle, while still balancing vertically.

Exemplar 6

The suitcase is now accelerating towards the center of the semicircle. This means there is a net force acting to the left (on the diagram). W has no component to the left so F must increase so that there is a component to the left allowing it to accelerate allowing it to stay on course. The centripetal force required is 9N so the horizontal component of F must be 9N bigger than the horizontal component of R. The suitcase must not move down or up though so their vertical components **[4]** must still add to 78.48N so F increases and R decreases. F

In contrast, the candidate who wrote the response in Exemplar 6 has a much better grasp of the situation.

	AfL	Rather than using the phrase 'centripetal force', candidates could be encouraged to think of motion in a circle as a special case of $F = ma$ where the resultant force F points towards the centre of the circle and the acceleration a is given by v^2/r. This should hopefully encourage them to think about which of the forces available in the situation could provide the resultant force for this motion to occur.

Question 5 (a) (i)

5 Hydrogen atoms excited in a discharge tube only emit four different discrete wavelengths of visible photons.

***(a)** In a semi-darkened room, a single slit is placed in front of the discharge tube. A student holds a diffraction grating which has 300 lines per millimetre.
The student looks through the grating at a 15 cm plastic ruler placed 0.50 m away, as shown in Fig. 5.1.
The paths of the different colours of light from the slit to the student's eye are shown in Fig. 5.2.

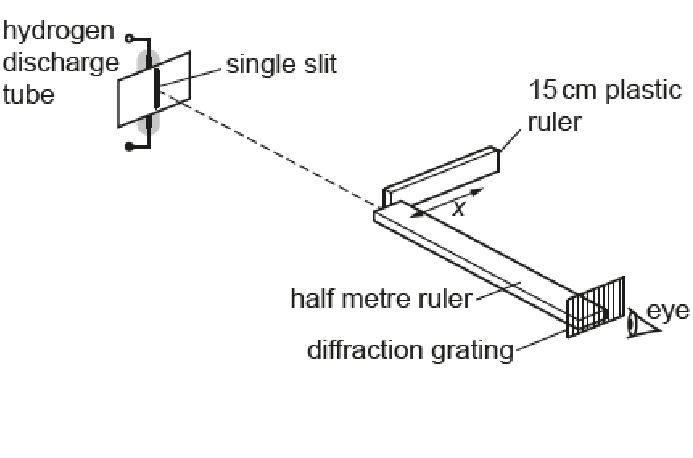


Fig. 5.1 (not to scale)

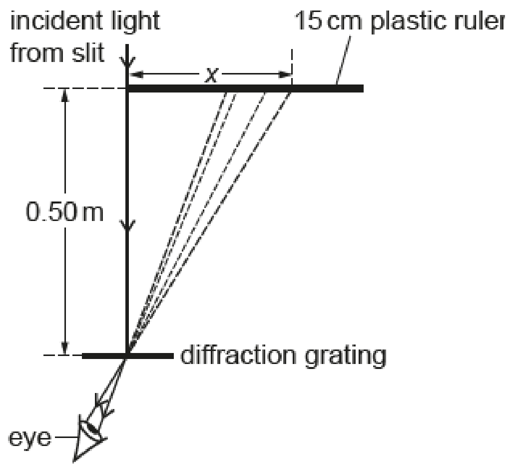


Fig. 5.2 (not to scale)

Four **first** order images of the slit, one at each photon wavelength, are observed as vertical lines against the background of the plastic ruler, as shown in Fig. 5.3.

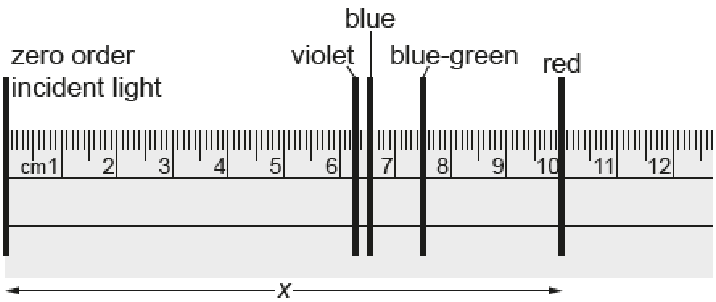


Fig. 5.3

The student decides to determine the wavelength of the photons which form the **red** line observed at x = 10 cm on the ruler.

- Describe how the information that has been given can be used to determine the wavelength of the red photons.
- Estimate the percentage uncertainty in the measured value of the wavelength. **[6]**

....

....

....

Unfortunately, a significant number of candidates did not recognise the diffraction grating experiment here, confusing it with the double slit experiment and so using the formula λ=ax/D. This may be because the formula nλ = dsinθ is in the astrophysics section of the formula sheet.

Candidates who chose to use the correct formula nλ = dsinθ were given for choosing the correct values for n, d and θ, for a correct calculation of λ, and for an accurate error analysis. Candidates who did not calculate λ could still gain full marks, as long as they gave accurate instructions as to how this could be done. Strong candidates successfully calculated a reasonable estimate of uncertainty in λ by combining the uncertainties in the distance measurements which had been used to find sin θ.

	AfL	The experiment to measure the wavelength of light using a diffraction grating is PAG 5.1 and so is often carried out in Year 12. It may be beneficial to carry out this practical activity in Year 13 instead during the study of spectral lines, to reinforce use of the formula *nλ = dsinθ*.

	OCR support	Being aware of the contents of the data , formulae and relationship booklet and its layout will support candidates, alleviating the need to recall numerical values of constants and allowing retrieval of correct formulae, or giving assurance that the student has recalled correctly.

Candidates who performed well tended to:	Candidates who did less well tended to:
• use $n = 1$ • use $d = 10^{-3}/300$ m • use trigonometry to find θ • estimate the uncertainty in λ	• use $n = 4$ • use d = 0.5m or d = 300mm • use a protractor to measure θ • estimate the uncertainty in one or more distance measurements only

Exemplar 7

Red photons occur only at the 4th order (n).
there are 300 lines per millimeter, which is ~~to~~
300 000 per meter., finally ~~slit separation is~~
Need to measure the angle θ between the
3rd and 4th order to use equation
dsinθ = nλ, Rearrange for λ

A more/ fully darker room would be better as
its ~~[illegible]~~ easier to determine ~~and~~ the colours
and see the light.

Exemplar 7 illustrates many aspects of a Level 1 response. Although the correct formula has been identified, it will not give a correct value for λ because incorrect values for *n*, *d* and *θ* have been chosen. The response has been put at the bottom of Level 1 because, although there is an attempt at a logical structure, almost all of the information it contains is inaccurate and therefore not relevant.

Question 5 (b) (i)

(b) (i) Show that the energy of a photon of wavelength 486 nm is 4.09×10^{-19} J.

[1]

This question was successfully attempted by the majority of candidates.

Exemplar 8

$$E = \frac{hc}{\lambda}$$

$$E = \frac{h \times (3 \times 10^8)}{(486 \times 10^{-9})}$$

$$= 4.090$$

Exemplar 8 shows the most common incorrect response. The candidate has not realised that, in a 'show that' question, an equation, full substitution and calculated response are all required. This includes inserting numerical values for the constants h and c.

Question 5 (b) (ii)

(ii) Fig. 5.4 shows some of the energy levels of an electron in a hydrogen atom.

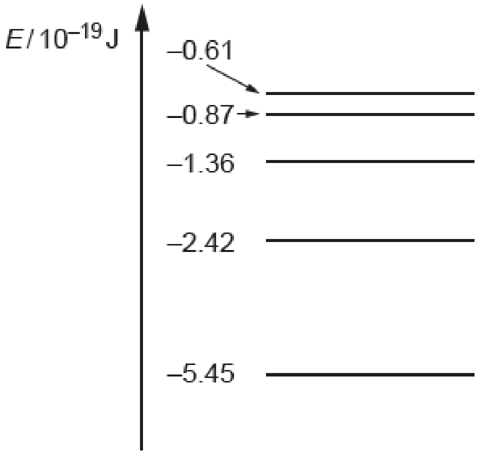


Fig. 5.4 (not to scale)

Draw an arrow on Fig. 5.4 to show an electron transition which would cause the **emission** of a photon of wavelength 486 nm. **[2]**

The majority of candidates scored at least 1 mark, although some would have been helped by better presentation.

Common problems in 5(b)(ii)

- drawing an upwards arrow (not realising that the emission of a photon would be caused by a drop in energy level)
- choosing the wrong two energy levels (not realising that the difference between -1.36 and -5.45 = 4.09)

Question 6 (a)

6 **(a)** Describe the **Doppler effect.**

....

.... **[1]**

Very few candidates were able to score this mark.

Common problems in 6(a)

- stating that the frequency of the source had changed rather than referring to an *observed* frequency
- referring to the frequency of an 'object' without specifying that the object was a wave source
- referring only to the movement of the source or the observer rather than describing relative motion between the two
- talking about the motion of the wave rather than the wave source.

?	**Misconception**	When a wave source moves towards or away from an observer, the frequency of the wave does not change; it only *appears* to have changed when viewed by the observer.

Exemplar 9

There is a change in wavelength / frequency when the Source is moving. [1]

Exemplar 9 illustrates a typical incorrect response.

Question 6 (b)

(b) Explain how ultrasound is used to measure the speed of blood flow in an artery.

....

....

....

.... **[2]**

There were 4 opportunities to score marks here, so most candidates were able to score at least one. The most usual marks to be scored were about the probe being placed at an angle, and that the frequency of the reflected wave was different from that of the emitted wave.

Common problems in 6(b)

- quoting the equation without clearly defining c as the speed of ultrasound in the medium and not the speed of light
- thinking that a time delay, rather than a frequency shift, was used to find the speed of blood
- confusing Doppler ultrasound with A- or B-scans

Question 6 (c) (i)

(c) In cosmology, the Doppler effect can be observed with light from distant galaxies. The Doppler effect can also be observed with sound waves.

Two students use sound waves to investigate the Doppler effect.
In an open space, one student swings a loudspeaker at constant speed in a horizontal circle of radius 0.60 m.
The other student stands a large distance away and holds a microphone. The microphone is connected to a data logger and computer.

Fig. 6.1 shows the situation, viewed from above.

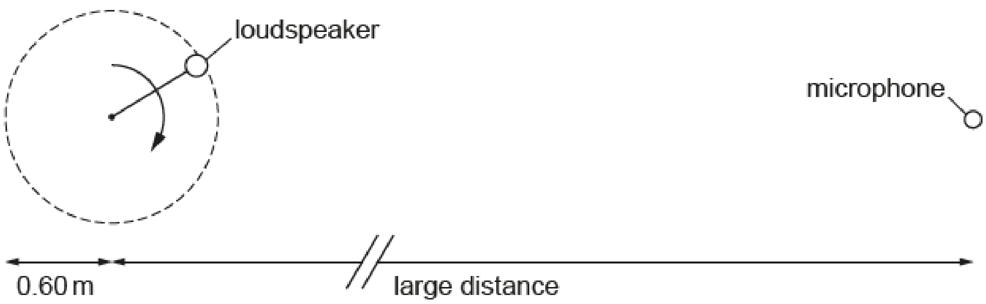


Fig. 6.1

The loudspeaker emits sound in all directions at a single frequency f_0 = 1700 Hz.

Fig. 6.2 shows the variation with time t of the frequency f received by the microphone.

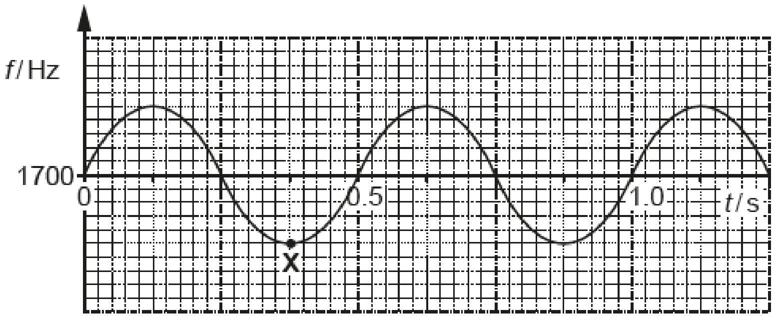


Fig. 6.2

(i) Use Fig. 6.2 to show that the speed of the loudspeaker is 7.5 m s^{-1}.

[2]

Most candidates scored this mark. Some tried to use the Doppler equation to find the speed of the sound (rather than the speed of the loudspeaker).

Question 6 (c) (ii)

(ii) The speed of sound in this experiment is 330 m s^{-1}.

Calculate the maximum change in frequency Δf of the sound detected by the microphone.

Δf = ... Hz **[2]**

The question had stated clearly that the students were investigating the Doppler effect, and candidates were expected to use the Doppler equation $\Delta f/f \approx v/c$.

Common problems in 6(c)(ii)

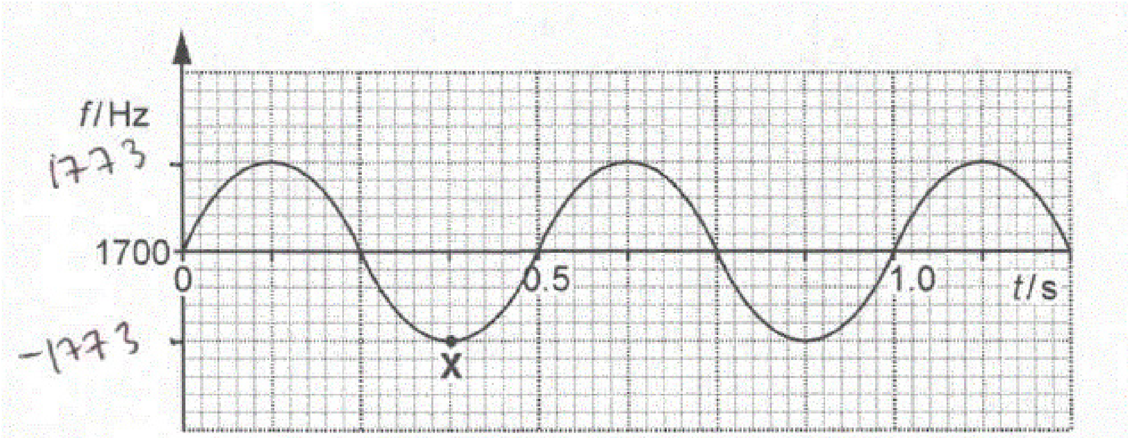
- using the formula for Doppler ultrasound from 6(b) and so obtaining an answer of 78Hz rather than 39Hz (see Exemplar 10)
- using the velocity of light rather than velocity of sound for *c*
- adding the velocity of the loudspeaker to the velocity of sound for *v*, substituting in the formula to find Δ*f*, and then subtracting the frequency of sound from the answer. Although this gave the correct answer, it is wrong physics and so was not given credit.

Question 6 (c) (iii)

(iii) Hence complete the scale on the *y*-axis of Fig. 6.2. **[1]**

Many candidates left 6(c)(iii) blank, although full marks could have been given from ECF from (c)(ii). The most common error here was using + and – the value obtained in (c)(ii), rather than subtracting or adding it to 1700, as demonstrated in Exemplar 10 below.

Exemplar 10



(ii) The speed of sound in this experiment is 330 m s^{-1}.

Calculate the maximum change in frequency Δf of the sound detected by the microphone.

$$\Delta f = \frac{2vf}{c} = \frac{2 \times 7.5 \times 1700}{330}$$

$$= \Delta f = 77.3$$

Δf = ...77.3........ Hz **[2]**

Question 6 (c) (iv)

(iv) Mark with an **X** on Fig. 6.1 the position of the loudspeaker which corresponds to the point **X** on Fig. 6.2. **[1]**

The purpose of this question was to test whether candidates could associate a maximum decrease in observed frequency (a 'red shift') with motion directly away from the observer / microphone. Unfortunately, not many were able to place the cross correctly, with many leaving this response blank.

Question 6 (d)

(d) In their laboratory notes, one student writes about the **accuracy** of the measurements whereas the other writes about their **precision**.

Define these terms.

accuracy: ....

....

precision: ....

.... **[2]**

This was generally well answered, although a few candidates reversed the definitions. Some candidates thought that the precision of an answer was determined by its number of significant figures.

	AfL	Centres should make sure that they are using the latest definitions, which can be found in *The Language of Measurement* (ASE 2010).

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