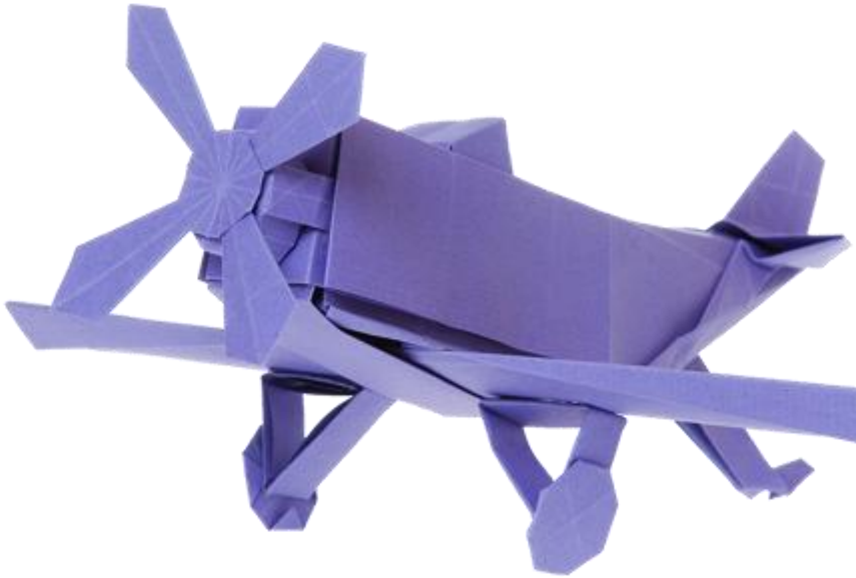
A Level Physics

Preparing for AO3 Questions

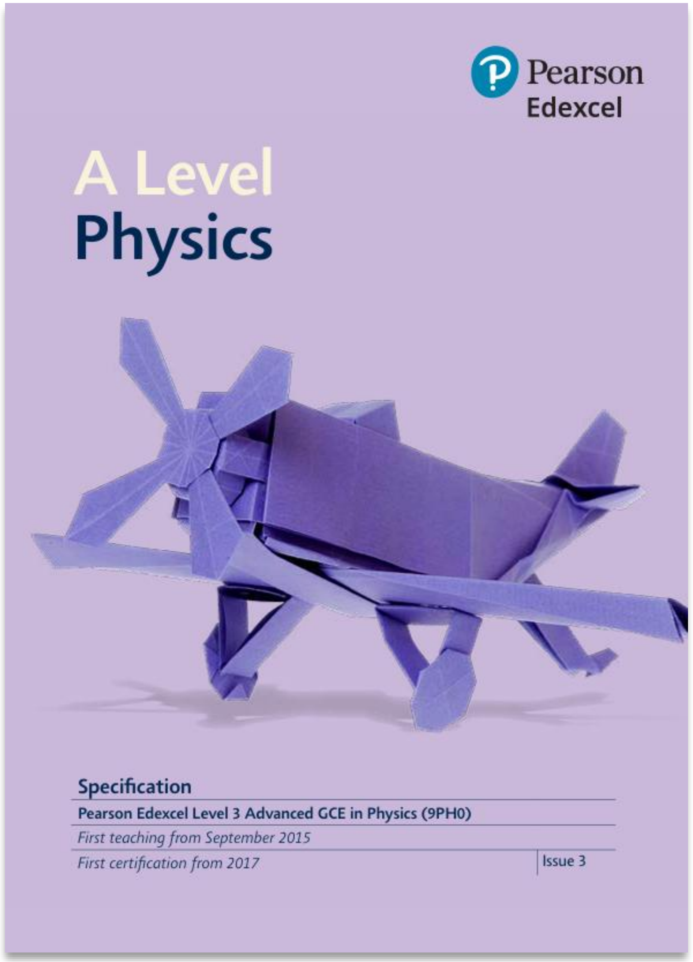
9PH0-25O1/01



Welcome to this Professional Development Session

Aims of this session:

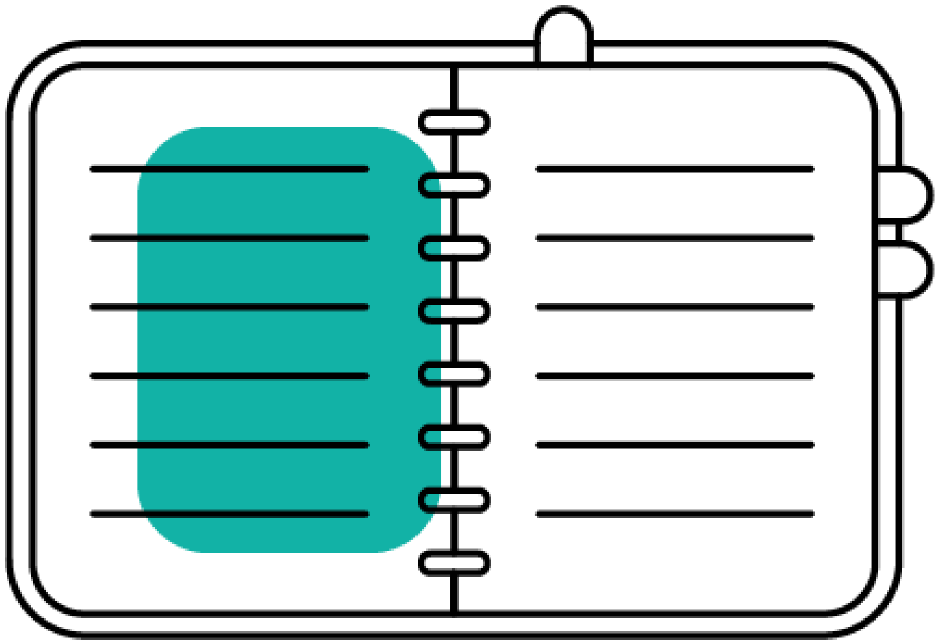
- to equip teachers with effective strategies to teach AO3 skills to A Level Physics students
- to enhance teachers' understanding of how AO3 skills are assessed in the Edexcel A Level Physics exam
- to provide teachers with practical tools and resources to help students develop and demonstrate AO3 skills.



Objectives

In this session you will:

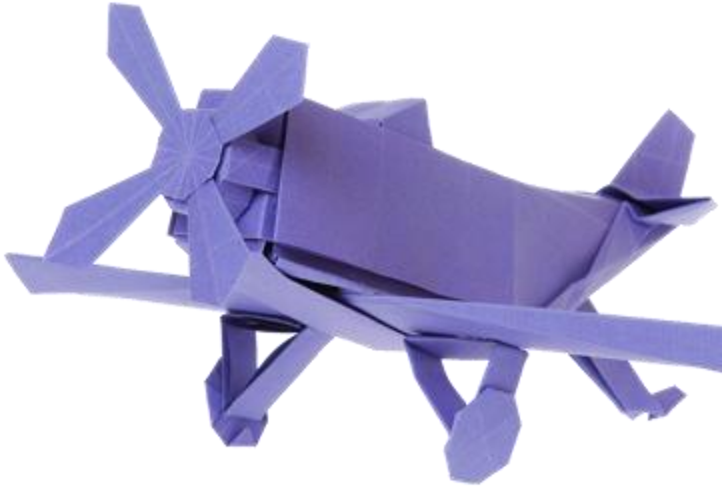
- identify the key components of AO3 skills as outlined in the Edexcel A Level Physics specification
- better understand how marks are awarded for AO3 questions
- learn various teaching strategies to help students develop AO3 skills.



Session Agenda

Item	Time
Understanding AO3 skills	10 min
Detailed analysis of questions	25 min
Common mistakes (and how to avoid them)	3 min
Strategies for teaching AO3 skills	5 min
Conclusion	2 min
Resources and support	2 min
Q & A	8 min

Understanding AO3 Skills



Balance of AOs on the papers

		% in AS	% in AL
AO1	Demonstrate knowledge and understanding of science	**35 – 37**	**31 – 33**
AO2	Application of knowledge and understanding of science in familiar and unfamiliar contexts	**41 – 43**	**41 – 43**
AO3	Analysis and evaluation of scientific information to make judgements and reach conclusions Experimental skills in science, including analysis and evaluation of data and methods	**20 – 23**	**25 – 27**

AO3 Skills

- The focus of questions that target AO3 is to assess the student's ability to analyse, interpret and evaluate different forms of physics information, ideas and evidence.
- AO3 questions may require students to make a conclusion, make a choice, or to justify a statement.
    - These questions usually require students to carry out calculations to come to a conclusion.
    - They don't tell the students exactly what to calculate.
    - These questions are found in all question papers.
- AO3 questions may require students to develop and refine practical design and procedures.
    - These questions assess skills developed when students carry out the core practicals.
    - This type of question is found in both AS papers, but only in Paper 3 of the A Level assessment.

Example of AO3 Questions

12 A wire-wound resistor consists of a long length of wire wound around an insulating core. A technician finds a wire-wound constantan resistor labelled 80 Ω.

(b) A potential difference of 9.8 V is applied across the resistor and the current in the resistor is 0.12 A.

Deduce whether the value labelled on the resistor is supported by these data.

uncertainty in the potential difference = ±0.1 V
uncertainty in the current = ±0.01 A

4 A student carried out an experiment to determine the focal length of a converging lens.

In his lab report he wrote:

"I made an initial determination of the focal length of the lens and concluded that it was about 15 cm. When I plotted a graph it confirmed my initial determination of the lens focal length."

Comment on whether the student's data is consistent with his initial determination of the focal length of the lens.

13 A 'tennis trainer' consists of a tennis ball suspended by a string from the top of a vertical pole. When the ball is hit it travels in a horizontal circle around the pole, as shown in both the photograph and the diagram.

The radius of the path of the ball is 1.2 m and the speed of the ball is 3.8 m s^{-1}.

Deduce whether these values are consistent with the angle between the string and the vertical pole shown in the photograph.

(5)

15 Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

13 A manufacturer gives the following information about a spring.

1. Follows Hooke's law up to loads of 5 N
2. Maximum extension without permanent deformation 0.4 m
3. Stiffness 21 N m^{-1} ±5%
4. Stores up to 1.6 J

A student carried out an investigation on the spring to test this information.

She applied a range of forces from 0 N to 5 N to the spring. She measured the length of the spring and recorded the extension for each force.

She plotted a graph of force against extension.

(b) Discuss the extent to which the student's results are consistent with the information given by the manufacturer.

Q12 9PH01 (2024)

Electrical power is transmitted from Norway to Britain using a cable laid under the North Sea.

The following information is published on a website.

> The cable has a diameter of 15 cm and a length of 720 km.
>
> It is made of copper of resistivity $1.7 \times 10^{-8}\ \Omega m$.
>
> The electrical power transmitted from Norway is 1400 MW and the transmission potential difference is 1100 kV.
>
> The efficiency of this process is almost 100%.

Deduce, by calculation, whether the claim for efficiency is correct.

- The data is already clearly set out in the question.
- The question is directing us to calculate a value for efficiency.
- $\text{Efficiency} = \dfrac{\text{output power}}{\text{input power}} = \dfrac{P_{\text{out}}}{P_{\text{in}}}$
- We know P_{in} and so we need to calculate P_{out}.
- Energy is conserved, and so P_{out} = [P_{in} − power losses in cable].
- To calculate the power losses in cable we need to know the resistance of the cable and the current it carries.

Q14(c) 8PH02 (2024)

The work functions of some minerals that have been found on the surface of the Moon are shown.

Mineral	Work function / eV
ilmenite	4.3
olivine	7.9
pyroxene	5.1

Ultraviolet radiation with a frequency of 2.0×10^{15} Hz is incident on a sample of one of these minerals and electrons are emitted by means of the photoelectric effect.

The released electrons have a maximum kinetic energy of 4.0 eV.

Deduce the mineral from which the photoelectron is released.

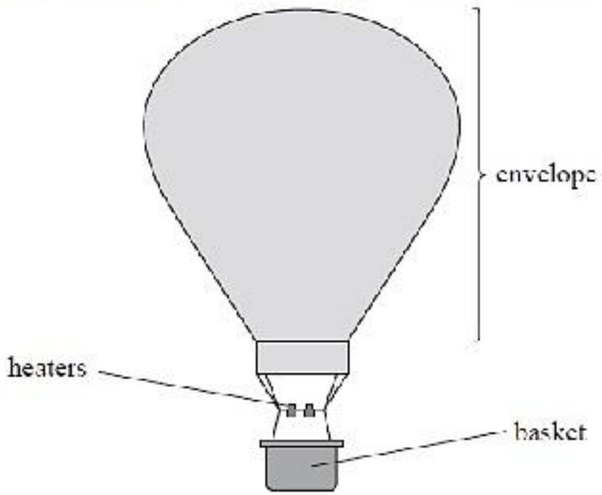
- The question is directing us to select a material from the table, so we need to calculate a value for the work function of the unknown mineral.
- We are given the frequency of the uv-radiation, so we can use $E = hf$ to calculate the energy in, J, of one photon of this radiation.
- Then we can convert the energy in J to an energy in eV.
- Finally, we can use $\text{photon energy} = \text{work function} + \text{max. K. E.}$ with max K.E. = 4.0 eV, to calculate the work function and compare with the values in the table.

Q17(a) 9PH02 (2024)

- The question directs us to determine whether the upward force acting on the balloon is greater than the downward force acting on the ballon.
- The upward force is equal to the upthrust (given in question).
- The downward force is equal to the total weight of air, balloon and passengers.
- To calculate the mass of air in the balloon, we use the density of air.
- The density of air is given at a temperature of 20^{o}C, so we need to determine the volume of air at 20^{o}C and then use $\text{density} = \frac{\text{mass}}{\text{volume}}$
- Finally, we can use

$$\text{weight} = (\text{total mass}) \times g$$

A hot air balloon consists of a fabric envelope, heaters and a basket, as shown.



When the balloon is set up, the envelope is partly filled with air at 20°C. The air is then heated to 120°C and expands to fill the envelope and becomes less dense.

The air pressure inside the envelope is always equal to the air pressure outside the envelope because the envelope is open at the bottom.

The balloon takes off when the upthrust is more than the total weight of the balloon, the air in the envelope and the passengers.

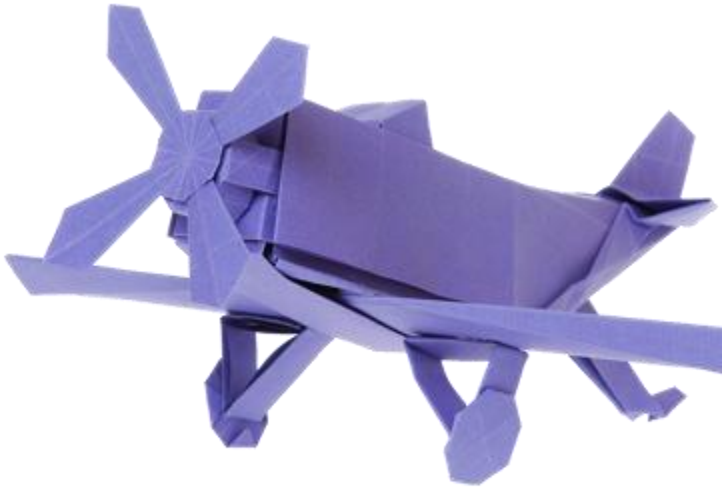
Deduce whether the balloon can take off.

volume of air at 120°C in inflated envelope = $2800\,\text{m}^3$
density of air at 20°C = $1.2\,\text{kg}\,\text{m}^{-3}$
mass of balloon = 380 kg
mass of passengers = 340 kg
upthrust when the envelope is full = 33 000 N

Common Challenges

- AO3 ‘calculation’ questions do not necessarily have an explicit route, so students may not know how to start their solution.
- Students may not be able to extract salient detail from the question.
- Students may be distracted by the context.
- Students may not understand the role that context plays in the question.
- Students may not state a conclusion.
- Students may omit a comparison with a value given in the question in giving their conclusion.

Detailed analysis of questions



Q12 9PH01 (2024)

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> The efficiency of this process is almost 100%.

Deduce, by calculation, whether the claim for efficiency is correct.

Question Number	Acceptable answers		Additional guidance	Mark
12	• Use of $P = VI$	(1)	Example of calculation 1400×10^6 W = 1100×10^3 V × I I = 1273 A	6
	• Use of $A = \pi r^2$	(1)	radius = 0.15 m /2 = 0.075 m $A = \pi(0.075)^2 = 0.0177$ m^2	
	• Use of $R = \rho l/A$	(1)	$R = 1.7 \times 10^{-8}\,\Omega$ m × 720 000 m / π (0.075 m)^2 $R = 0.693\,\Omega$	
	• Use of $P = I^2R$	(1)	P_{lost} = (1273 A)^2 × 0.693 Ω = 1.12 MW	
	• Use of efficiency = power out/power in Accept for MP5 power loss/power in	(1)	Efficiency calculation (1400–1.12) MW / 1400 MW or 1.12 MW / 1400 W	
	• 100% and consistent conclusion (MP6 dependent on fully correct method)	(1)	Efficiency = 99.9 % OR 1 – 0.0008 = 99.9 %	

Example 1

$P = IV$

$$I = \frac{1400 \times 10^6}{1100 \times 10^3} = 1272.727273\,A$$

$$R = \frac{\rho l}{A} \qquad R = \frac{1.7 \times 10^{-8} \times 720 \times 10^3}{\pi \times \left(\frac{15 \times 10^{-2}}{2}\right)^2} = 0.69264\ldots$$

$$P = I^2 R = 1272^2 \times 0.69264 = 1.12 \times 10^6\,W \rightarrow \text{power losses}$$

$$1400\,mW - 1.12\,mW = 1398.88$$

$$\text{efficiency} \quad \frac{1398.88}{1400} = 99.9\%$$

so yes efficiency is close to 100%

Example 2

$$R = \frac{\rho l}{A} = \frac{(1.7\times10^{-8})(720\times10^{3})}{(0.075)^2\pi} = 0.693\,\Omega$$

~~Power dissipated $= \frac{V^2}{R} = \frac{(1100\times10^{3})^2}{0.693}$~~

~~$= 1.75\times10^{12}$ W~~

$=$ ~~1750 M~~

Power Dissipated $= \frac{1100^2}{0.693}$

~~$E = \frac{1100000}{0.693}$~~

$= 1.75\times10^{6}$ W

$$\frac{1400 - 1.75}{1400}\times100 = 99.88\%$$

$= 99.9\%$

(Total for Question 12 = 6 marks)

This is almost 100% efficient

So the claim is correct

Q14(c) 8PH02 (2024)

The work functions of some minerals that have been found on the surface of the Moon are shown.

Mineral	Work function / eV
ilmenite	4.3
olivine	7.9
pyroxene	5.1

Ultraviolet radiation with a frequency of 2.0×10^{15} Hz is incident on a sample of one of these minerals and electrons are emitted by means of the photoelectric effect.

The released electrons have a maximum kinetic energy of 4.0 eV.

Deduce the mineral from which the photoelectron is released.

14(c)	• Conversion between eV and J • Use of $hf = \phi + \frac{1}{2}mv_{max}^2$ • $\phi = 4.3$ (eV) therefore the mineral is Ilmenite	(1) (1) (1)	Example of calculation $\phi = \frac{6.63 \times 10^{-34} \text{J s} \times 2.0 \times 10^{15} \text{ Hz}}{1.6 \times 10^{-19} \text{ C}} - 4.0$ $\phi = 4.3$ eV	3

Example 1

Deduce the mineral from which the photoelectron is released.

(3)

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

$hf = \phi + \frac{1}{2}mv^2_{max}$

$(6.63\times10^{-34})\times(2\times10^{15}) - (4\times1.6\times10^{-19}) = \phi$

$6.86\times10^{-19}\,J = \phi$

$\frac{6.86\times10^{-19}}{1.6\times10^{-19}} = 4.2875 = 4.3$

ilmenite was released

Example 2

Deduce the mineral from which the photoelectron is released.

(3)

$hf = \phi + K_{E\,max}$

$(6.63\times10^{-34}) \times (2\times10^{15}) = \phi + 4$

$1.326\times10^{-18} = \phi + 4$

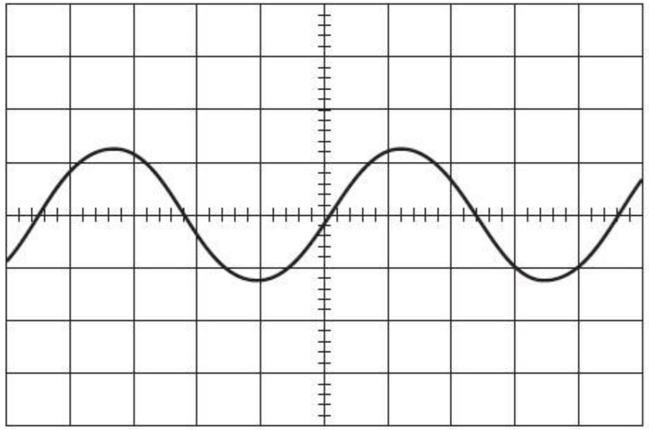
~~$(1.326\times10^{-18}) \times (1.6\times10^{-19})$~~

pyroxene

Q6(b) 9PH03 (2024)

The plate is set into movement by a vibration generator. The wavelength of the waves produced in the plate was estimated to be 0.32 m.

The signal applied to the vibration generator is shown on the oscilloscope trace below. The time base of the oscilloscope was set to $0.50\,\text{ms div}^{-1}$.



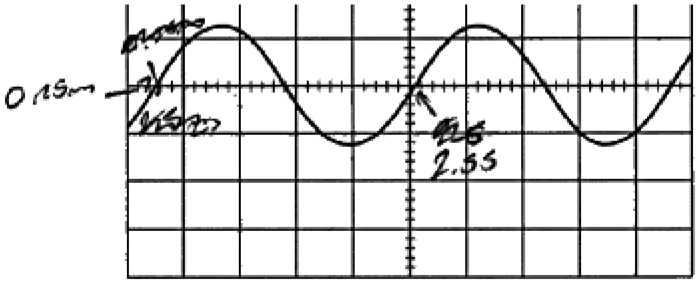
The waves produced in the plate travel at a speed much less than the speed of sound in air.

Evaluate whether the data supports a value for the speed of waves in the plate that is much less than the speed of sound in air.

speed of sound in air = $340\,\text{m s}^{-1}$

6(b)	• 1 full cycle read from oscilloscope trace 4.5 → 4.7 div • Converts from div to s • Use of $f = 1/T$ • Use of $v = f\lambda$ • $v = 140\ \text{m s}^{-1}$, which is (much) less than $340\ \text{m s}^{-1}$	(1) (1) (1) (1) (1)	<u>Example of calculation</u> $T = 4.6\ \text{div} \times 0.5\ \text{ms div}^{-1} = 2.3\ \text{ms}$ $f = \dfrac{1}{2.3 \times 10^{-3}\ \text{s}} = 435\ \text{Hz}$ $v = 435\ \text{s}^{-1} \times 0.32\ \text{m} = 139\ \text{m s}^{-1}$ Allow "the speed of sound in air" for $340\ \text{m s}^{-1}$	5

Example 1



The waves produced in the plate travel at a speed much less than the speed of sound in air.

Evaluate whether the data supports a value for the speed of waves in the plate that is much less than the speed of sound in air.

speed of sound in air = $340\,\mathrm{m\,s^{-1}}$

(5)

$v = \lambda f$

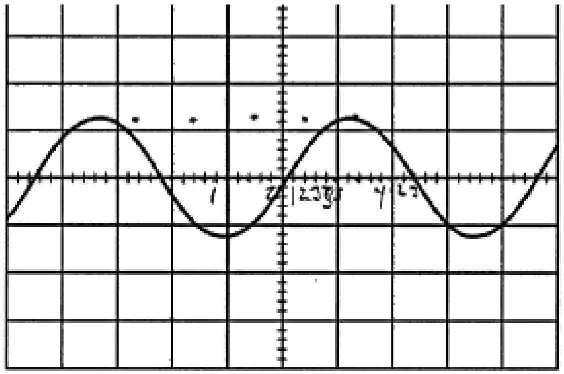
2.55 − 0.25 = 2.3 ms

$\frac{1}{2.3 \times 10^{-3}}$ = 434.78 Hz

0.32 × 434.78 = 139.13 m s⁻¹

139 < 340 ∴ it does travel slower.

Example 2



4·3 × 0·5ms ×10⁻³ s
⇓
0.0215 s

The waves produced in the plate travel at a speed much less than the speed of sound in air.

Evaluate whether the data supports a value for the speed of waves in the plate that is much less than the speed of sound in air.

speed of sound in air = 340 m s^{-1}

(5)

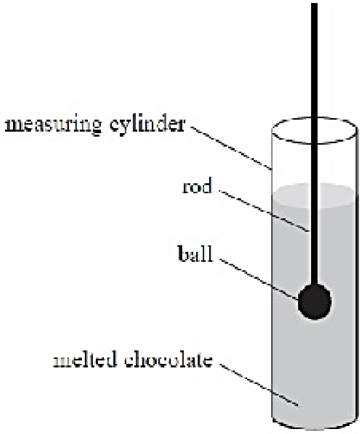
$\frac{1}{0.0215} = 46.5 Hz$

$v = f\lambda = 46.5 \times 0.32 = 14.88 ms^{-1}$

And so is far less than the value for speed of sound in air which is 340 ms^{-1}

Q12(a) 9PH03 (2024)

A student investigated the viscosity of some melted chocolate using a falling-ball method. Since chocolate is opaque, a thin rod was attached to the ball so that the movement of the ball could be monitored. The apparatus is shown in the diagram.



r is the radius of the ball
ρ_B is the density of the ball
ρ_C is the density of the chocolate
η is the viscosity of the chocolate.

The chocolate was maintained at a constant temperature during the investigation.

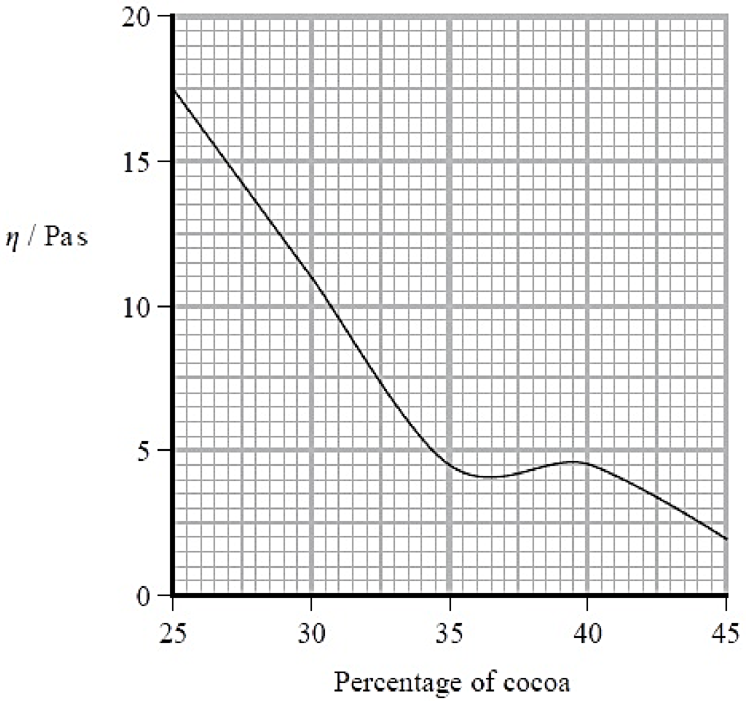
(i) The student used a stopwatch to measure the time t for the ball to fall 22.5 cm whilst travelling at its terminal velocity v.
Her results are shown in the table.

t_1 / s	t_2 / s	t_3 / s
9.6	9.9	9.6

v is given by the formula

$$v = \frac{2r^2 g(\rho_B - \rho_C)}{9\eta}$$

The graph is taken from a commercial website. It shows how, at the temperature of the experiment, η depends on the percentage of cocoa in the chocolate.



The chocolate wrapper indicated that the chocolate had a 35% cocoa content.
Assess whether the student's timing data supports this percentage cocoa content.

$r = 4.25 \times 10^{-3}$ m
$\rho_B = 7750$ kg m^{-3}
$\rho_C = 1330$ kg m^{-3}

Q12(a) 9PH03 (2024)

12(a)(i)	**EITHER**		Example of calculation	
	• Calculation of mean t	**(1)**	$t = \frac{(9.6 + 9.9 + 9.6)\text{ s}}{3} = 9.7\text{ s}$	
	• Use of $s = ut$	**(1)**	$v = \frac{0.225\text{ m}}{9.7\text{ s}} = 0.0232\text{ m s}^{-1}$	
	• Use of $v = \frac{2r^2g(\rho_B - \rho_C)}{9\eta}$	**(1)**	$\eta = \frac{2 \times (4.25 \times 10^{-3}\text{ m})^2 \times 9.81\text{ m s}^{-2} \times (7750 - 1330)\text{ kg m}^{-3}}{9 \times 0.0232\text{ m s}^{-1}}$ $\eta = 10.9$ Pa s, so cocoa content is 30% (from graph)	
	• Cocoa content = 30% **Or** viscosity at 35% = 4.5 (Pa s)	**(1)**		
	• Conclusion consistent with their graph value	**(1)**	Cocoa content is 30% so not consistent **Or** viscosity value is 4.5 Pa s so not consistent	
	OR			
	• Viscosity at 35% = 4.5 (Pa s)	**(1)**		
	• Use of $v = \frac{2r^2g(\rho_B - \rho_C)}{9\eta}$	**(1)**		
	• Use of $s = ut$ to calculate time to fall T_{fall}	**(1)**		
	• Calculation of mean t	**(1)**		
	• Conclusion consistent with calculated value of T_{fall}	**(1)**	Time taken would be 4.0 s so not consistent with mean time	**5**

Example 1

Assess whether the student's timing data supports this percentage cocoa content.

$r = 4.25 \times 10^{-3}\,\text{m}$
$\rho_B = 7750\,\text{kg}\,\text{m}^{-3}$
$\rho_C = 1330\,\text{kg}\,\text{m}^{-3}$

(5)

$v = \frac{s}{t}$ $\quad \frac{22.5\times10^{-2}}{9.7} = 0.023\ \text{ms}^{-1}$

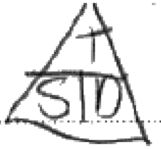
$t = \frac{9.6 + 9.6 + 9.1}{3} = 9.7$

$0.023... = \frac{2(4.25\times10^{-3})^2(9.81)(7750-1330)}{9\eta}$

$\eta = 10.898...$

$= 10.9\ \text{Pa s}$ timing data does not support 35% but supports 30% of cocoa.

Example 2



$$v = \frac{2 \times (4.25 \times 10^{-3})^2 \times 9.81 \times (7750 - 1330)}{9 \times 4.5} \quad (5)$$

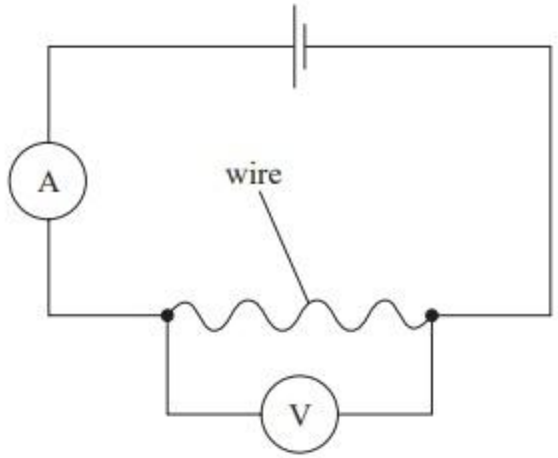
~~$\eta = \frac{F}{6\pi r v}$~~ ~~$v = 0.0561 \times 22.5 \times 10^{-2}$~~

$$\frac{22.5 \times 10^{-2}}{0.0561} = 4.01 \text{ seconds}$$

The students time does not support his cocoa content percentage.

Q12(c) 8PH01 (2024)

12 A student carried out an experiment to determine the resistivity of a metal alloy.
The student used a wire made of the alloy and connected it in a circuit, as shown.



(c) The student stated that the ammeter reading was the most significant source of uncertainty in the calculated value of resistivity.

The percentage uncertainty in the ammeter reading was 0.9%.
The percentage uncertainty in the measurement of diameter was 0.8%.
The percentage uncertainty in the measurement of length was 0.1%.
The percentage uncertainty in the voltmeter reading was 0.3%.

Assess the validity of the student's statement.

12(c)	• The area is determined by d^2	(1)	<u>Example Calculation</u> %U(diameter^2) = 2 × 0.8 % = 1.6 %	
	• Percentage uncertainty in diameter is doubled. %U = 2 %	(1)		
	• The student's statement is incorrect as percentage uncertainty in diameter squared is the greatest percentage uncertainty	(1)	MP3 dependent on MP1 and 2	3

Example 1

(c) The student stated that the ammeter reading was the most significant source of uncertainty in the calculated value of resistivity.

The percentage uncertainty in the ammeter reading was 0.9%.
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The percentage uncertainty in the measurement of length was 0.1%.
The percentage uncertainty in the voltmeter reading was 0.3%.

Assess the validity of the student's statement.

(3)

This statement would not be true as for calculating the cross-sectional area of the wire (πr^2) would cause the radius' uncertainty to double from 0.8% to 1.6% which is greater than the other quantities' uncertainties.

Example 2

(c) The student stated that the ammeter reading was the most significant source of uncertainty in the calculated value of resistivity.

The percentage uncertainty in the ammeter reading was 0.9%.
The percentage uncertainty in the measurement of diameter was 0.8%.
The percentage uncertainty in the measurement of length was 0.1%.
The percentage uncertainty in the voltmeter reading was 0.3%.

Assess the validity of the student's statement.

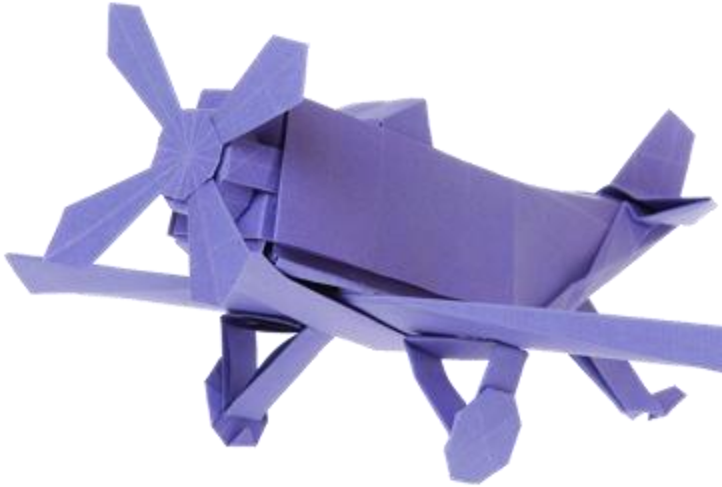
(3)

The percentage uncertainty of the ammeter is ~~0.9% which~~ the largest at 0.9% [supporting the student], however the overall [percent] uncertainty in the diameter when it is divided by 2 and squared to work out the cross-sectional area [for ρ] is 2(0.8% × 2) ~~= 3~~ which equals ±3.2% therefore the diameter measurement is the largest source of uncertainty in the calculated resistivity thus the student's statement is invalid.

(Total for Question 12 = 9 marks)

Pearson Edexcel

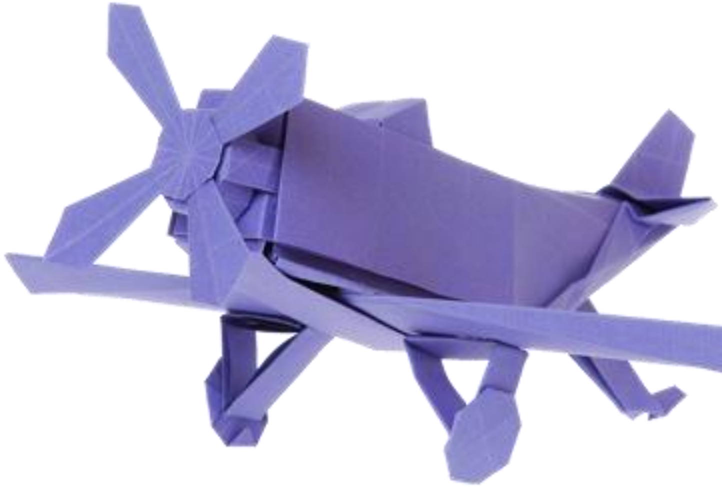
Common mistakes
(and how to avoid them)



Common pitfalls

- Students do not identify key data in the question.
  - Encourage students to list key data using standard symbols.
- Students omit units for calculated quantities.
  - Reinforce with students that all calculated quantities should have a correct unit.
- Students do not state a conclusion.
  - A conclusion is a judgement reached by reasoning. The reasoning should be explicit.
  - Questions with the command words ‘assess’, ’comment on’, ‘deduce’, ‘discuss’, ‘evaluate’ usually require a conclusion.
- Students state a conclusion, but it is incomplete.
  - In a numerical question a conclusion usually requires a comparison between a value given in the question and a value calculated by the student.

Strategies for teaching AO3 skills



Teaching Strategies

- Give students extensive problem-solving practice.
- Establish a standard routine problem-solving routine with students.
- Allow students to apply basic principles to a variety of contexts.
- Recommend that students work towards the value given in the question.
- Encourage students to calculate some quantities as a starting point, even if they are not able to see how to complete a full solution.
- Insist that students always give a reason as part of their conclusion.
- Remind students to always include units for quantities they calculate.

Teaching Strategies

Model problem solving using ***‘I do, we do, you do’***.

I DO:

- demonstrate the problem-solving process by going through the solution to a problem
- give a full commentary on your actions, to make the steps explicit to students.

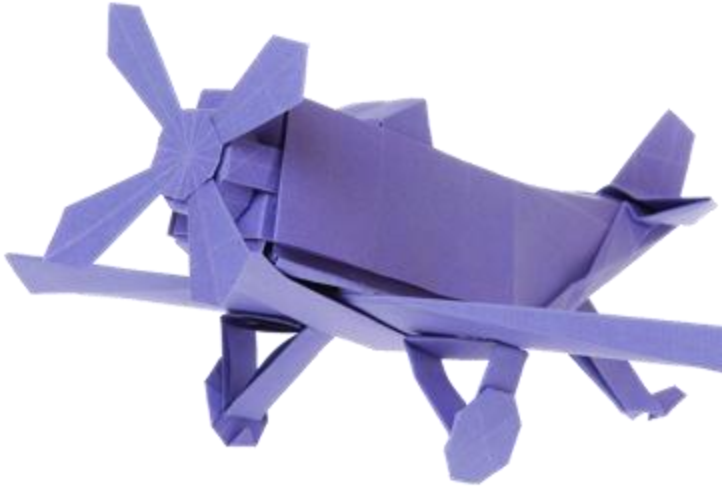
WE DO:

- go through a solution to a problem using cold calling to prompt students to identify what to do at each stage.

YOU DO:

- give students a problem to solve on their own
- insist that students provide a full solution
- do not accept a numerical answer without full working
- expect to see full substitutions into equations and correct units.

Conclusion



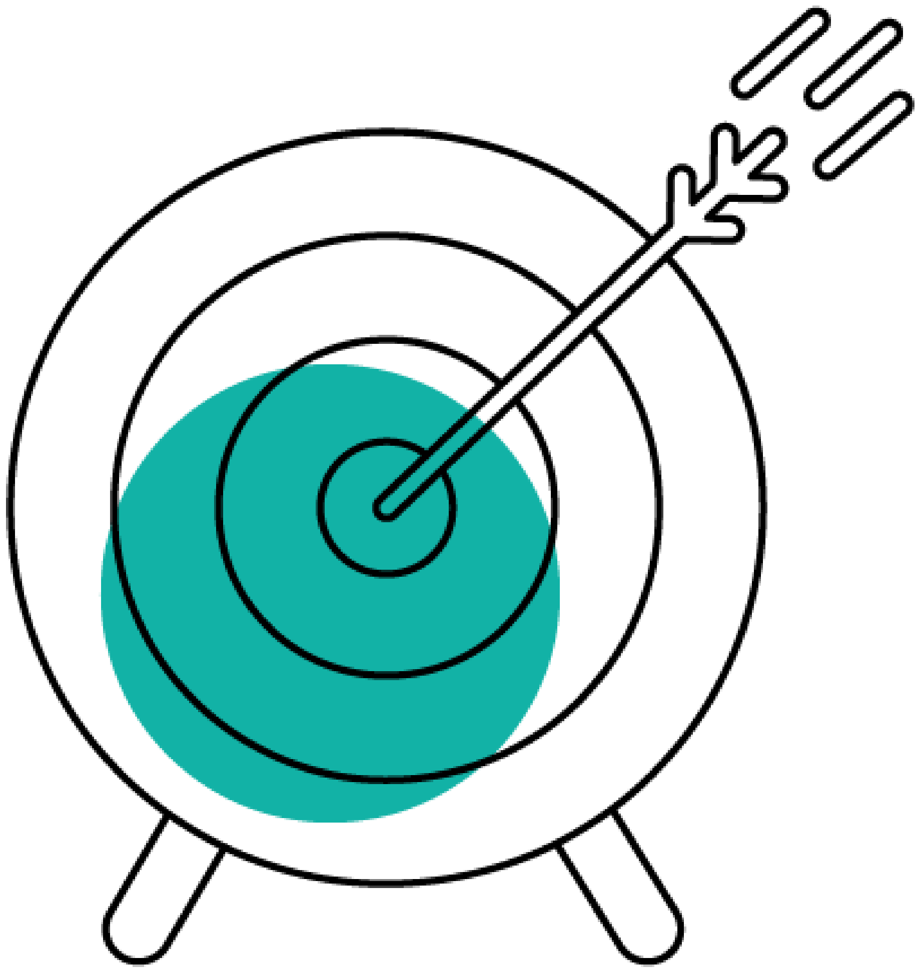
Concluding Remarks

- AO3 accounts for about a quarter of the marks in Advanced Level assessment.
- Students need to be helped to refine their exam technique for these questions.
- They should start by identifying the command words used in AO3 questions.
- Students need extensive problem-solving practice in which they apply basic principles to a wide range of contexts.
- They must always give a reason to back up their judgement; in quantitative questions this is usually a comparison of values.

Summary

This session looked at:

- identifying the key components of AO3 skills as outlined in the Edexcel A Level Physics specification
- how marks are awarded for AO3 questions
- various teaching strategies to help students develop AO3 skills.



Useful links

1. Grade Boundaries

   This page shows the minimum marks needed to achieve a certain grade for all UK examinations. Also refer to the Examiners' Report.

2. Examination Results Statistics

   Results statistics summarise the overall grade outcomes of students sitting Edexcel examinations.

3. Results Plus

   Edexcel's free online service giving instant and detailed analysis of your students' exam and mock performance.
   – See your students' scores for every exam question.
   – Understand how your students' performance compares with Edexcel national averages.

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Any questions?

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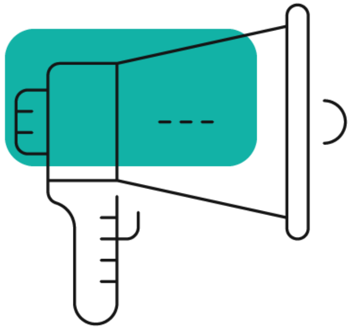

Your Feedback Matters

Following this event, you will receive an invitation to share your thoughts about the session. Your feedback is invaluable to us, as it helps us tailor our professional development materials to better meet your needs. Please don’t hesitate to let us know what you’d like to see more of and what areas you think could be improved.

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