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Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557

For first teaching in 2015

H557/02 Autumn 2020 series

Version 1

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

i	Reports for the Autumn 2020 series will provide a broad commentary about candidate performance, with the aim for them to be useful future teaching tools. As an exception for this series they will not contain any questions from the exam paper nor examples of candidate responses.

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.

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Paper 2 series overview

This exam paper consists of three questions of about 10 marks each, three questions of around 15 marks each and a section based on questions developed from the Advance Notice article. As with all the Physics B papers, Paper 2 requires candidates to answer questions from any area of the course.

The October 2020 exam paper was taken by a small cohort of candidates. Although there were some excellent responses to individual questions and good overall marks, in some cases there was an unsurprising lack of preparation evident in some of the papers. The lack of formal teaching and support for more than six months was evident in the amount of avoidable errors in calculations and, particularly, in the responses to questions based on the Advance Notice article where the lack of preparation and support was most evident in the cohort overall. The exam paper certainly included some challenging questions which would have differentiated the candidates well in a normal examination session and some candidates found these particularly challenging, leading to a greater proportion of questions left blank by candidates. However, some candidates had clearly prepared carefully for the examination and remembered most of the concepts covered in the previous two years and maintained the mathematical fluency to approach calculations with confidence.

Candidates who did well on this paper generally did the following:	*Candidates who did less well on this paper generally did the following:*
• Performed standard calculations with accuracy, showing full working. • Carefully used data from graphs, including showing construction lines for gradients and accurately drawing lines of best-fit. • Matched detail of response with number of marks available. • Showed familiarisation with the scope and physics of the Advance Notice article. • Supported descriptive/explanatory responses with data or mathematical reasoning.	• Performed calculations without full working. • Misread graphs or drew inaccurate lines through points. • Relied on background knowledge rather than specific points of physics in explanatory responses – leading to superficial statements.

Section overview

Section A

Question 1

This question is about charging a capacitor. The candidates are presented with a circuit diagram and a graph showing the increase in p.d. across the capacitor with time as the capacitor is charged. Many candidates understood the usefulness of a data logger but some did not reach the mark through lack of clarity in their writing. Part (a) (ii) proved problematic for the majority.

	AfL	Using this question to set up a circuit and capture data to determine the capacitance through use of $V = V_0 e^{-t/RC}$ will be a very useful exercise – note that this is an endorsed practical.
	Misconception	Many candidates attempted to find the capacitance by calculating the charge on the capacitor after a given time. Nearly all those who attempted this assumed that the charging current is constant.

Part (a)(iii) – calculating energy stored, was accessible to most although there were some errors with powers of ten. In part (b)(i) the candidates were required to draw a line as the capacitor discharged through a resistor of twice the value of the resistor in the charging circuit. Only the higher achieving candidates studied the circuit diagram sufficiently carefully to gain credit for a correctly drawn line and explanation.

The last part of the question proved very challenging – most candidates incorrectly assuming that the energy stored on a capacitor is proportional to the potential difference across the component.

Question 2

This question is about a consideration of time dilation using the famous description of a 'light clock' on a moving train. The first part of the question is a simple calculation of the time taken for light to travel a short distance – this proved accessible to most candidates although some made power of ten errors. The second part – to explain why the moving clock appears to run slow relative to 'stationary' observers was generally answered well although some candidates did not comment on the constant speed of light. The algebraic manipulation to reach an equation for time dilation was generally well performed with most candidates showing confidence and clarity. Part (c) requires candidates to calculate the half-life of a moving particle as measured by a stationary observer. Surprisingly, a fair proportion of the candidates did not use the gamma factor on the stated half-life at rest but tried to calculate the half-life using the equation

$$T_{\frac{1}{2}} = \frac{\ln 2}{\lambda}.$$

It was pleasing to see that several of the higher-scoring candidates used clear arguments to discuss the statement 'from the point of view of a photon, it takes no time to cross the Universe'.

Question 3

This question is based on work from the first year of the course and centres around a measurement of the Plank constant. Part (a) is a standard calculation and was answered correctly by most of the cohort. Candidates also showed confidence in drawing a best-fit line on a graph, although a small proportion did not gain credit as their line was too far from the expected gradient. The determination of a value of *h* from the data was generally successful, although many missed out on marks because they neither showed clear construction lines on the graph or clear values in their calculation, even though they were asked to show all working.

As always, there was some confusion evident in calculating uncertainty and a reasonable proportion of responses did not match the number of significant figures of the value with the uncertainty (that is, for example, they gave the value to a greater precision than the uncertainty).

Section B

Question 4

This question is about digital imaging and brings together ideas from the study of lenses, digital resolution and digital processing. The question is firmly rooted in the earliest topic of the course and candidates taking this examination will not have formally studied these ideas for two years.

The first part of the question is a standard calculation of lens power, expressed as curvature added to waves. This proved to be accessible to almost all. However, far fewer candidates gained credit in the second part of the question for using wave curvature to explain formation, or non-formation of images.

Part (c) requires candidates to use the equation $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$ and whereas many responses were clear, the question revealed some misconceptions.

?	**Misconception**	Some candidates assume that *u* is positive, others that *f* varies as the distance to the object varies. Confusion between object and image distances are also more common than one would hope.

After the consideration of the optics of the camera, the question shifts focus to digital imaging. Part (d) proved more challenging than expected as candidates were required to calculate the magnification of the image to find its length. The resolution calculation in part (e) proved to be one of the more difficult challenges of the whole exam paper, with very few candidates reaching a value for a length of a pixel, a crucial step in calculating the resolution. However, the HSW ('how science works') element in the last part of the question was answered thoughtfully and sensibly by many who also showed recall of basic processing operations.

Question 5

This question is about the physics of bungee jumping. Parts (a)(i) and (ii) of the question is about energy stored in a stretched band and were generally accurately answered. Part (a)(iii), a LOR question about the forces on the ball during its motion from release to instantaneous rest at maximum extension of the band was not well answered. Most candidates stated that the ball would stop increasing downward as soon as the band began to extend, rather than when it reached the equilibrium extension. This led to the incorrect statement that the maximum velocity of the ball occurs when the length of the band is equal to the unstretched length. Many candidates wrote about the force of air resistance rather than the force from the band and many also framed their response in terms of energy rather than force.

	AfL	This will be a very useful question to use for AfL as it clearly reveals misunderstandings which can lead to fruitful discussions.

Pleasingly, most candidates recognised that the maximum acceleration occurs at maximum tension, but only the best responses showed an understanding of the net accelerating force on the ball, with most calculations ignoring the weight of the ball acting in the opposite direction to the accelerating force. The last part of the question concerned the microscopic structure of polymers and metals and applied these ideas to the choice of materials for bungee cords. Most candidates gained at least two marks for this part and showed reasonable recall of the structure of these classes of materials.

Question 6

Concerns gravitational field strength and potential. It opens with a ‘show that’ questions as values are required in later parts of the question. The first task is to calculate the change in gravitational potential energy of a satellite from a field strength versus radial distance graph. Some candidates read off values for field strength at the two distances from the centre of the Earth and multiplied these values by r to gain the difference in potential between the two distances and then multiplied the potential difference by the mass of the satellite to reach the expected value. The best candidates calculated the area between the graph and the axis to estimate the change in potential. A small, but significant proportion, incorrectly applied the equation *change in p.e. = mgh* without considering the changing value of g.

Part (a)(ii) requires candidates to use their value for change in potential energy (or the ‘show that’ value) to reach a given value for the mass of the Earth. Only the very best candidates understood the subtlety of the task and there were few correct responses.

Part (b)(i) requires candidates to calculate the force on a satellite at a given height above the surface. This would be a trivial task were it not for the need to add a height in km to a radius given in m. Although most managed this, the less arithmetically confident struggled. Part (b)(ii) – a standard calculation of orbit period, proved accessible to most candidates.

The last part of the question concerns the relative merits of polar and geostationary satellites. Although it is possible that most candidates will have considered that they have answered this question to a high standard, this is not the case. Only the best responses considered that the Earth rotates beneath the polar orbiting satellite as it revolves around the Earth. Nor did they consider the higher resolution achievable for a lower orbit. Similarly, the consideration of the advantages of geostationary satellites for communication was not always completely explained.

Section C

The questions in this section are based on the Advance Notice article which is about dating ancient flutes and the limitations of the method. Usually this section of the exam paper allows the candidates to show their understanding of the article which has been sharpened by discussions in class and practice questions written by their colleagues and teachers.

	AfL	Asking students to read the Advance Notice article and write their own questions to be discussed in class is a very useful way of increasing understanding of the article and will also increase fluency in technical vocabulary.

Question 7

Concerns digitally sampling a note from a flute. Part (a) requires a simple calculation of frequency from the time period read from the graph. Nearly all candidates gained this mark. The second part of the question asks the candidates to give the minimum sampling frequency required. The majority correctly stated that the sampling frequency must be at least twice that of the highest frequency component to avoid aliasing (or words to that effect ‘to avoid spurious low frequency signals’ is an alternative that shows more understanding than the single word ‘aliasing’ but both responses were credited). However, few candidates considered that the fundamental frequency is not the highest frequency component shown so many responses gained two out of the three marks available. This idea is clearly considered in the Advance Notice article so these responses may show a lack of familiarity with the article.

Part (c)(i) asks for an explanation of the increase in frequency of the note from a flute when the temperature of the air increases. Many correctly identified that the velocity of sound increases but only the higher achieving candidates linked this to the constant wavelength of the note to provide a complete explanation. The calculation in (c)(ii) was not well performed – a sizeable proportion of the cohort did not use the statement in the stem that the velocity of sound is proportional to the square root of the absolute temperature and assumed linear proportionality.

Question 8

This question is about carbon dating. Most candidates gained two marks from a possible three in part (a) by correctly identifying the particle as an anti-neutrino and clearly explaining lepton conservation. However, few linked the variability of the energy of the emitted beta particle to the energy taken away by the anti-neutrino. Part (b) is a standard exponential decay calculation with a slight novelty in that candidates are considering ratios of isotopes rather than count-rate, activity, or number. This did not cause any problems for the more confident candidates and a good proportion gained both marks.

Part (c) is a LOR question, closely linked to the Advance Notice article. It requires candidates to explain the difficulties of dating plants near active volcanoes. Although candidates could gain credit for using ideas from the article, many produced rather superficial responses and very few attempted to make a calculation of the effect of 10% 'ancient carbon' on the dating. However, the discussions of the use of tree ring data were more convincing. This question highlighted the lack of preparation of the cohort due to the unusual circumstances of the examination.

The last question on the exam paper concerns accelerator mass spectrometry and is again closely based on the article. The calculation in part (a) was a useful differentiator as it required several steps or a little algebraic manipulation to reach the final value. Some candidates may have been rushing to complete the exam paper and were happy to record values for the radius that appear highly unlikely. The last part of the final question asks candidates to explain the problems that contamination with particular ions can cause to the measurement. Some candidates noticed that the mass of the ions are the same as the mass of a carbon-14 nucleus and linked the presence of these ions to an inaccurate determination of the proportion of carbon-14 in the sample.

Key teaching and learning points – comments on improving performance

This examination, taken under unusual conditions, has highlighted the importance of careful consideration of the Advance Notice.

Guidance on using this paper as a mock

This exam paper is one of three in the series. Some questions are more generic than others so candidates are likely to be required to perform similar tasks in future examinations. If questions are selected from the suite of exam papers from 2020 it would be worth considering Questions 1,3,4, 5 and 6.

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