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Examiners' report

PHYSICS B (ADVANCING PHYSICS)

H557

For first teaching in 2015

H557/02 Summer 2023 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. A selection of candidate answers is also provided. 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 and the mark scheme can be downloaded from OCR.

Paper 2 series overview

Paper 2 – Scientific Literacy in Physics is a synoptic paper that includes questions on an advance notice article. The three questions in Section A are of medium length, usually contributing a total of around thirty marks each to the paper. Section B comprises three longer questions, including a level of response question. Section C is based on the advance notice article and includes short and long questions and a level of response question.

The advance notice information gave candidates some idea of the major areas tested but this is a challenging examination. Once again, the majority of the candidates attempted all the questions and there was little evidence of candidates running out of time.

As in previous series, the higher performing candidates demonstrated the ability to apply physics to novel areas, accurately used technical vocabulary and had prepared carefully for the questions on the advance notice article. However, recall-based tasks caused more problems for candidates than in past series.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• showed full working to all calculations • used correct technical vocabulary • provided full written explanations when required, linking concepts of physics to the context of the question • applied physics to novel situations with accuracy and clarity • showed familiarity with the physics covered in the advance notice article • drew diagrams and graphs with care.	• did not show full working in calculations • did not use or misused technical vocabulary • did not link explanations to core physics • showed insufficient care when drawing graphs or diagrams • showed lack of recall of some fundamental physics.

Section A overview

Section A comprises three questions of about 10 marks each. In this examination, the questions in this section focused on the Boltzmann factor, projectile motion and waves.

Question 1 (a) (i) and (ii), (b) (i) and (ii)

1 Digestion is an example of an activation process. The energy required for a particular molecule to break apart is 1.2×10^{-19} J.

(a) (i) Calculate the Boltzmann factor for this process.

Human body temperature = 310 K

Boltzmann factor = ... **[1]**

(ii) Explain how an individual particle can gain sufficient energy to complete a reaction when the energy required is far greater than the average energy of the particles in the reaction.

....

....

.... **[2]**

The presence of an enzyme increases the Boltzmann factor of the process by a large amount.

(b) (i) Explain why this change to the Boltzmann factor affects the rate at which the digestion reaction takes place. Include a description of the information the Boltzmann factor gives about the individual particles involved in an activation process.

....

....

....

....

.... **[3]**

(ii) The enzyme increases the Boltzmann factor at 310 K to a value of 6.7×10^{-7} by reducing the activation energy required for the reaction.

Calculate the activation energy of the reaction in the presence of the enzyme.

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

The calculations at the start and end of Question 1 were performed accurately by the majority of the candidates. Parts a (ii) and b (i), requiring explanatory answers, were less confidently answered by many and were the first example of candidates missing marks through not including sufficient detail or technical language.

In part a (ii), many responses simply stated that particles collided with one another and missed the idea that energies (far) above the mean require multiple, successive energy-gaining collisions.

Part b (i) was an opportunity for candidates to construct a logical argument. Although a good proportion of the responses gained at least one mark, only the best described the Boltzmann factor, stated what an increase in the value shows and applied this understanding to the context of the question.

Explanatory responses

Throughout the paper, many candidates did not score full marks in questions requiring explanatory responses. This was often because the explanations did not cover all the points in the stem of the question in a logical manner, building a simple argument. Responses often were focused on the context of the question without considering the underlying physics.

Question 2 (a) (i) and (ii)

2 A 'T-shirt cannon' fires a wrapped T-shirt from the ground into the spectators sitting at a height of 10 m above the ground as indicated in **Fig. 2.1**.

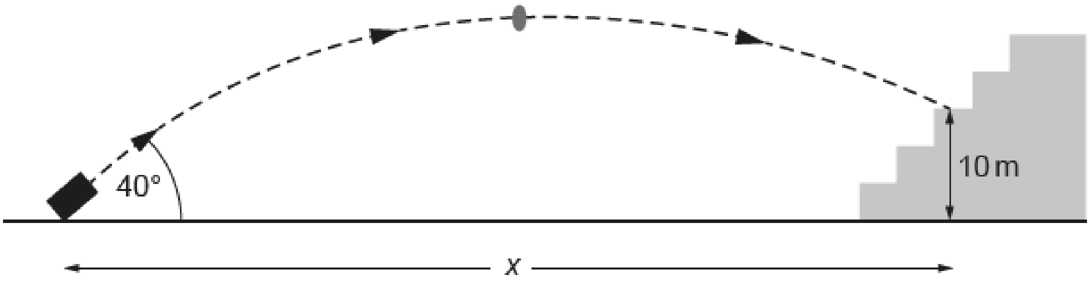

Fig. 2.1 (not to scale)

(a) **(i)** The velocity of the shirt when it leaves the cannon is $30\,\text{m}\,\text{s}^{-1}$ at an angle of 40° to the horizontal. Ignoring the effects of air resistance, show that the highest point reached by the shirt is less than 20 m vertically above the cannon. Assume the shirt is fired from ground level.

(ii) Calculate the horizontal distance x between the cannon and the place where the T-shirt landed in the spectators.

horizontal distance = ... m **[3]**

Both these calculations were answered accurately by the majority of the candidates. Many responses in part a (ii) used the quadratic equation to find two possibles values for time in the air.

Question 2 (b)

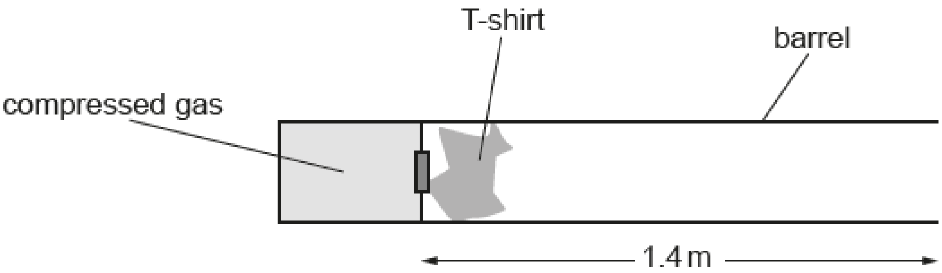

Fig. 2.2

(b) The wrapped t-shirt is accelerated by a release of compressed gas into the barrel of the cannon. The barrel is 1.4 m long as shown in **Fig. 2.2**.

Calculate the average force exerted on the T-shirt as it accelerates through the barrel.

mass of shirt = 0.50 kg

force = ... N **[2]**

The context of this straightforward calculation made the question challenging for some. Mistaking the calculated value of acceleration for the force was a common error.

Question 2 (c)

(c) The barrel has a uniform radius of 0.05 m. When the compressed gas is released the pressure on the left side of the T-shirt is 4.0×10^4 Pa greater than atmospheric pressure. Calculate the initial force on the T-shirt and explain why it is greater than the average force.

initial force = ... N

....

....

.... **[3]**

Some candidates were confused by the pressure on the left side described as 'greater than atmospheric pressure' and did not consider the net force on the T-shirt. Credit was given to explanations of the reduction in force involving velocity-dependent drag forces. Whereas many candidates linked the decrease in force with decreasing pressure, only those candidates who performed well across the paper made clear statements linking decreasing pressure difference with increasing volume.

Question 3 (a)

3 A sample of argon gas is very slowly compressed in a piston as indicated in **Fig. 3.1**.

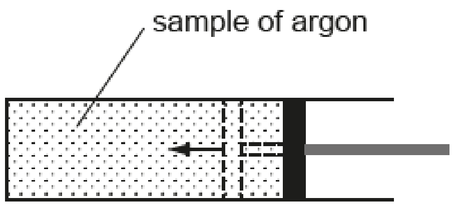

Fig. 3.1

(a) Draw graphs on **Fig. 3.2a** and **Fig. 3.2b** showing how the pressure P of the gas varies with the volume V and how the pressure varies with $\frac{1}{V}$. Assume that the temperature of the gas does not change during compression.

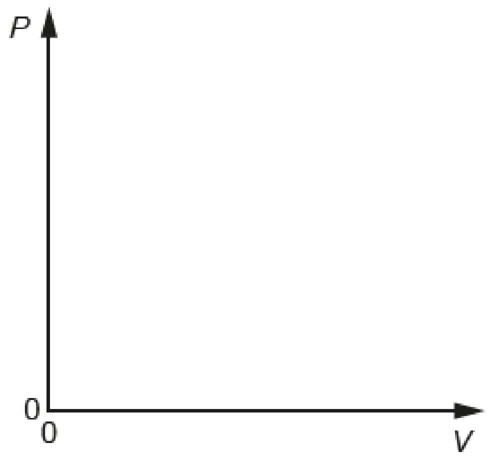

Fig. 3.2a

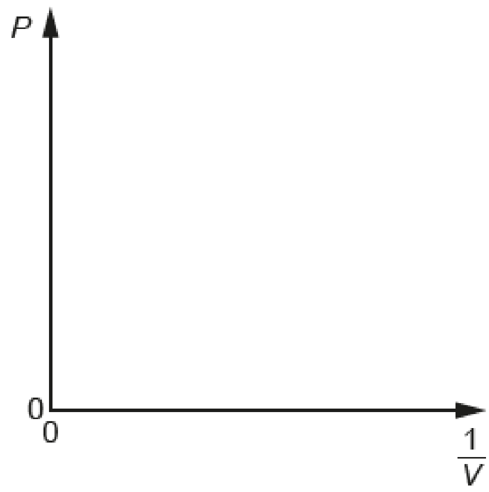

Fig. 3.2b

[2]

This question is essentially a recall task for the first graph and the second graph can be derived from the first. A significant proportion of the candidates did not gain both marks. Many candidates drew linear relationships for the P-V graph. A number of responses did not gain the mark for the P-V graph due to inaccurate drawing; sometimes drawing an exponential curve with a *y* intercept or drawing curves that go back on themselves instead of approaching the axes asymptotically.

Question 3 (b)

(b) The temperature of the gas is 298 K. The mass of an argon atom is 6.6×10^{-26} kg.

Show that the root mean square speed of the atoms is about 430 m s^{-1}.

[3]

Most candidates accurately performed this calculation.

Question 3 (c) (i)

(c) This part of the question considers how the behaviour of the gas changes if the piston is moved in quickly.

An argon atom moving at +430 m s^{-1} strikes the face of the piston which is moving at –1.5 m s^{-1} as represented in **Fig. 3.3**.

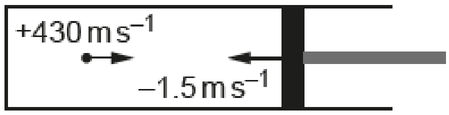

Fig. 3.3

(i) The collision between the atom and the piston is elastic. Explain why the velocity of the gas atom is –433 m s^{-1} after the collision.

....

....

....

.... **[2]**

This explanatory task was challenging for the majority of the candidates. Many cited the conservation of momentum but did not consider this from the frame of reference of the particle and relate this to the motion of the particle in the laboratory frame of reference. Of course, the term 'frame of reference' was not expected but some understanding of the relative velocity of the end of the piston and the atom was needed to give an explanation of the increase in the velocity of the gas atom.

Question 3 (c) (ii)

(ii) Describe and explain how the behaviour of the gas would change if the gas were compressed more quickly.

You may use equations and refer to your graphs in **Fig. 3.2a** and **3.2b** in your explanation.

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....

....

.... **[3]**

Most responses were given credit for recognising that the speed of the atoms increased but only the best answers explained how this increase in speed causes the behaviour of the gas to differ from that of a gas compressed more slowly. It was common to see the explanation that the pressure will increase as volume decreases without any suggestion that the pressure for a given volume of gas is greater if the gas is compressed quickly. This part of the question, together with part c (i) could produce fruitful discussions in class.

Section B overview

Section B comprises three questions of around fifteen marks each. These questions tend to have longer sections and are typically more challenging than Section A questions.

Question 4 (a)

4 **Fig. 4.1** shows apparatus that demonstrates standing waves in air. The two speakers, separated by about 2 metres, are connected to the same signal generator, producing coherent oscillations.

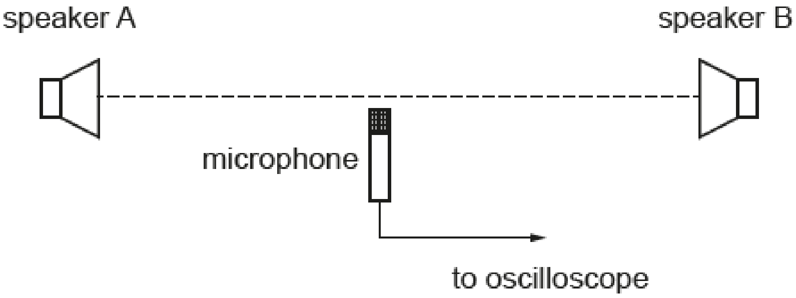

Fig. 4.1

(a) Explain how standing waves are set up in between the two speakers and how this is observed.

....

....

....

....

.... **[3]**

This question tested the use of simple technical vocabulary. The majority of responses recognised that the demonstration showed the effects of superposition – but many responses used the less precise term 'interference' or 'superimposition'. Similarly, although ideas of maxima and minima were recognised, relatively few responses linked antinode to zero phase difference or nodes to waves superposing in antiphase. A significant minority stated that antinodes were positions of antiphase superposition. Relatively few responses considered the display on the oscilloscope linked to the microphone – most merely stated that the sound would be louder at antinodes, suggesting that the microphone was connected to a speaker rather than an oscilloscope.

Question 4 (b) (i)

(b) (i) The signal generator vibrates the speakers at a frequency of 3.00 kHz. The microphone detects positions of minimum amplitude (nodes) separated by 5.60 cm.

Calculate the velocity of sound in air.

velocity of sound = ... $m\,s^{-1}$ **[1]**

About one third of the candidates missed gaining the mark in this calculation through not realising that the distance between adjacent nodes is half a wavelength.

Question 4 (b) (ii)

(ii) A student suggests that a more accurate determination of the velocity of sound could be made if the distance between several nodes was measured instead of the distance between adjacent nodes. Explain the student's reasoning.

....

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....

....

.... **[3]**

The best responses showed a good understanding of the absolute uncertainty and percentage uncertainty. The term 'absolute uncertainty' was not required although it was pleasing to see well-prepared candidates using the term. However, many candidates focused on the advantages of taking a mean rather than reducing the percentage uncertainty in the reading. As in many of the questions requiring explanatory responses, candidates missed gaining marks through not making their argument in a logical, sequential manner.

Question 4 (c) (i), (ii), (iii) and (iv)

(c) The electron in a hydrogen atom can be modelled as a standing wave in a box of length equal to that of the diameter of the atom as indicated in **Fig. 4.2**.

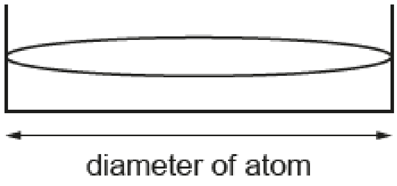

Fig. 4.2

(i) Show that the momentum of an electron in a box of length 2.4×10^{-10} m is about 1.4×10^{-24} kg m s^{-1}.

[1]

(ii) Calculate the kinetic energy of the electron.

kinetic energy = ... J **[2]**

(iii) Calculate the potential energy of an electron at a distance of 1.2×10^{-10} m from a proton.

potential energy = ... J **[2]**

(iv) Use your answers to **(ii)** and **(iii)** to explain whether or not the electron would escape from the proton at this distance and explain how an estimate for the minimum size of a hydrogen atom can be calculated.

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....

.... **[3]**

Most responses gained marks for the calculations in parts (i), (ii) and (iii). The most common error was omitting the negative sign for the potential energy in part (iii). This made gaining 3 marks for part (iv) more difficult, although most responses that had recognised the negative value of potential energy correctly stated that the total energy of the electron needs to be positive for it to 'escape'.

Question 5 (a) (i)

5 This question is about using alpha particles in radiotherapy. **Fig. 5.1** shows a graph of the number of ion-pairs formed by an alpha particle travelling through air. After 70 mm the alpha particle captures two electrons to become a helium-4 atom and ionisation stops.

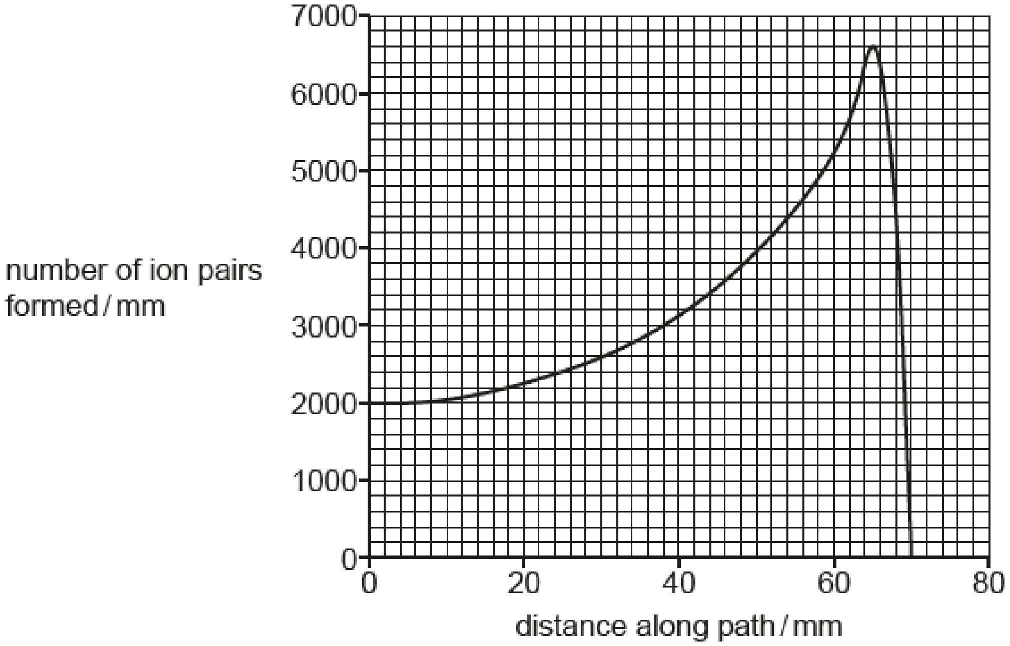

Fig. 5.1

(a) (i) State how the graph shows that an alpha particle produces about 240 000 ion pairs along its track.

....

.... **[1]**

Nearly all candidates recognised that the area under the curve gives the number of ion pairs produced.

Question 5 (a) (ii)

(ii) It takes about 30 eV to produce an ion-pair. Estimate the kinetic energy of the alpha particle when it is ejected from a nucleus. Explain your reasoning.

Reasoning: ....

....

kinetic energy = ... MeV **[2]**

This straightforward calculation was correctly performed by the majority. However, only a minority of responses clearly explained that the 30 eV required for ionisation was transferred from the kinetic energy of the alpha particles in each ionisation event.

Question 5 (a) (iii)

(iii) Explain why beta particles have a longer range in air than alpha particles of the same initial energy.

....

....

.... **[2]**

Whereas the majority of responses recognised that the beta particles are less ionising than alpha particles (or vice versa) only the best responses linked this to fewer ionisation events in unit distance. This meant that few responses gained both marks for a complete explanation.

Question 5 (b) (i)

(b) (i) $^{224}_{88}$Ra (radium-224) is an alpha emitter that can be used in radiotherapy. It decays as shown:

$$^{224}_{88}\text{Ra} \rightarrow {}^{220}_{86}\text{Rn} + {}^{4}_{2}\text{He}$$

Assuming that the radium nucleus is stationary when it emits an alpha particle, use the principle of conservation of momentum to calculate the percentage of the kinetic energy released in the decay transferred to the alpha particle.

proportion of kinetic energy transferred to alpha particle = ... % **[2]**

This calculation proved challenging for many. Many responses stated that the majority of the kinetic energy was transferred to the radium nucleus rather than to the alpha particle.

Question 5 (b) (ii)

(ii) Alpha emitters can be implanted into body tissue. The range of alpha particles in the tissue is typically about 0.1 mm.

State why the range is smaller in tissue than in air.

....

.... **[1]**

Rather like part a (iii), only the best responses linked the increase in density to an increase in the number of ionisations per unit distance.

Question 5 (b) (iii)*

(iii)* Use the data below to calculate the energy of an alpha particle released when a nucleus of radium decays. Use this figure to calculate the effective dose delivered to a group of cells of total mass 0.004 kg over two hours, a period much shorter than the half-life of radium. State and explain any assumptions you make in the calculation and whether you think they are reasonable.

mass of radium nucleus = 223.97191 u

mass of radon nucleus = 219.9642 u

mass of alpha particle = 4.00150 u

quality factor of alpha radiation = 20

activity of alpha source = 18 kBq

density of tissue = 990 kg m^{-3}

....

....

....

....

....

.... **[6]**

The first LOR question on the paper was more accessible than in previous series. Roughly half the candidates gained 4 or more marks. Although very few responses took account of the 2% of the kinetic energy transferred to the radon nuclei, many responses showed an excellent understanding of the context and, encouragingly, gave clear statements and explanations of the assumptions made. There were very few incorrect or implausible assumptions given.

Exemplar 1

Before mass = 223.97191u

After mass = 219.9642u + 4.0015u =
= 223.9657u

loss of mass = 223.97191 − 223.9657
0.00621u
= 1.031481×10^{-29} kg
$E = mc^2 = 9.283329 \times 10^{-13}$ J
Assuming all energy delivered to group of cells no. of decays = $2 \times 60 \times 60 \times 18000 = 1.296 \times 10^8$

energy delivered = $1.296 \times 10^8 \times 9.28.. \times 10^{-13}$
= $1.2.. \times 10^{-4}$ J
dose = $1.2 \times 10^{-4} \div 0.004 = 0.03$ .. Gy
effective dose = 20 × 0.03 .. = 0.602 Sv

Assumed that activity remained constant which is resonable a 2hr << $T_{1/2}$. And assumed all energy released delivered to tissue which is resonable as 9~~8~~.2% is ~~around~~ near 100% **[6]**

Turn over

This response gained Level 3. The calculation is clearly laid out and correct in all aspects. The commentary on the assumptions is brief but worthwhile and shows a good grasp of the context. Note that it is possible to gain 6 marks without including the loss of energy to the radon nucleus.

Question 6 (a) (i)

6 **Fig. 6.1** shows wavefronts produced by a very small object. The wavefronts are approaching a converging lens.

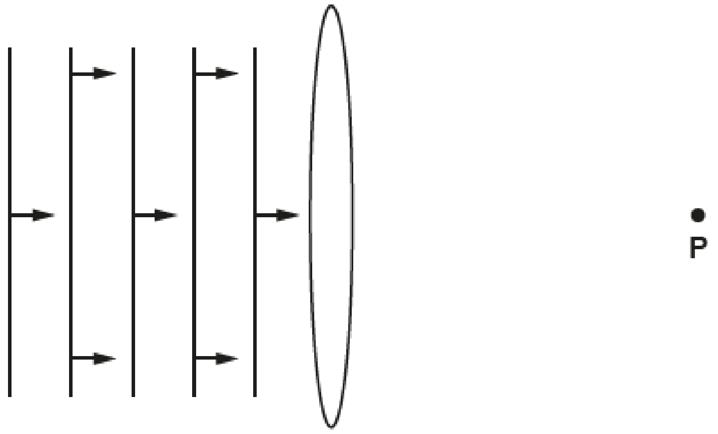

Fig. 6.1

(a) **(i)** What feature of **Fig. 6.1** shows that the object producing the wavefronts is a long way from the lens?

....

.... **[1]**

The best responses were framed in terms of the curvature of the wavefront. 'Plane' wavefronts and 'straight' wavefronts were also acceptable responses, but the better candidates used the more precise technical vocabulary.

Misconception

A significant proportion of the candidates stated that the wavefronts approaching the lens were parallel. This is an insufficient reason for considering the object to be a long way from the lens as wavefronts with non-zero curvature can be parallel.

Question 6 (a) (ii)

(ii) Add wavefronts to the right of the lens which focus at point P.

[1]

Less than half the candidates gained credit for this straightforward task. Many candidates drew wavefronts emerging from the lens with positive curvature while other did not gain the mark because the gap between wavefronts was inconsistent.

Assessment for learning

Examinations frequently require candidates to add to diagrams and graphs. Practising such techniques is vital, either through note taking or classwork/homework exercises.

Question 6 (a) (iii)

(iii) The lens adds curvature of +1.8 D to the waves. Calculate the distance from the lens to point P. Explain your reasoning.

distance to P = ... m

Reasoning: ....

.... **[2]**

Nearly all responses gained the mark for calculating the distance to P and the better responses clearly linked the result to the waves from the object having zero curvature.

Question 6 (b) (i)

(b) Simple lenses can produce chromatic aberration, resulting in different lens-powers for different colours. This happens because different wavelengths of light travel through glass at different speeds.

(i) Complete the table below of the refractive index from air to glass for different wavelengths of light.

velocity of all wavelengths in air = $3.00 \times 10^8\,\mathrm{m\,s^{-1}}$

wavelength / nm	**velocity of light in glass / $\mathrm{m\,s^{-1}}$**	**refractive index**
410	$1.81 \times 10^8\,\mathrm{m\,s^{-1}}$	
710		1.62

[2]

Only the weakest responses (a very small minority) did not gain both marks for this calculation.

Question 6 (b) (ii)

(ii) Explain why the power of the lens will be greater for shorter wavelength light and the effect this will have on the focal length of the lens for light of different wavelengths.

....

....

....

.... **[2]**

Most candidates gained credit for linking power to focal length. The better responses clearly linked higher refractive index with greater added curvature although credit was given to explanations involving 'greater refraction' and similar statements.

Question 6 (c) (i)

(c) **Fig. 6.2** shows a highly simplified diagram of the eye.

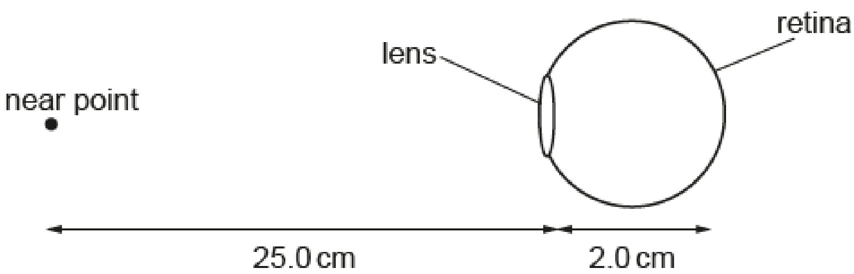

Fig. 6.2 (not to scale)

The distance between the lens and the retina, the surface on which the image is formed, is 2.0 cm.

The curvature of the eye lens increases as it focuses on nearby objects. The nearest point an object can be brought to focus by a person with normal vision is 25 cm. This is called the near-point.

(i) This letter **X** is approximately 4 mm high. Calculate the height of the image of the **X** on the retina of a person with normal vision when viewed from the near point of 25 cm.

image height = ... m **[2]**

This two-part calculation (calculation of magnification followed by calculation of image size – although the two parts were often worked as one piece of arithmetic) proved discriminating. Candidates who performed less successfully on the paper as a whole found the context difficult to link to the physics involved.

Question 6 (c) (ii)

If an individual is unable to focus as close as 25 cm they can use a converging lens to bring the image into focus.

(ii) Calculate the power of a lens required to allow a person with a near point of 50 cm to focus an object at a distance of 25 cm.

lens power = ... D **[2]**

This question was very discriminating. Only those candidates who performed well across the paper showed an understanding of the context and correctly calculated the difference in power required for focusing at 25 cm and 50 cm.

Question 6 (d)

(d) Here are some data about two materials used for spectacle lenses.

material	density / $kg\,m^{-3}$	refractive index
high-index glass	3.2×10^3	1.70
plastic (polycarbonate)	1.2×10^3	1.59

Explain why high-index glass might be chosen for more powerful spectacle lenses whereas polycarbonate might be a better choice for lower power lenses. Make your reasoning clear.

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....

....

.... **[3]**

This proved to be a challenging question. Many responses suggested that high refractive index material is chosen to produce powerful lenses because it 'refracts more'. Only the better candidates linked refractive index to lens design and the relative merits of low mechanical density and high refractive index.

Misconception

Although 'optical density' is not a term used in the specification or the endorsed student book, a number of candidates confused optical density and mechanical density. Some clearly read the density column in the table to mean optical density and did not consider the mass of the lenses.

Section C overview

Section C is based on the advance notice article. Once again, many of the candidates seemed well prepared for the section, with clear familiarity with the context of the questions set. There was little evidence of candidates running out of time at the end of the paper.

Question 7 (a) (i)

7 This question is about a simple generator (lines 19–27). **Fig. 7** shows how the flux through a square coil varies with time as the coil rotates in a uniform magnetic field.

The emf ε generated is given by the equation

ε = maximum flux linkage × $2\pi f \sin(2\pi ft)$

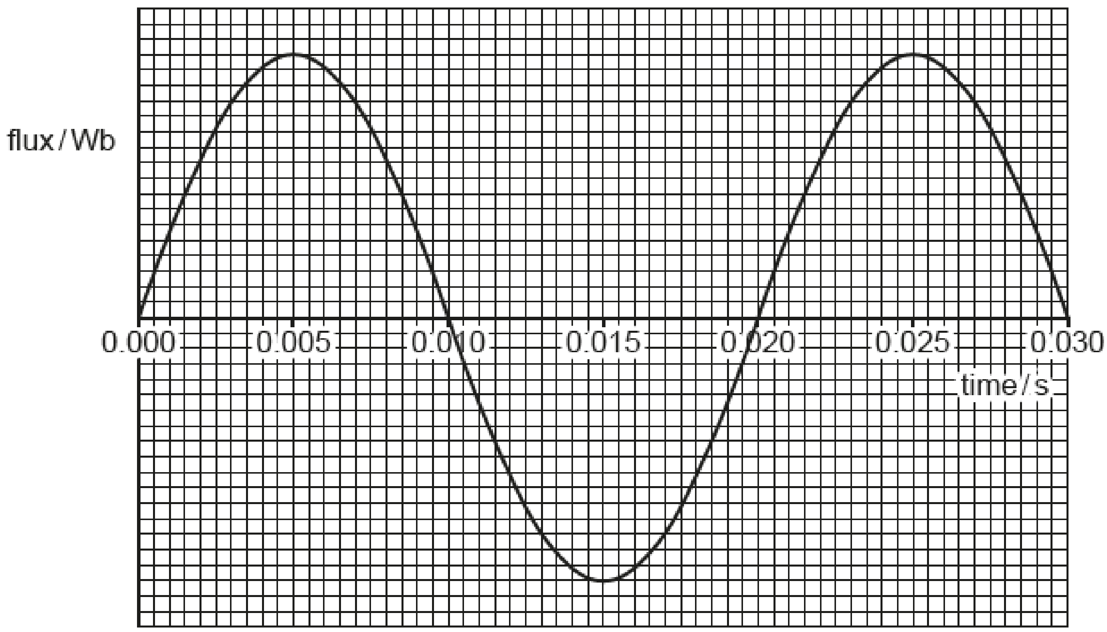

Fig. 7

The maximum e.m.f. induced in the coil is 24.0 V.

(a) **(i)** Calculate the maximum flux linkage in the coil.

maximum flux linkage = ... Wb turns **[2]**

This question required candidates to extract the time period from the graph, calculate frequency of the coil and read the maximum e.m.f. from the stem of the question. An understanding that the maximum value of a sine function is +/- 1 was also needed. These requirements meant that the question proved to be quite challenging. The most common error was using a value for sin ($2\pi ft$) other than unity.

Question 7 (a) (ii)

(ii) The coil has sides of length 12 cm. It has 400 turns. Calculate the flux density *B* of the magnetic field.

flux density *B* = ... T **[2]**

This task was also challenging. More than half the candidates did not gain marks, even though errors carried forward from the previous part were taken into account. A common error was to treat the coil as a circular coil, even though it was described as a square coil and the stem stated it had 'sides of length 12 cm'. Less able candidates did not seem to appreciate the link between flux and flux density.

Question 7 (b)

(b) Suggest and explain two modifications to the generator that would increase the e.m.f. induced without changing the frequency of the rotor. You may refer to equations in your explanations.

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....

.... **[4]**

Nearly all candidates gained credit for this question, with the best responses showing a firm understanding of the context and correct use of technical vocabulary. Some responses quoted the relevant equations as part of their explanations. As in the 2022 question paper, some candidates confused permeance and permeability. Descriptions of three phase generation did not gain credit as the e.m.f. of each phase was unaltered by this change alone.

Question 8 (a)

8 This question is about the output power from a wind farm (lines 29–41).

(a) Use the concept of the kinetic energy of a volume of air moving with velocity v to show that the power of the wind striking area A is given by

$$P = \frac{1}{2}\rho A v^3$$

where ρ is the density of the air.

[2]

This question was answered clearly by the high-scoring candidates, some of whom had clearly been through a similar derivation as part of their preparation for the paper. The key requirement was to show an understanding that mass transferred per second is density multiplied by cross sectional area multiplied by distance moved per second.

Question 8 (b)*

(b)* Here are some data about a wind farm:

efficiency = 43%
turbine height = 90 m
blade diameter = 120 m
number of turbines = 85
density of air = 1.2 kg m^{-3}
output power = 900 MW.

Use the data above and the equations in the article to estimate the wind speed at a height of 10 m required to produce this power. Explain your method.

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....

wind speed = ... m s^{-1} **[6]**

Although this LOR question was towards the end of a long paper, nearly all candidates gained credit for their responses with around a third of the candidates reaching Level 3. The most common error was to ignore the number of turbines and assume that the output power was produced by a single turbine. Candidates making this error could still gain marks for subsequent calculations and nearly all managed to use the power equation given in Question 8 (a) with the equation given in the article. The best responses explained each step in the method, interspersing explanations and calculations, but clear responses which separated calculation and explanation also gained full marks.

Exemplar 2

Since the total power output is known divide 900 MV by 85 to give the power output for 1 turbine. Since the turbine is 43% efficient we need to find what 100% of the energy would be by $\times \frac{100}{43}$ to our figure. ~~Then~~ Then using ~~½~~ $P = \frac{1}{2}\rho A V^3$ as given ~~the~~ in the booklet V_{90} can be calculated. Using $V_h = V_{10}\left(\frac{h}{10}\right)^{\frac{1}{7}}$ as given using $h = 90$ a value for the V at 10 m can be found.

$$100 \times \frac{900 \times 10^6}{43} = \frac{1}{2} \times 1.2 \times \pi \left(\frac{120}{2}\right)^2 \times V^3 \times 85$$

$$100 \times \frac{1.06 \times 10^7}{43} = \frac{1}{2} \times 1.2 \times \pi 3600 \times V^3$$

$$V^3 = \frac{2.46 \times 10^7 \times 2}{1.2 \times 3600\pi} = 3630 \text{ ms}^{-1}$$

$\cancel{3630 = V_{10}\left(\frac{90}{10}\right)^{\frac{1}{7}}}$

$V_{10} =$

$V = 15.4$ $\quad 15.4 = V_{10}\left(\frac{90}{10}\right)^{\frac{1}{7}}$

$V_{10} = 11.2$

wind speed = 11.2 ms^{-1} **[6]**

This candidate laid out the calculation logically and clearly. The introductory explanation showed understanding of the context and included all aspects of the calculation.

Assessment for learning

Question 8 (b), and the rest of Section C, together with the article, will be a useful resource for homework or classwork as it covers a lot of techniques commonly used in A Level Physics and gives candidates practice at describing what they are doing in a calculation rather than hurrying through to the final answer.

Question 9 (a)

9 This question is about a small hydroelectric turbine. Water flows down a penstock from a head height of 195 m. (See Figs 4 and 5 in the article.)

The output power of the turbine is 94.5 kW.
Flow rate of water = 55 $kg\,s^{-1}$.

(a) Calculate the efficiency at which the potential energy of the water is transferred to energy output.

efficiency = ... % **[2]**

The majority of the candidates gained both marks for this calculation, showing an understanding of rate of energy transfers in this context.

Question 9 (b) (i)

(b) **(i)** Consider water flowing from a pipe of cross-sectional area $7.9 \times 10^{-3}\,m^2$.

Water flows out of the pipe at a rate of $55 \times 10^{-3}\,m^3\,s^{-1}$. Show that the velocity of the water leaving the pipe is about $7\,m\,s^{-1}$.

[1]

Nearly all candidates gained the mark for this simple calculation, showing that running out of time was not usually a problem.

Question 9 (b) (ii)

The water strikes a surface and divides as shown in **Fig. 9**. The horizontal velocity of the water reduces to zero when it strikes the surface.

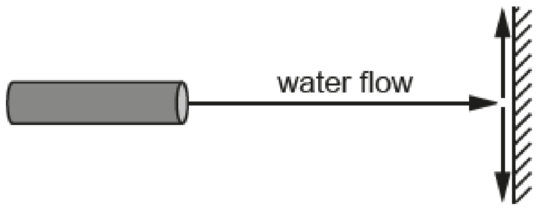

Fig. 9

(ii) Calculate the magnitude of the force exerted on the surface.

density of water = $1000\,kg\,m^{-3}$

force = ... N **[2]**

This calculation is more complex than part (b) (i) and only about half the candidates gained both marks. Making the connection between force as rate of change of momentum, noting that the change in velocity is $7\ m\ s^{-1}$ and using the flow rate of water from the previous part proved a challenge for many.

Question 9 (b) (iii)

(iii) Maximum power is extracted from a Pelton turbine when the velocity of the turbine vane is half that of the water jet.

Calculate the maximum power that can be transferred to the generator when the water in the situation described in **(b)(i)** strikes a surface moving to the right with a velocity of $3.5\,m\,s^{-1}$.

power = ... W **[2]**

This calculation was rarely answered correctly, perhaps as it is near the end of the paper. Responses often missed that the force will halve when the change in momentum halves, and the relationship between power, force and velocity was unfamiliar to many so very few responses gained the second marking point.

Question 9 (b) (iv)

(iv) Describe and explain how the design of the vane increases the power output of the Pelton turbine (see **Fig. 7** in the article).

....

....

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....

....

.... **[4]**

The last question on the paper was also challenging as it required candidates, once again, to write a reasoned argument based on standard physics and apply to the context. About half the candidates gained at least one mark, usually for recognising that the change in velocity is greater when the water 'bounces back'. Good responses linked this to change of momentum and then linked the increased change of momentum to increased power output by a fully argued route.

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