Example Candidate Responses

Cambridge International AS & A Level

Cambridge International AS and A Level Physics

9702

Paper 4 – A Level Structured Questions

For examination from 2016

Cambridge Advanced

CAMBRIDGE International Examinations

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Contents

Introduction

The main aim of this booklet is to exemplify standards for those teaching Cambridge International AS & A Level Physics (9702), and to show how different levels of candidates' performance (high, middle and low) relate to the subject's curriculum and assessment objectives.

In this booklet candidate responses have been chosen to exemplify a range of answers. Each response is accompanied by a brief commentary explaining the strengths and weaknesses of the answers.

For each question, each response is annotated with a clear explanation of where and why marks were awarded or omitted. This, in turn, is followed by examiner comments on how the answer could have been improved. In this way it is possible for you to understand what candidates have done to gain their marks and what they will have to do to improve their answers. At the end there is a list of common mistakes candidates made in their answers for each question.

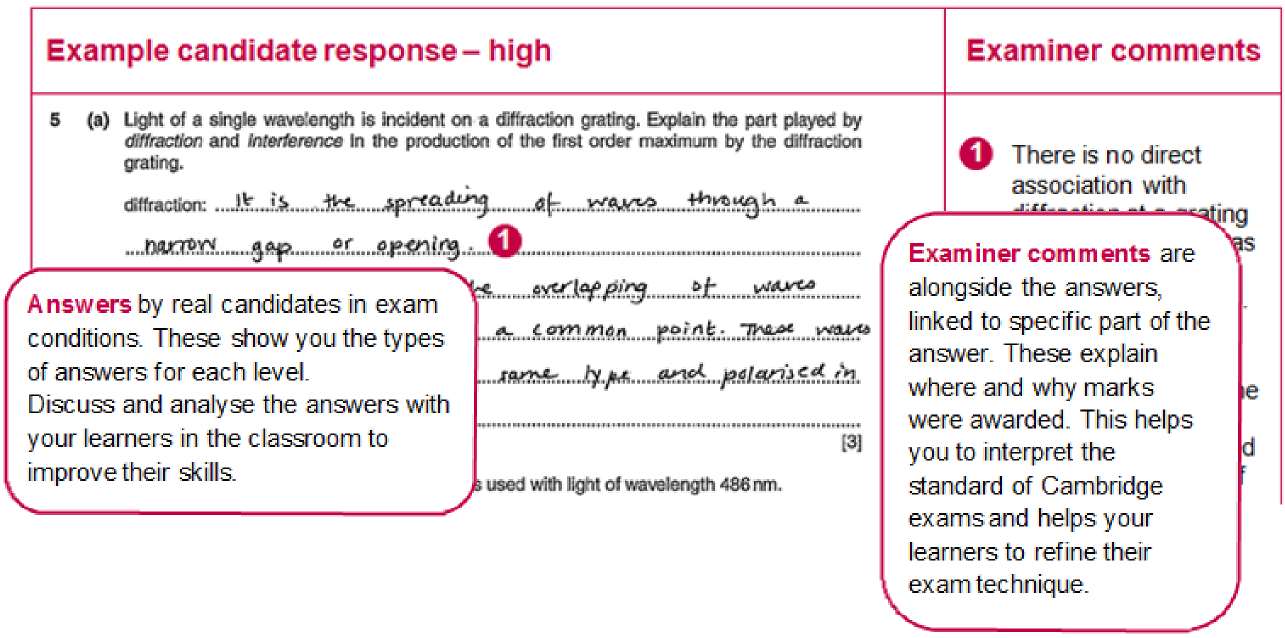
This document provides illustrative examples of candidate work. These help teachers to assess the standard required to achieve marks, beyond the guidance of the mark scheme. Some question types where the answer is clear from the mark scheme, such as short answers and multiple choice, have therefore been omitted.

The questions, mark schemes and pre-release material used here are available to download as a zip file from Teacher Support as the Example Candidate Responses Files. These files are:

Question Paper 22, June 2016	
Question paper	9702_s16_qp_22.pdf
Mark scheme	9702_s16_ms_22.pdf
Question Paper 33, June 2016	
Question paper	9702_s16_qp_33.pdf
Mark scheme	9702_s16_ms_33.pdf
Question Paper 42, June 2016	
Question paper	9702_s16_qp_42.pdf
Mark scheme	9702_s16_ms_42.pdf
Question Paper 52, June 2016	
Question paper	9702_s16_qp_52.pdf
Mark scheme	9702_s16_ms_52.pdf

Past papers, Examiner Reports and other teacher support materials are available on Teacher Support at **https://teachers.cie.org.uk**

How to use this booklet



Example candidate response – high

Examiner comments

5 (a) Light of a single wavelength is incident on a diffraction grating. Explain the part played by *diffraction* and *interference* in the production of the first order maximum by the diffraction grating.

diffraction: It is the spreading of waves through a narrow gap or opening. 1

...e overlapping of waves ... a common point. These waves ... same type and polarised in ...

[3]

...s used with light of wavelength 486 nm.

1 There is no direct association with diffraction at a grating ...

Answers by real candidates in exam conditions. These show you the types of answers for each level. Discuss and analyse the answers with your learners in the classroom to improve their skills.

Examiner comments are alongside the answers, linked to specific part of the answer. These explain where and why marks were awarded. This helps you to interpret the standard of Cambridge exams and helps your learners to refine their exam technique.

How the candidate could have improved their answer

(a) The question was an application of diffraction a... needed to apply their knowledge to the application... interference needed to be applied to the productio... applications as well as learning basic theory is req...

This explains how the candidate could have improved their answer and helps you to interpret the standard of Cambridge exams and helps your learners to refine exam technique.

(b) The diffraction grating equation was used and the given data interpreted correctly. There was a mathematical error in the calculation and the final answer was not realistic. The candidate needed to be more familiar with likely values for applications of basic theory.

Common mistakes candidates made in this question

(a) Diffraction was described as the bending of light. ... diffraction is a wave property and hence diffraction a... have passed through the diffraction element. The ef... was not described for this specific example.

This lists the common mistakes candidates made in answering each question. This will help your learners to avoid these mistakes at the exam and give them the best chance of achieving a high mark.

(b) The angle given on the diagram was used as the angle θ in the diffraction grating equation. The distance *d* was quoted as the number of lines per mm *N*. There were power of ten errors converting *d* in metres to *N* in mm^{-1}.

Assessment at a glance

Candidates for Advanced Subsidiary (AS) certification take Papers 1, 2 and 3 in a single examination series.

Candidates who, having received AS certification, wish to continue their studies to the full Advanced Level qualification may carry their AS marks forward and take Papers 4 and 5 in the examination series in which they require certification.

Candidates taking the full Advanced Level qualification at the end of the course take all five papers in a single examination series.

Candidates may only enter for the papers in the combinations indicated above.

Candidates may not enter for single papers either on the first occasion or for resit purposes.

All components are externally assessed.

Component	Weighting	
	AS Level	**A Level**
Paper 1 Multiple Choice **1 hour 15 minutes** This paper consists of 40 multiple choice questions, all with four options. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on an answer sheet. [40 marks]	31%	15.5%
Paper 2 AS Level Structured Questions **1 hour 15 minutes** This paper consists of a variable number of questions of variable mark value. All questions will be based on the AS Level syllabus content. Candidates will answer all questions. Candidates will answer on the question paper. [60 marks]	46%	23%
Paper 3 Advanced Practical Skills **2 hours** This paper requires candidates to carry out practical work in timed conditions. The paper will consist of two experiments drawn from different areas of physics. The experiments may be based on physics not included in the syllabus content, but candidates will be assessed on their practical skills rather than their knowledge of theory. Candidates will answer both questions. Candidates will answer on the question paper. [40 marks]	23%	11.5%
Paper 4 A Level Structured Questions **2 hours** This paper consists of a variable number of questions of variable mark value. All questions will be based on the A Level syllabus but may require knowledge of material first encountered in the AS Level syllabus. Candidates will answer all questions. Candidates will answer on the question paper. [100 marks]	–	38.5%

Component	Weighting	
	AS Level	A Level
Paper 5 Planning, Analysis and Evaluation **1 hour 15 minutes** This paper consists of two questions of equal mark value based on the practical skills of planning, analysis and evaluation. The context of the questions may be outside the syllabus content, but candidates will be assessed on their practical skills of planning, analysis and evaluation rather than their knowledge of theory. Candidates will answer both questions. Candidates will answer on the question paper. [30 marks]	–	11.5%

Teachers are reminded that the latest syllabus is available on our public website at **www.cie.org.uk** and Teacher Support at **https://teachers.cie.org.uk**

Paper 4 – A Level Structured Questions

Question 1

Example candidate response – high

1 A binary star consists of two stars A and B that orbit one another, as illustrated in Fig. 1.1.

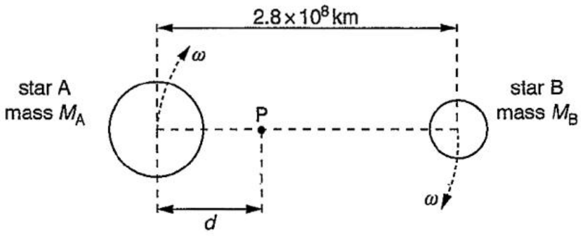


Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance d from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude.

Because the centripetal force acting on both stars are provided by the gravitational force ❶ $F_G = \frac{G M_A M_B}{r^2} = m\omega^2 r = m\left(\frac{2\pi}{T}\right)^2 r$. The angular velocity ω and period T of both stars are the same. So the centripetal force (and gravitational forces) for both stars are the same. ❷ [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed ω of the stars.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{4 \times 365 \times 24 \times 3600}$$

$$= 4.98 \times 10^{-8} \text{ rad s}^{-1}$$

❸

ω = 4.98×10^{-8} rad s^{-1} [2]

Examiner comments

❶ The candidate clearly states what provides the centripetal force in this system of two stars.

Mark for (a) (i) = 2/2

❷ An equation is provided linking the two forces and the candidate explains why the two forces are the same.

❸ A correct calculation is performed with the candidate clearly showing how the period T is converted from years to seconds.

Mark for (a) (ii) = 2/2

Example candidate response – high, continued

(b) The separation of the centres of the stars is 2.8 × 10[8] km. ($\mathcal{L}$)
The mass of star A is M_A. The mass of star B is M_B.

The ratio $\dfrac{M_A}{M_B}$ is 3.0.

(i) Determine the distance *d*.

$\because \omega, T, F_c$ are the same for A and B

$\therefore M_A \omega^2 d = M_B \omega^2 (2.8\times10^8 - d)$. **4**

$\therefore \dfrac{M_A}{M_B} = \dfrac{2.8\times10^8 - d}{d} = 3$

$\therefore d = ~~7\times10~~\ 7.0\times10^7$ km

d = ... 7.0×10^7 ...... km [3]

(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B.
Explain your working.

~~$\therefore \frac{M_A}{M_B} = 3$~~ $\therefore$ ~~$M_B = \frac{M_A}{3}$~~ ~~$M_A = 3M_B$~~

~~$(7\times10^7)M_A$~~ $\therefore$ ~~$3M_B \times (7\times10^7) = M_B \times (2.8\times10^8 - 7\times10^7)$~~

~~$\mathcal{L} = d_A + d_B \rightarrow$~~ ~~$d_B = \mathcal{L} - d_A$~~ $d_A = \mathcal{L} - d_B$

~~$M_A \cdot d_A = M_B \cdot d_B$~~

~~$M_A \cdot d_A = M$~~

~~$M_A(\mathcal{L} - d_B) = M_B \cdot d_B$~~

~~$M_B = \dfrac{M_A(\mathcal{L} - d_B)}{d_B}$~~

$\because \dfrac{M_A}{M_B} = 3 \quad \therefore$ ~~$M_B =$~~ $M_A = 3M_B$

$\therefore G\dfrac{3M_B \cdot M_B}{\mathcal{L}^2} = M_B\omega^2\mathcal{L}$ **5**

$6.67\times10^{-11} \times \dfrac{3M_B}{(2.8\times10^8\times10^3)^2} = (4.98\times10^{-8})^2 \times (2.8\times10^8\times10^3 - 7\times10^7)$

$M_B = 2.72\times10^{29}$ kg

M_B = ... 2.72×10^{29} ...... kg [3]

[Total: 10]

Examiner comments

4 The candidate uses the fact that the centripetal force on the two stars is the same and performs a correct calculation.

Mark for (b) (i) = 3/3

5 A correct starting equation is provided and correct distance values in metres inserted. However, the candidate has made an arithmetical error, as the correct answer should be 2.04×10^{29} kg.

Mark for (b) (ii) = 2/3

Total marks awarded = 9 out of 10

How the candidate could have improved their answer

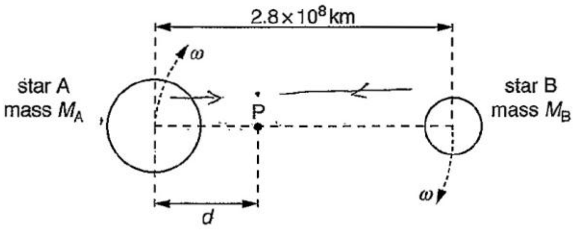
(b) (i) The candidate needed to make a correct calculation here.

Mark awarded = **(a) (i) 2/2, (ii) 2/2**
Mark awarded = **(b) (i) 3/3, (ii) 2/3**

Total marks awarded = 9 out of 10

Example candidate response – middle	Examiner comments

1 A binary star consists of two stars A and B that orbit one another, as illustrated in Fig. 1.1.



$mr\omega^2$ $\frac{mv^2}{r}$ $mv\omega$

$F_c = ma$

Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance *d* from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude. **1**

Both stars have same angular speed. ~~and acceleration~~. They act as point masses so mass has negligible effect on force. [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed *ω* of the stars.

$\omega = \theta / T = \frac{2\pi}{T} = \frac{2\pi}{T} = \frac{2\pi f}{} = \frac{2\pi}{4 \times 365 \times 24 \times 3600}$

$= 4.98 \times 10^{-8}$ **2**

ω = 4.98 × 10^{-8} rad s^{-1} [2]

Examiner comments

1 There is no reference to gravity in this answer.

Mark for (a) (i) = 0/2

2 A correct answer with a clear conversion of years into seconds.

Mark for (a) (ii) = 2/2

Example candidate response – middle, continued

(b) The separation of the centres of the stars is 2.8×10^8 km.
The mass of star A is M_A. The mass of star B is M_B.
The ratio $\frac{M_A}{M_B}$ is 3.0.

Fc force.

(i) Determine the distance *d*.

$M_A \times d \times \omega^2 = M_B \times (2.8\times10^8 - d)\,\omega^2$

$\frac{M_A}{M_B} \times d \times \omega^2 = (2.8\times10^8 - d)\,\omega^2$

$3 \times d = 2.8\times10^8 - d$

$3d + d = 2.8\times10^8$

7.0×10^7 km

❸

d = 7.0×10^7 km [3]

(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B.
Explain your working.

$F_c = mr\omega^2$. $r = 2.1\times10^8$ km.

$Mr\omega^2 = \frac{GM_A}{r^2}$

❹

$(7.0\times10^7) \times (40.98\times10^{-8})^2 = \frac{(6.67\times10^{-11})(M_A)}{(7.0\times10^7)^2}$

❺

2602.7
2600 2.6×10^3 kg

$\frac{M_A}{M_B} = 3$

$\frac{(2.6\times10^3)}{3} = M_B$ 870

M_B = 8.7×10^2 kg [3]

[Total: 10]

Examiner comments

❸ A correct answer using the values provided.

Mark for (b) (i) = 3/3

❹ The candidate makes a common error here, using the same distance for both the radius of the orbit of star B and the distance between the two stars.

❺ This candidate also incorrectly cancels the distances.

Mark for (b) (ii) = 0/3

Total marks awarded = 5 out of 10

How the candidate could have improved their answer

(a) (i) Some reference to gravitational forces was required here.

(b) (ii) The candidate needed to insert the correct distance between the two stars for the gravitational force and understand the basic mathematics required to simplify the equations.

Mark awarded = **(a) (i) 0/2, (ii) 2/2,**
Mark awarded = **(b) (i) 3/3, (ii) 0/3**

Total marks awarded 5 out of 10

Example candidate response – low

1 A binary star consists of two stars A and B that orbit one another, as illustrated in Fig. 1.1.

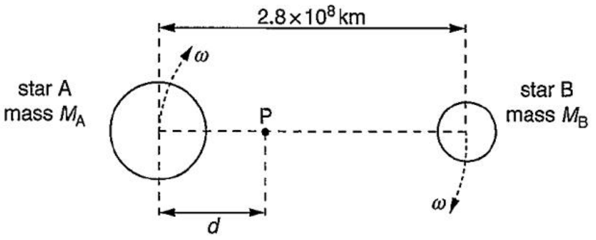


Fig. 1.1

The stars are in circular orbits with the centres of both orbits at point P, a distance *d* from the centre of star A.

(a) (i) Explain why the centripetal force acting on both stars has the same magnitude. **1**

The Torque forces ~~of~~ on both stars are a couple. The ~~(Tx)~~ force of torque is equal to the centripetal force ~~which~~ ~~is~~. The torque forces = force on ~~each~~ one × the distance between them, which are same. [2]

(ii) The period of the orbit of the stars about point P is 4.0 years.

Calculate the angular speed *ω* of the stars.

$\omega = \frac{2\pi}{T}$

$T = 4 \times 365 \times 24 \times 60 \times 60$

$= 126144000$ s

$= \frac{2\pi}{126144000}$

$= 4.98 \times 10^{-8}$

$= 5.0 \times 10^{-8}$ **2**

ω = 5.0×10^{-8} rad s^{-1} [2]

Examiner comments

1 There is no reference to gravity in this answer. The forces involved are not torque forces.

Mark for (a) (i) = 0/2

2 A correct answer with a clear conversion from years to seconds. The candidate also correctly rounds the answer to two significant figures.

Mark for (a) (ii) = 2/2

Example candidate response – low, continued

(b) The separation of the centres of the stars is 2.8×10^8 km.
The mass of star A is M_A. The mass of star B is M_B.
The ratio $\frac{M_A}{M_B}$ is 3.0.

(i) Determine the distance *d*.

$$\frac{GM_A}{r^2} = \frac{GM_B}{r^2} \qquad \frac{GMm}{r} = F \times d$$

$$\frac{M_A}{M_B} = \frac{r^2}{r^2} \qquad 3 = (2.8 \times 10^8)^2$$

3

d = ...1.6 × 10^8...................... km [3]

(ii) Use your answers in **(a)(ii)** and **(b)(i)** to determine the mass M_B of star B.
Explain your working.

$$F = m\omega^2 r \qquad m = \frac{F}{\omega^2 r} = \frac{F}{(5.0 \times 10^{-8})^2 \times 1.6 \times 10^8} = \frac{F}{4 \times 10^{-7}}$$

4

M_B = ...$\frac{F}{4 \times 10^{-7}}$...................... kg [3]

[Total: 10]

Examiner comments

3 No marks are awarded for this section as the candidate has not made use of the fact that the centripetal forces on the two stars are the same.

Mark for (b) (i) = 0/3

4 The candidate inserts *F* for the force on star B and has not related this to the gravitational force. The equation for the centripetal force just uses a mass *m*, and in a correct solution M_B needs to be linked to the correct radius and similarly M_A to the correct radius.

Mark for (b) (ii) = 0/3

Total marks awarded = 2 out of 10

How the candidate could have improved their answer

The candidate required a better understanding of Newton's law of gravitation and its application to rotating stars.

(a) (i) Here, there was no reference to gravitational forces.

(b) (i) Required the candidate to realise that the centripetal forces on the two stars are the same.

(b) (ii) The candidate needed to use their answers to (a) (ii) and (b) (i), as stated in the question.

Mark awarded = **(a) (i) 0/2, (ii) 2/2**
Mark awarded = **(b) (i) 0/3, (ii) 0/3**

Total marks awarded = 2 out of 10

Common mistakes candidates made in this question

(a) (i) Many candidates did not link the forces on the rotating system of the stars to gravitational forces.

(a) (ii) A common error was to perform an incorrect calculation from years into seconds. Working with 360 days in a year was a common error, along with using 60 rather than 3600 seconds in an hour.

(b) (i) The common error in this section was to simply link the mass of star A or B to the incorrect radius of rotation.

(b) (ii) A very common error in this section was to use Kepler's law, assuming that one star was at the centre of a rotating system.

Question 4

Example candidate response – high

4 A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator, as shown in Fig. 4.1.

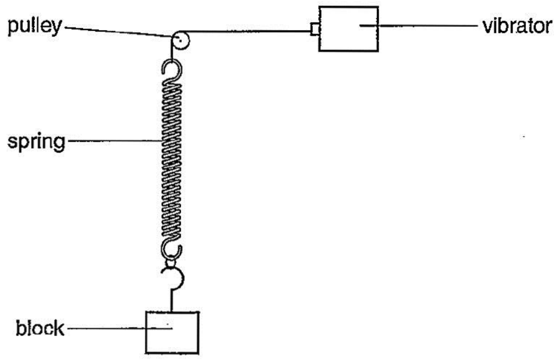


Fig. 4.1

(a) The vibrator is switched off.
The metal block of mass 120 g is displaced vertically and then released. The variation with time *t* of the displacement *y* of the block from its equilibrium position is shown in Fig. 4.2.

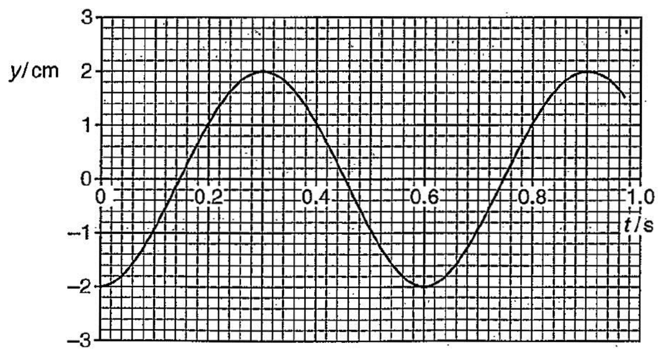


Fig. 4.2

For the vibrations of the block, calculate

(i) the angular frequency ω,

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.6}$

$\omega = 10.47$

1

ω = ...10.5...... rad s^{-1} [2]

Examiner comments

1 The candidate starts with the correct equation and correctly reads the period from the graph as 0.6 seconds. They then perform a correct calculation obtaining a correct answer to three significant figures. An answer to two significant figures of 10 also scores the marks.

Mark for (a) (i) = 2/2

Example candidate response – high, continued

(ii) the energy of the vibrations.

$$E = \frac{1}{2} m \left(\omega \sqrt{x_0^2 - x^2}\right)^2$$

$$= \frac{1}{2} m \omega^2 x_0^2$$

$$= \frac{1}{2} \times 120 \times 10^{-3} \times (10.47)^2 \times (2 \times 10^{-2})^2$$

$$= 2.631 \times 10^{-3}$$

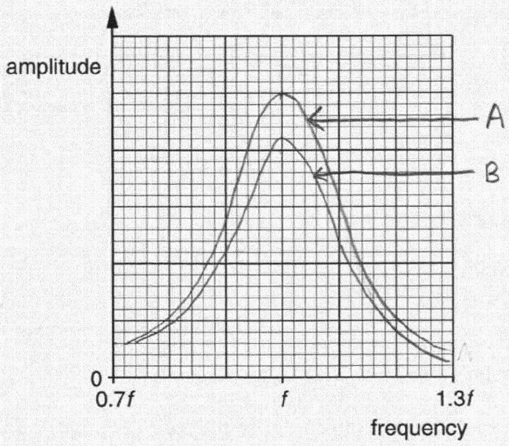
2

energy = ...2.6×10^{-3}.......... J [2]

(b) The vibrator is now switched on.

The frequency of vibration is varied from 0.7*f* to 1.3*f* where *f* is the frequency of vibration of the block in **(a)**.

For the block, complete Fig. 4.3 to show the variation with frequency of the amplitude of vibration. Label this line A. [3]



3

4

Fig. 4.3

(c) Some light feathers are now attached to the block in **(b)** to increase air resistance.

The frequency of vibration is once again varied from 0.7*f* to 1.3*f*. The new amplitude of vibration is measured for each frequency.

On Fig. 4.3, draw a line to show the variation with frequency of the amplitude of vibration. Label this line B. [2]

[Total: 9]

Examiner comments

2 A correct starting equation is provided and then correct substitutions for the various terms are shown, leading to a correct solution.

Mark for (a) (ii) = 2/2

3 The candidate has drawn a clear line which has the correct shape and a peak at *f*. One mark is not awarded because the line does not start at 0.7*f* nor finish at 1.3*f*.

Mark for (b) = 2/3

4 The candidate has drawn a second line, labelled B, which is correctly below A along all its length with a maximum at *f*.

Mark for (c) = 2/2

Total marks awarded = 8 out of 9

How the candidate could have improved their answer

(b) The candidate needed to draw graph lines clearly starting from 0.7*f* to 1.3*f*, as required in the question, to gain full marks.

Mark awarded = **(a) (i) 2/2, (ii) 2/2**
Mark awarded = **(b) 2/3**
Mark awarded = **(c) 2/2**

Total marks awarded = 8 out of 9

Example candidate response – middle

4 A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator, as shown in Fig. 4.1.

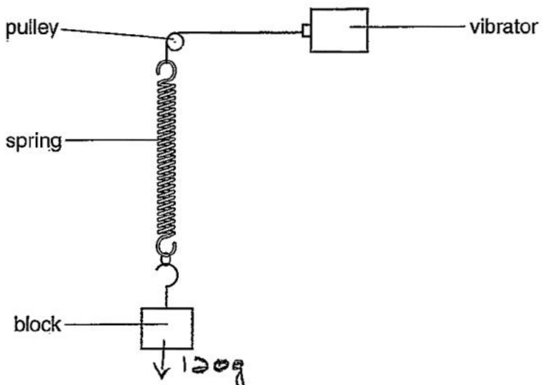


Fig. 4.1

(a) The vibrator is switched off.
The metal block of mass 120 g is displaced vertically and then released. The variation with time *t* of the displacement *y* of the block from its equilibrium position is shown in Fig. 4.2.

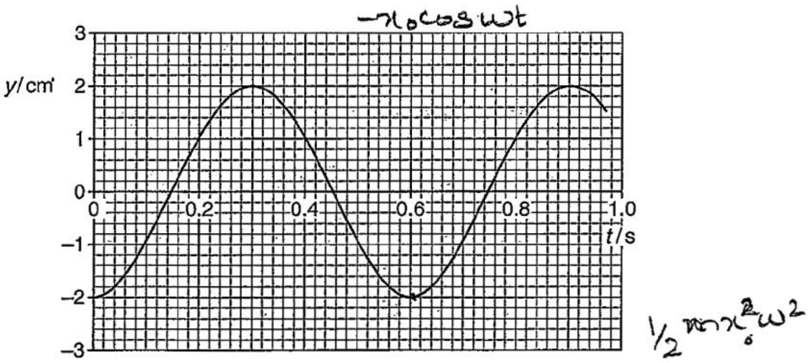


Fig. 4.2

For the vibrations of the block, calculate

(i) the angular frequency ω, ✓

$\omega = 2\pi f$ $= 1/0.6 = f = 1.67$ Hz.

$= 10.5$

1

ω = ...10.5.......... rad s^{-1} [2]

Examiner comments

1 A correct answer to three significant figures is given here.

Mark for (a) (i) = 2/2

Example candidate response – middle, continued

(ii) the energy of the vibrations.

$T.E = \frac{1}{2} m x_0^2 \omega^2$

$= \frac{1}{2}(0.12)(2\times10^{-2})^2(10.5)^2$

$= 2.646\times10^{-3}$

2

energy = 2.65×10^{-3} J [2]

(b) The vibrator is now switched on.

The frequency of vibration is varied from 0.7*f* to 1.3*f* where *f* is the frequency of vibration of the block in **(a)**.

For the block, complete Fig. 4.3 to show the variation with frequency of the amplitude of vibration. Label this line A. [3]

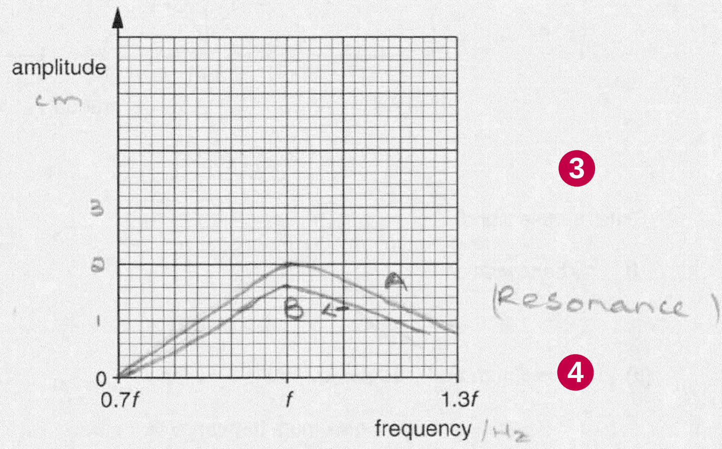


Fig. 4.3

(c) Some light feathers are now attached to the block in **(b)** to increase air resistance.

The frequency of vibration is once again varied from 0.7*f* to 1.3*f*. The new amplitude of vibration is measured for each frequency.

On Fig. 4.3, draw a line to show the variation with frequency of the amplitude of vibration. Label this line B. [2]

[Total: 9]

Examiner comments

2 A correct answer to three significant figures is given here.

Mark for (a) (ii) = 2/2

3 The shape of graph line A is not correct, so the answer is not awarded the shape mark. The peak is at *f* to within half a square but the graph goes down to zero at 0.7*f*. A correct resonance curve always has a positive value even down to zero frequency.

Mark for (b) = 1/3

4 Curve B should always be below curve A but the two lines touch at 0.7*f* so no marks are awarded for line B.

Mark for (c) = 0/2

Total marks awarded = 5 out of 9

How the candidate could have improved their answer

(b) & (c) The graph lines needed to be drawn with the correct overall general shape. The major error on both graphs occurred at low frequencies when both lines reached zero amplitude at 0.7*f*. Line B should always be below Line A.

Mark awarded = **(a) (i) 2/2 (ii) 2/2**
Mark awarded = **(b) 1/3**
Mark awarded = **(c) 0/2**

Total marks awarded = 5 out of 9

Example candidate response – low

4 A metal block hangs vertically from one end of a spring. The other end of the spring is tied to a thread that passes over a pulley and is attached to a vibrator, as shown in Fig. 4.1.

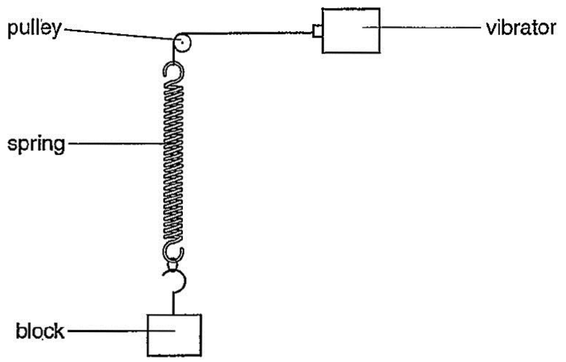


Fig. 4.1

(a) The vibrator is switched off.
The metal block of mass 120 g is displaced vertically and then released. The variation with time *t* of the displacement *y* of the block from its equilibrium position is shown in Fig. 4.2.

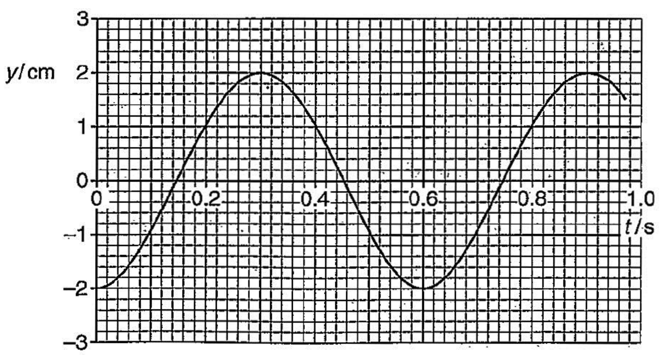


Fig. 4.2

For the vibrations of the block, calculate

(i) the angular frequency ω,

~~$f = \frac{1}{T}$~~

~~$= \frac{1}{0.6} = 1.67$~~

$\omega = \frac{2\pi}{T}$

$= \frac{2\pi}{0.6}$

$=$

1

ω = ~~1.67~~ 10.47 rad s^{-1} [2]

Examiner comments

1 A correct answer gaining full marks.

Mark for (a) (i) = 2/2

Example candidate response – low, continued

(ii) the energy of the vibrations.

$\frac{1}{2} \times m \times \omega^2$

$= \frac{1}{2} \times 0.12 \times (10.47)^2$

$= 0.06 \times 109.6 = 6.58$

energy = ...6.58...... J [2]

(b) The vibrator is now switched on.

The frequency of vibration is varied from 0.7*f* to 1.3*f* where *f* is the frequency of vibration of the block in **(a)**.

For the block, complete Fig. 4.3 to show the variation with frequency of the amplitude of vibration. Label this line A. [3]

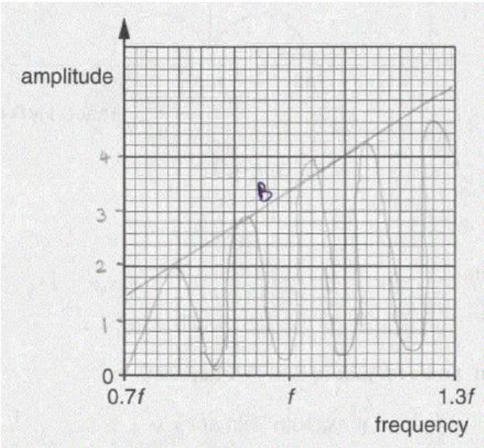


Fig. 4.3

(c) Some light feathers are now attached to the block in **(b)** to increase air resistance.

The frequency of vibration is once again varied from 0.7*f* to 1.3*f*. The new amplitude of vibration is measured for each frequency.

On Fig. 4.3, draw a line to show the variation with frequency of the amplitude of vibration. Label this line B. [2]

[Total: 9]

Examiner comments

2 The candidate starts with an incorrect physics equation.

Mark for (a) (ii) = 0/2

3 Only one line is labelled, which would be acceptable and the candidate could gain the mark for the second as it is assumed to be line A. This line is incorrect as it is the wrong shape and the peak is not at *f*. (Note, the second line is very faint, starting at 0, with five peaks under line B)

Mark for (b) = 0/3

Mark for (c) = 0/2

Total marks awarded = 2 out of 9

How the candidate could have improved their answer

(a) (ii) This answer started with an incorrect physics equation and an amplitude term was missing.

The candidate needed a better understanding of the shape of resonance graphs to obtain marks in this section.

Mark awarded = **(a) (i) 2/2, (ii) 0/2**
Mark awarded = **(b) 0/3**
Mark awarded = **(c) 0/2**

Total marks awarded = 2 out of 9

Common mistakes candidates made in this question

(a) (i) The majority of candidates were able to perform this calculation correctly, although many misread the graph.

(a) (ii) The majority of candidates started with the correct equation, although the most common error was to not convert the mass of the block to kg or the amplitude to metres.

(b) Candidates often did not draw a curve covering the range 0.7*f* to 1.3*f*, as requested by the question. Many curves started or ended with an amplitude of zero.

(c) Many candidates were not awarded marks in this section because their line B touched line A at some point. The examiner needed to see a clear space between the two curves. Some candidates drew A and B lines which were straight rather than curves.

Question 6

Example candidate response – high

6 (a) By reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre.

1 The electric field lines spread outwards ~~f~~ radially and would meet at a point in the centre of the sphere. The electric field lines show the strength of the electric field, which is ~~conc~~ concentrated in the centre. Thus all the charge is considered to act at its centre. [2]

(b) Two isolated protons are separated in a vacuum by a distance *x*.

(i) Calculate the ratio

$$\frac{\text{electric force between the two protons}}{\text{gravitational force between the two protons}}$$

$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} = \frac{(1.60\times10^{-19})^2}{4\pi\varepsilon_0 x^2}$

2

$F = \frac{GMm}{r^2} = \frac{6.67\times10^{-11}\times(1.67\times10^{-27})^2}{x^2}$

$\frac{(1.60\times10^{-19})^2}{4\pi\varepsilon_0 \cancel{x^2}} \div \frac{6.67\times10^{-11}\times(1.67\times10^{-27})^2}{\cancel{x^2}}$

$\frac{2.56\times10^{-38}}{1.11\times10^{-11}} \times \frac{1}{1.86\times10^{-64}}$

$\frac{2.56\times10^{-38}}{2.07\times10^{-74}} = \frac{1.24\times10^{36}}{1}$ ratio = 1.24×10^{36} [3]

(ii) By reference to your answer in **(i)**, suggest why gravitational forces are not considered when calculating the force between charged particles.

3 The gravitational forces are negligable compared to the force between charges. (1.24×10^{36} : 1 / F_E : F_G) [1]

[Total: 6]

Examiner comments

1 The candidate is awarded the first mark for stating that the field lines spread out radially. The candidate then writes incorrectly about the field lines meeting at the centre. To be awarded the second mark, they needed to say that the field lines appeared to meet at the centre.

Mark for (a) = 1/2

2 Two correct equations with correct numerical values, followed by a correct calculation to greater than two significant figures, so this answer is awarded full marks.

Mark for (b) (i) = 3/3

3 The candidate refers to the answer in (b) (i) to explain correctly why the gravitational forces can be ignored.

Mark for (b) (ii) = 1/1

Total marks awarded = 5 out of 6

How the candidate could have improved their answer

(a) The candidate needed to realise that there are no field lines inside a spherical conductor and so should have considered the shape of the field lines outside the sphere.

Mark awarded = **(a) 1/2**
Mark awarded = **(b) (i) 3/3, (ii) 1/1**

Total marks awarded = 5 out of 6

Example candidate response – middle	Examiner comments
6 (a) By reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. **1** Outside spherical conductor, charges can move and hence there is a resultant force on charge. With resultant force, there is field acting on the charge. [2]	**1** The candidate makes no reference to the properties of field lines outside a spherical conductor and the answer is based on the forces on charges. Mark for (a) = 0/2
(b) Two isolated protons are separated in a vacuum by a distance *x*. **(i)** Calculate the ratio $\frac{\text{electric force between the two protons}}{\text{gravitational force between the two protons}}$ = $\frac{Q_1Q_2}{4\pi\varepsilon_0 x^2} \div \frac{GM_1M_2}{x^2}$ $= \frac{(1.6\times10^{-19})^2}{4\pi(8.85\times10^{-12})x^2} \div \frac{6.67\times10^{-11}(1.67\times10^{-27})^2}{x^2}$ **2** $= \frac{(1.6\times10^{-19})^2}{4\pi(8.85\times10^{-12})} \times \frac{1}{6.67\times10^{-11}(1.67\times10^{-27})^2}$ $= 1.24\times10^{36}$ (3sf) ratio = 1.24×10^{36} [3]	**2** A correct calculation with the values substituted in the equations clearly seen. Mark for (b) (i) = 3/3
(ii) By reference to your answer in **(i)**, suggest why gravitational forces are not considered when calculating the force between charged particles. It is too small compared to electric force since ratio is big. **3** [1] [Total: 6]	**3** A correct answer to this part of the question with a clear comparison between the two forces in a reference to the large ratio. 'Too small' is accepted as a measure of the size of the ratio. Mark for (b) (ii) = 1/1 **Total marks awarded = 4 out of 6**

How the candidate could have improved their answer

(a) The candidate needed to refer to the field lines, as required by the question.

Mark awarded = **(a) 0/2**
Mark awarded = **(b) (i) 3/3, (ii) 1/1**

Total marks awarded = 4 out of 6

Example candidate response – low	Examiner comments
6 (a) By reference to electric field lines, explain why, for points outside an isolated spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. Electric field lines show the path and direction **1** of an isolated positive charge. Since the isolated spherical conductor has a charge and is in the electric field it can be considered as a point charge. [2]	**1** The initial statement is partially correct when considering field lines. There is no mention of the direction of the field lines outside the conductor. Mark for (a) = 0/2
(b) Two isolated protons are separated in a vacuum by a distance *x*. **(i)** Calculate the ratio $\dfrac{\text{electric force between the two protons}}{\text{gravitational force between the two protons}}$ $= \dfrac{kQQ_2}{x^2} \div \dfrac{GM_1M_2}{x^2}$ **2** $= \dfrac{kQQ_2}{x^2} \times \dfrac{x^2}{GM_1M_2}$ $= \dfrac{\frac{1}{4\pi\varepsilon_0} \times (1.6\times10^{-19})^2}{6.67\times10^{-11} \times 2(1.67\times10^{-27})} = \dfrac{2.3\times10^{48}}{2.2\times10^{-37}}$ ratio = 1.03 [3]	**2** The initial equations for the ratio are correct and the candidate makes a correct substitution for the electric force. The substitution for the gravitational force has a missing power of 2 followed by an arithmetical error. Mark for (b) (i) = 1/3
(ii) By reference to your answer in **(i)**, suggest why gravitational forces are not considered when calculating the force between charged particles. It's almost the same, since the ratio between the two forces is one. **3** [1] [Total: 6]	**3** This follows on correctly from the answer to (b) (i), but the question states that the gravitational forces are ignored so the answer contradicts this. Mark for (b) (ii) = 0/1 **Total marks awarded = 1 out of 6**

How the candidate could have improved their answer

(a) The candidate referred to the field lines here. However, the examiner expected to see some reference to the shape of the field lines which implies that the charge appears to be at the centre.

(b) (i) The candidate started with the correct equations and squared the electric charge. Rather than squaring the mass in the gravity calculation, however, the candidate replaced *m* squared with 2 × *m*. There was also a power of 10 error in the calculation of the electric force.

(b) (ii) This question should have alerted the candidate to the fact that the ratio of 1 calculated in (b) (i) was not correct.

Mark awarded = **(a) 0/2**
Mark awarded = **(b) (i) 1/3, (ii) 0/1**

Total marks awarded = 1 out of 6

Common mistakes candidates made in this question

(a) Very few candidates referred to the field lines outside the conductor and many candidates wrote about the field lines meeting at the centre. Since there are no field lines in a spherical conductor, they can only *appear* to meet at the centre.

(b) (i) A number of candidates who started with the correct equations inserted $2 \times e$ for e^2 or $2 \times m$ for the mass of the proton squared. The other common error was to insert 1.66 rather than 1.67 for the mass of the proton.

(b) (ii) Omitting to make a comparison between the gravitational force and the electric force was a common error. Many candidates simply stated that the gravitational force was small or was small because the mass of the proton was small. The question required an answer based on the answer to (b) (i), implying some comparison between the two forces.

Question 12

Example candidate response – high

12 High-energy electrons collide with a metal target, producing X-ray photons.

The variation with wavelength of the intensity of the X-ray beam is illustrated in Fig. 12.1.

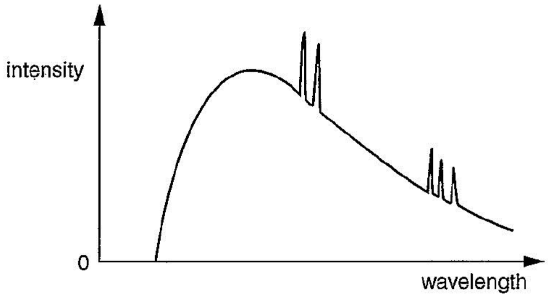


Fig. 12.1

(a) Explain why there is

(i) a continuous distribution of wavelengths,

1 Electromagnetic radiation is ~~released~~ emitted one electrons accelerate. Electrons has a wide range of acceleration so there is a range of wavelengths. Electrons are accelerating continuously so continuous distribution of wavelengths. [3]

(ii) a sharp cut-off at short wavelength,

2 For shortest wavelength, acceleration is greatest. [2]

(iii) a series of peaks superimposed on the continuous distribution of wavelengths.

3 De-excitation of some electrons in target atom gives line spectra forming some peaks on distribution graph. [1]

(b) In the X-ray imaging of body structures, longer wavelength photons are frequently filtered out of the X-ray beam.

(i) State how this filtering is achieved.

4 Place a aluminium filter in x-ray beam. [1]

(ii) Suggest the reason for this filtering.

5 ~~A~~ So that long wavelengths X-rays are absorbed by aluminium rather than body. [1]

[Total: 8]

Examiner comments

1 This answer is awarded the final two marks for saying that there are a range of accelerations leading to a range of wavelengths.

Mark for (a) (i) = 2/3

2 Candidates needed to explain that in one collision all the energy of the electron is given to one photon. While the candidate's statement is correct in general, there is no mention of one photon or one collision.

Mark for (a) (ii) = 0/2

3 A correct answer making reference to the de-excitation atoms in the target.

Mark for (a) (iii) = 1/1

4 A correct answer. Aluminium sheet or foil would also have been acceptable.

Mark for (b) (i) = 1/1

5 A correct answer making reference to the X-rays absorbed in the aluminium, not in the body.

Mark for (b) (ii) = 1/1

Total marks awarded = 5 out of 8

How the candidate could have improved their answer

(a) (i) Here the candidate needed to introduce their answer by explaining the basic process of x-ray production, where whenever electrons/charged particles are accelerated or are stopped, this produces photons of electromagnetic radiation, i.e. X-ray photons are produced.

(a) (ii) The idea of a single electron decelerating producing a single photon was missing in the answer.

Mark awarded = **(a) (i) 2/3**
Mark awarded = **(a) (ii) 0/2**
Mark awarded = **(a) (iii) 1/1**
Mark awarded = **(b) (i) 1/1**
Mark awarded = **(b) (ii) 1/1**

Total marks awarded = 5 out of 8

Example candidate response – middle

12 High-energy electrons collide with a metal target, producing X-ray photons.

The variation with wavelength of the intensity of the X-ray beam is illustrated in Fig. 12.1.

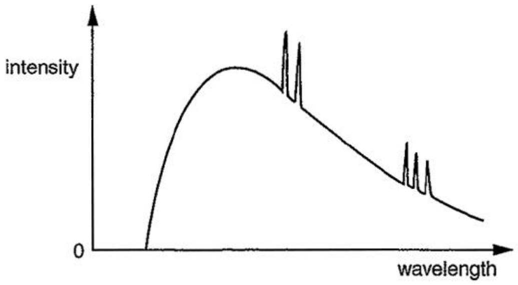


Fig. 12.1

(a) Explain why there is

(i) a continuous distribution of wavelengths,

1 Because there was ~~of~~ ~~de~~ continuous range of deacceleration of electrons when they hit metal plate so the X-rays emitted also had continuous distribution of wavelength. For each acceleration there is particular wavelength. [3]

(ii) a sharp cut-off at short wavelength,

2 It is because of the maximum energy/frequency electron ~~which was due to single photon~~ hitting the metal & emitting single photon [2]

(iii) a series of peaks superimposed on the continuous distribution of wavelengths.

3 ~~It~~ is Because of low impact time of between metal & the electron collision & also because of transition in metal when electron hit the metal. [1]

(b) In the X-ray imaging of body structures, longer wavelength photons are frequently filtered out of the X-ray beam.

(i) State how this filtering is achieved.

4 An Aluminium filter is placed in the way of X-ray beam. [1]

(ii) Suggest the reason for this filtering.

5 They ~~take~~ lack energy to penetrate through body skin they only increase the dose they don't ~~part~~ take part in image. [1]

[Total: 8]

Examiner comments

1 A correct answer, just missing a statement about the basic process taking place when X-rays are produced. Two marks are awarded for the range of accelerations giving rise to a range of wavelengths.

Mark for (a) (i) = 2/3

2 This answer almost gains the first mark. All it needs is a statement that all the energy is given to a single photon. There is also no mention of a single collision.

Mark for (a) (ii) = 0/2

3 The candidate needed to talk about the de-excitation of atoms in the target. The use of the word *transitions* would imply excitation.

Mark for (a) (iii) = 0/1

4 Aluminium filter is a correct answer.

Mark for (b) (i) = 1/1

5 Although the candidate does not state explicitly that long wavelength X-rays are absorbed in the body, mentioning an increased dose and not contributing to the image gains the mark.

Mark for (b) (ii) = 1/1

Total marks awarded = 4 out of 8

How the candidate could have improved their answer

(a) (i) The candidate just needed to explain the basic process of X-ray production to gain full marks here.

(a) (ii) The examiner needed to see some reference to all the energy of a single electron being given to one photon in a single collision.

(a) (iii) The candidate wrote about transitions in the metal but it was not clear that de-excitation is taking place; *transition* could be *excitation*.

Mark awarded = **(a) (i) 2/3**
Mark awarded = **(a) (ii) 0/2**
Mark awarded = **(a) (iii) 0/1**
Mark awarded = **(b) (i) 1/1**
Mark awarded = **(b) (ii) 1/1**

Total marks awarded = 4 out of 8

Example candidate response – low

12 High-energy electrons collide with a metal target, producing X-ray photons.

The variation with wavelength of the intensity of the X-ray beam is illustrated in Fig. 12.1.

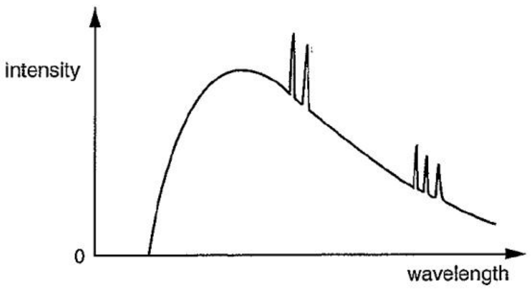


Fig. 12.1

(a) Explain why there is

(i) a continuous distribution of wavelengths,

1 Electrons have various velocities. High wavelength X ray beams are due to low energy electrons. [3]

(ii) a sharp cut-off at short wavelength,

2 Electrons would have an energy value more than one specific value. (threshold frequency) [2]

(iii) a series of peaks superimposed on the continuous distribution of wavelengths.

3 When a series of electrons hit the metal target and more than one photon is emited from the similar wavelength electrons. [1]

(b) In the X-ray imaging of body structures, longer wavelength photons are frequently filtered out of the X-ray beam.

(i) State how this filtering is achieved.

By keeping a thin Aluminium sheet between the body and beam. [1]

(ii) Suggest the reason for this filtering.

It absorbs high wavelength X ray beams which would be absorbed by the body and not contribute to the image. [1]

[Total: 8]

Examiner comments

1 This answer does not explain the basic process of X-ray production, that electrons are accelerated in the anode.

Mark for (a) (i) = 0/3

2 There is no mention of electrons producing photons.

Mark for (a) (ii) = 0/2

3 This is the first time the word *photon* is mentioned but there is no indication that the photons are due to transitions in the metal anode.

Mark for (a) (iii) = 0/1

Mark for (b) = 2/2

Total marks awarded = 2 out of 8

How the candidate could have improved their answer

(a) (i) & (ii) There was no mention of photons being produced here. The candidate needed to explain the basic process of X-ray production to gain marks in these two sections. When the candidate wrote about the electrons having a range of energies, it was not clear that the range of energies is prior to hitting the anode or in the anode.

(a) (iii) This was the first time the word photon was mentioned but unfortunately the answer did not include any reference to the photons being produced by electron transitions in the anode.

Mark awarded = **(a) (i) 0/3**
Mark awarded = **(a) (ii) 0/2**
Mark awarded = **(a) (iii) 0/1**
Mark awarded = **(b) (i) 1/1**
Mark awarded = **(b) (ii) 1/1**

Total marks awarded = 2 out of 8

Common mistakes candidates made in this question

(a) (i) Many candidates wrote about electrons having a range of energies or accelerations prior to hitting the target, when in practice they all have the same energy. On many occasions answers did not make it clear where the accelerations were taking place. Very few candidates mentioned the accelerations giving rise to photons.

(a) (ii) Many candidates read the words ‘cut-off at short wavelength’ in the question and wrote about the photoelectric effect and X-ray photons emitting electrons from the target.

(a) (iii) Candidates who wrote in general about the line spectra being due to electron transitions often did not mention that the transitions were in atoms in the target.

(b) (i) A common error was to write about the use of lead grids for filtering.

(b) (ii) Many candidates stated that the long wavelength X-rays were less penetrating, whereas the important factor about shielding is that the long wavelength X-rays are absorbed by the body and hence do not contribute to the image. They are therefore removed so that they do not increase the radiation dose of the patient.

Question 13

<table>
<tr><th>Example candidate response – high</th><th>Examiner comments</th></tr>
<tr><td>

13 (a) Explain what is meant by *gamma radiation* (*γ-radiation*).

1 The emission of gamma particles from a radioactive sample due to spontaneous and random nature. [2]

(b) A source of gamma radiation is placed a fixed distance away from a detector and counter, as illustrated in Fig. 13.1.

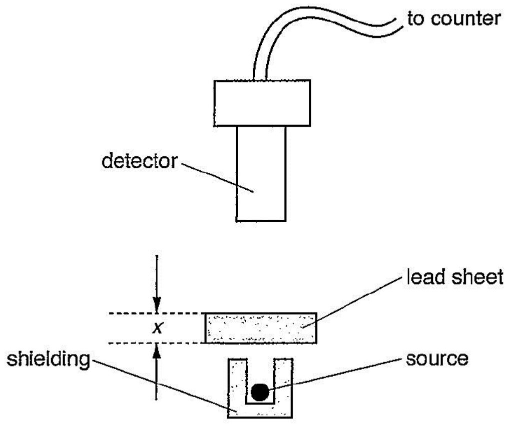


Fig. 13.1

A sheet of lead of thickness x is placed between the source and the detector.
The average count rate C, corrected for background, is recorded. This is repeated for different values of x.
The variation with thickness x of $\ln C$ is shown in Fig. 13.2.

$$C = C_0 e^{-\mu n}$$

$$\ln C = \ln C_0 e^{-\mu n}$$

$$\ln C = -\mu n + \ln C_0$$

</td><td>

1 The candidate first needs to state what gamma radiation is, i.e. photons of electromagnetic radiation. The second mark is for stating the origin of the radiation. Neither of the two available marks can be awarded for this answer.

Mark for (a) = 0/2

</td></tr>
</table>

Example candidate response – high, continued

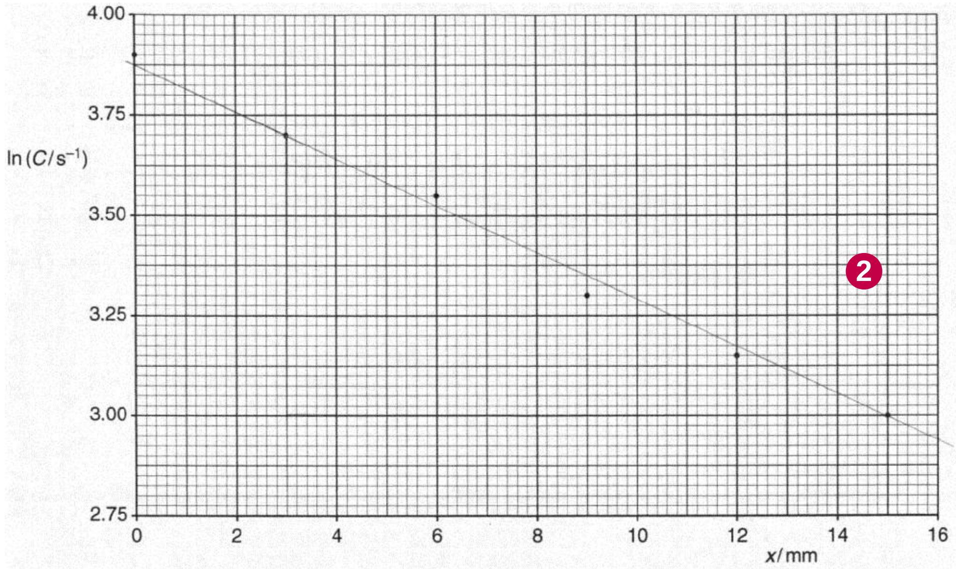


Fig. 13.2

(15, 3)

The absorption of gamma radiation in lead may be represented by the equation

(3, 3.7)

$$C = C_0 e^{-\mu x}$$

where C_0 is the count rate for $x = 0$ and μ is the linear attenuation (absorption) coefficient.

Use Fig. 13.2 to determine the linear attenuation coefficient μ for this gamma radiation in lead.

$C = C_0 e^{-\mu x}$

$\ln C = \ln(C_0 e^{-\mu x})$

$\ln C = \ln C_0 + (-\mu x)$

$\ln C = -\mu x + \ln C_0$

$y = m x + c$

$-\mu =$ gradient.

$m = \dfrac{3.7 - 3}{3 - 15}$ mm

$-\mu = -0.05833$

3

μ = ~~0.06~~ 0.058 mm^{-1} [4]

(c) The value of μ calculated in **(b)** is for gamma radiation in lead.

Suggest and explain whether the value of μ for aluminium would be the same, greater or smaller.

4 Attenuation coefficient would be smaller for Aluminium as the absorption ~~of~~ by Al is lesser than of Lead. [2]

[Total: 8]

Examiner comments

2 The candidate has drawn a suitable graph although the slope is a little shallow.

3 The candidate measures the gradient obtaining an answer a little lower than the correct answer for μ due to the shallow slope of the graph. The answer is to be given in units of mm^{-1} so no scale conversion is required as the x-axis is in mm.

Mark for (b) = 3/4

4 Candidates need to realise that the absorption in aluminium is less than lead so that μ would be smaller. In order to answer this question, a comparison between the absorption in lead and aluminium is required as a starting point. This candidate scores both marks.

Mark for (c) = 2/2

Total marks awarded = 5 out of 8

How the candidate could have improved their answer

(a) The candidate needed to explain the term in italics by stating that gamma rays are electromagnetic waves produced in the nucleus of an atom.

(b) The candidate needed to draw a straight line using all the points. The graph was a little shallow and a more carefully drawn straight line would have produced a better answer closer to the expected value 0.061.

Mark awarded = **(a) 0/2**
Mark awarded = **(b) 3/4**
Mark awarded = **(c) 2/2**

Total marks awarded = 5 out of 8

Example candidate response – middle	Examiner comments
13 (a) Explain what is meant by *gamma radiation* (*γ-radiation*). It is the electromagnetic wave of the very high frequency range and are released during the decay of a radioactive nucleus [2]	**1** A correct answer scores both marks. Mark for (a) = 2/2

(b) A source of gamma radiation is placed a fixed distance away from a detector and counter, as illustrated in Fig. 13.1.

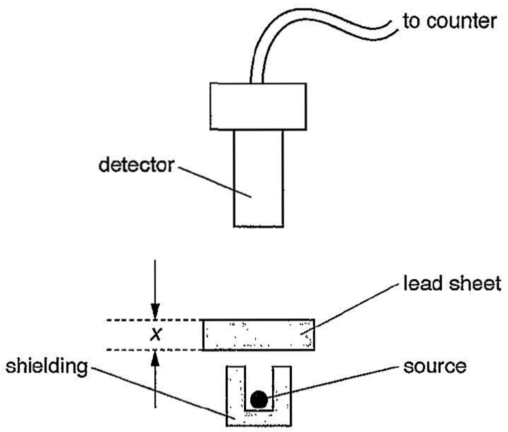


Fig. 13.1

A sheet of lead of thickness x is placed between the source and the detector.
The average count rate C, corrected for background, is recorded. This is repeated for different values of x.
The variation with thickness x of ln C is shown in Fig. 13.2.

Example candidate response – middle, continued

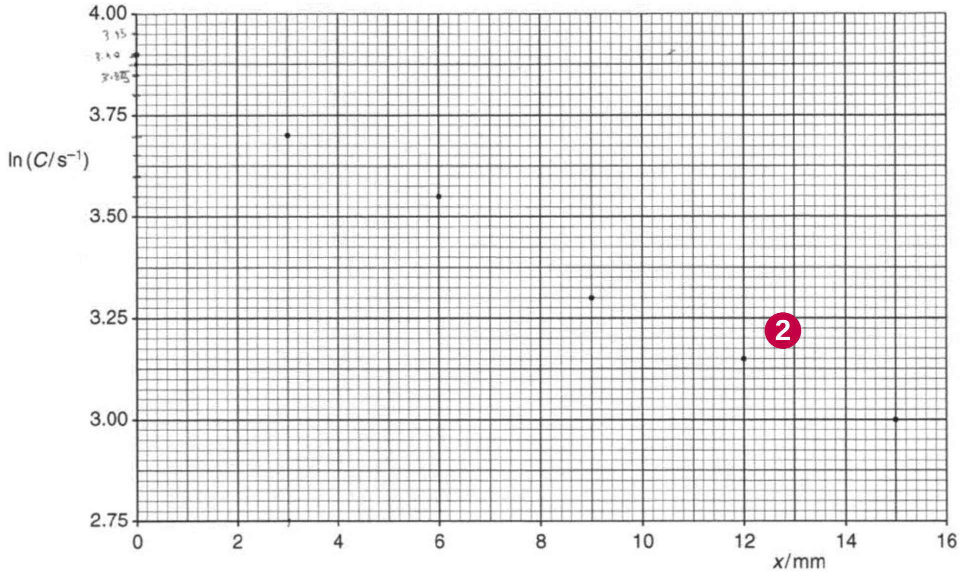


Fig. 13.2

The absorption of gamma radiation in lead may be represented by the equation

$$C = C_0 e^{-\mu x}$$

where C_0 is the count rate for $x = 0$ and μ is the linear attenuation (absorption) coefficient.

Use Fig. 13.2 to determine the linear attenuation coefficient μ for this gamma radiation in lead.

$C_0 = 3.855$, $x = 0$

$C = 3.70$, $x = 3$ mm.

$3.70 = 3.855 \times e^{-\mu(3)}$

$0.9598 = e^{-\mu(3)}$

$-0.041 = -\mu(3)$

$\mu = \frac{0.041}{3} =$ ~~0.0136~~ $0.0137 = 1.37 \times 10^{-2}$

3

μ = ~~0.0137~~ 1.37×10^{-2} mm^{-1} [4]

(c) The value of μ calculated in **(b)** is for gamma radiation in lead.

Suggest and explain whether the value of μ for aluminium would be the same, greater or smaller.

4 It would be lower as aluminium ~~is~~ ~~a~~ absorbs less gamma radiations than lead [2]

[Total: 8]

Examiner comments

2 Like many others, this candidate has not drawn a line through the points.

3 Like many others, this candidate inserts values from the graph, not realising that the *y* axis is ln *C* and not *C*.

Mark for (b) = 0/4

4 There is a comparison between lead and aluminium here so the answer scores full marks.

Mark for (c) = 2/2

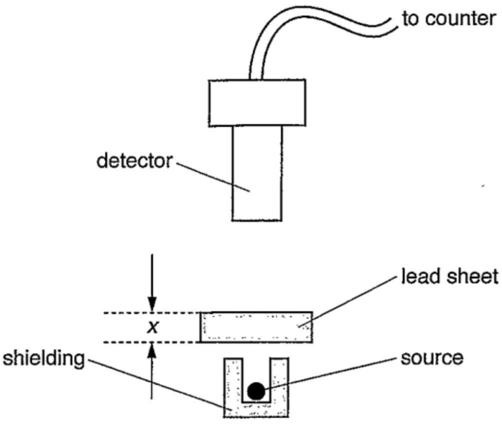
Total marks awarded = 4 out of 8

How the candidate could have improved their answer

(b) The candidate needed to draw a suitable straight line through the points and then convert the equation into a form matching the straight line graph drawn.

Mark awarded = **(a) 2/2**
Mark awarded = **(b) 0/4**
Mark awarded = **(c) 2/2**

Total marks awarded = 4 out of 8

Example candidate response – low	Examiner comments
13 **(a)** Explain what is meant by *gamma radiation* (γ-*radiation*). Electromagnetic waves emitted from a radioactive sample. **1** [2] **(b)** A source of gamma radiation is placed a fixed distance away from a detector and counter, as illustrated in Fig. 13.1.  **Fig. 13.1** A sheet of lead of thickness *x* is placed between the source and the detector. The average count rate *C*, corrected for background, is recorded. This is repeated for different values of *x*. The variation with thickness *x* of ln *C* is shown in Fig. 13.2.	**1** This answer scores the first mark for recognising that gamma rays are electromagnetic waves, but does not gain the origin mark. Mark for (a) = 1/2

Example candidate response – low, continued

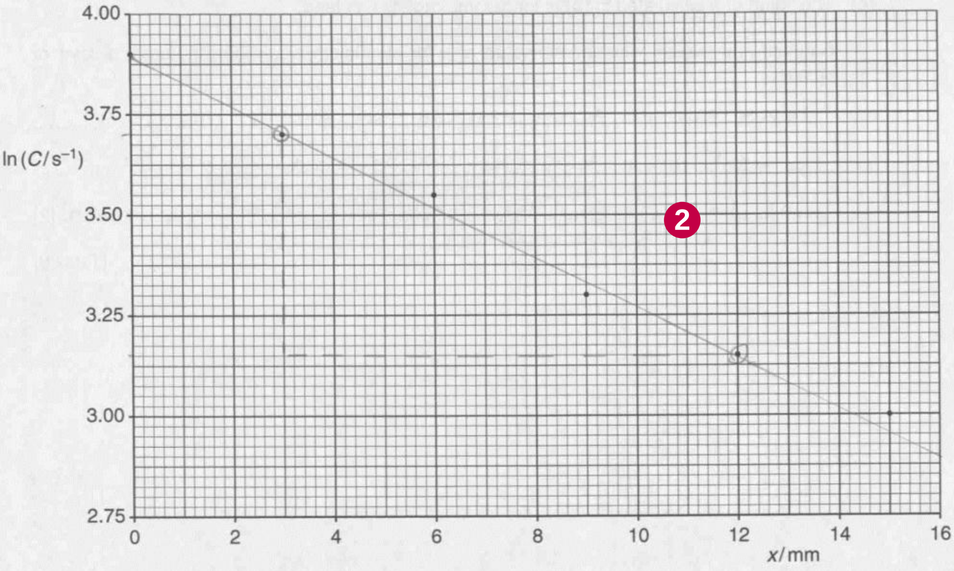


Fig. 13.2

The absorption of gamma radiation in lead may be represented by the equation

$$C = C_0 e^{-\mu x}$$

where C_0 is the count rate for $x = 0$ and μ is the linear attenuation (absorption) coefficient.

Use Fig. 13.2 to determine the linear attenuation coefficient μ for this gamma radiation in lead.

~~ln C = -μxC₀~~

ln C = -μx + C₀

y-axis = m x-axis

(3, 3.7) (12, 3.15) **3**

m = (y2 - y1)/(x2 - x1)

= (3.15 - 3.7)/(12 - 3) = -0.55/9 = -0.06

-0.06 = -μ

μ = 0.06

μ = ...0.06........ mm⁻¹ [4]

(c) The value of μ calculated in **(b)** is for gamma radiation in lead.

Suggest and explain whether the value of μ for aluminium would be the same, greater or smaller.

Smaller, because the gradient will be small if aluminium is used, since the value of "C" and "ln C" will be larger even for large values of x, since aluminium [2] can't stop gamma that much. **4**

[Total: 8]

Examiner comments

2 A mark is awarded for a suitable straight line.

3 The candidate understands that the slope of the graph is required here, but then obtains an answer to one significant figure. The candidate is not awarded the significant figure mark or the accuracy mark.

Mark for (b) = 2/4

4 A typical answer in which there is no comparison with lead as required by the question.

Mark for (c) = 0/2

Total marks awarded = 3 out of 8

How the candidate could have improved their answer

(b) The candidate should have used the whole of the graph to measure the slope and obtain an answer to at least two significant figures.

(c) The candidate should have realised that a comparison between the absorption in lead and aluminium was required for the answer.

Mark awarded = **(a) 1/2**
Mark awarded = **(b) 2/4**
Mark awarded = **(c) 0/2**

Total marks awarded = 3 out of 8

Common mistakes candidates made in this question

(a) The origin of the gamma rays was often missing from candidates' answers.

(b) Many candidates did not draw a line on the graph but just used two points from the graph and then inserted them into the equation. The answer they obtained then depended upon the two points chosen. Many candidates drew a straight line graph then ignored the graph and used two of the points given. Some candidates, having drawn a straight line graph, did not use the whole graph to estimate the slope. Many candidates did not realise that the *y* axis is plotted as ln *C* and not *C* and substituted ln *C* values directly into the equation given in the text.

(c) A comparison of aluminium and lead was often missing here.

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