



Cambridge International AS & A Level

PHYSICS

9702/21

Paper 2 AS Level Structured Questions

October/November 2023

MARK SCHEME

Maximum Mark: 60

Published

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These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

PUBLISHED**GENERIC MARKING PRINCIPLE 5:**

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

- 1 Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
- 2 The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
- 3 Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
- 4 The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
- 5 'List rule' guidance

For questions that require ***n*** responses (e.g. State **two** reasons ...):
 - The response should be read as continuous prose, even when numbered answer spaces are provided.
 - Any response marked *ignore* in the mark scheme should not count towards ***n***.
 - Incorrect responses should not be awarded credit but will still count towards ***n***.
 - Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.
 - Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
()	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the context for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
—	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.

Mark categories

B marks	These are <u>independent</u> marks, which do not depend on other marks. For a B mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are <u>method</u> marks upon which A marks later depend. For an M mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an M mark, then the later A mark cannot be awarded either.
C marks	These are <u>compensatory</u> marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a C mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the C mark is awarded. If a correct answer is given to a numerical question, all of the preceding C marks are awarded automatically. It is only necessary to consider each of the C marks in turn when the numerical answer is not correct.
A marks	These are <u>answer</u> marks. They may depend on an M mark or allow a C mark to be awarded by implication.

PUBLISHED

Question	Answer	Mark
1(a)	scalar and vector have magnitude	B1
	vector has direction (and scalar does not have direction)	B1
1(b)(i)	$r = [(3 \times 28) / 4\pi]^{1/3}$ $= 1.9 \text{ cm}$	A1
1(b)(ii)	percentage uncertainty in $V = (0.5 / 28) \times 100$ $(= 1.79\%)$	C1
	percentage uncertainty in $r = 1.79 / 3$ $= 0.6\%$	A1

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Question	Answer	Mark
2(a)(i)	arrow upwards ($\uparrow$) and labelled upthrust / U arrow downwards ($\downarrow$) and labelled weight / W / mg arrow downwards ($\downarrow$) and labelled tension / T <i>1 mark: One or two correctly labelled arrows</i> <i>2 marks: Three correctly labelled arrows</i>	B2
2(a)(ii)	$U = T + W$ or upthrust = tension + weight	C1
	$\rho Vg = T + W$ $V = [(4.00 \times 10^2) + (3.39 \times 10^4)] / (1.23 \times 9.81)$	C1
	$V = 2.84 \times 10^3 \text{ m}^3$	A1
2(a)(iii)	$m = W / g$ or $a = F / m$	C1
	$a = (4.00 \times 10^2) / [(3.39 \times 10^4) / 9.81]$	C1
	$a = 0.12 \text{ m s}^{-2}$	A1
2(b)	there is air resistance (which increases with speed)	B1
	(average) resultant force is less (than weight)	B1
	(average) acceleration is less (than $g / 9.81$, so speed is less than 100 m s^{-1})	B1
2(c)(i)	(extension $\Rightarrow$) $2.5 \times 2.4 \times 10^{-5} = 6.0 \times 10^{-5} \text{ (m)}$	A1

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Question	Answer	Mark
2(c)(ii)	$E_{(P)} = \frac{1}{2} Fx$ or $E_{(P)} = \frac{1}{2} kx^2$ and $F = kx$	C1
	$E_{(P)} = \frac{1}{2} \times 4.00 \times 10^2 \times 6.0 \times 10^{-5}$ or $E_{(P)} = \frac{1}{2} \times 6.7 \times 10^6 \times (6.0 \times 10^{-5})^2$ $E_{(P)} = 0.012 \text{ J}$	A1
2(c)(iii)	longer extension or smaller spring constant	M1
	elastic potential energy is greater	A1

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Question	Answer	Mark
3(a)	displacement	A1
3(b)(i)	$a = \text{gradient}$ or $a = \Delta v / (\Delta)t$ or $a = (v - u) / t$	C1
	e.g. $a = (0.30 - 0.12) / (0.35 - 0.15)$	A1
	$a = 0.90 \text{ m s}^{-2}$	
3(b)(ii)	$(0.25 \times 0.48) + (0.75 \times 0.12) = (0.25 v) + (0.75 \times 0.30)$	C1
	or	
	$(0.48 - 0.12) = (0.30 - v)$	
	or	
	$(\frac{1}{2} \times 0.25 \times 0.48^2) + (\frac{1}{2} \times 0.75 \times 0.12^2) = (\frac{1}{2} \times 0.25 \times v^2) + (\frac{1}{2} \times 0.75 \times 0.30^2)$	
	$v = (-)0.060 \text{ m s}^{-1}$	A1
	direction: to the left / from the right / opposite to (its) initial velocity / opposite to (initial / final) velocity of B	B1
3(c)	sketch: horizontal line from (0, 0.48) to (0.15, 0.48)	B1
	horizontal line from (0.35, -0.06) to (0.5, -0.06)	B1
	straight line between (0.15, 0.48) and (0.35, -0.06)	B1

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Question	Answer	Mark
4(a)	(when two or more) waves meet / overlap (at a point)	B1
	(resultant) displacement is the sum of the individual displacements	B1
4(b)	$\lambda = ax / D$	C1
	$\lambda = [(0.65 \times 10^{-3}) \times (1.7 \times 10^{-3})] / 1.9$	C1
	$\lambda = 5.8 \times 10^{-7} \text{ m}$	A1
4(c)(i)	waves are out of phase by a quarter of a cycle / period or when one wave has maximum/minimum displacement, the other wave has zero displacement	B1
4(c)(ii)	(statement 2 is) not correct (because) waves do not have phase difference of 180° / not in antiphase or one wave has some displacement when other has no displacement or the displacements of the waves are not always equal and opposite	B1
4(d)	more diffraction (of light/waves by slits) or light/waves are more spread (by slits) or light/waves (from slits) have less intensity	B1
	more (bright/dark) fringes or bright fringes are less bright / are dimmer / have lower intensity or no change to fringe spacing/separation/width	B1

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Question	Answer	Mark
5(a)	sketch: approximately horizontal line above horizontal dashed line from $t = 0$ to $t = t_1$ and approximately horizontal line below horizontal dashed line from $t = t_1$ to $t = t_2$	A1
5(b)	$I = P / A$	C1
	$A = \pi \times 0.028^2$ or $\pi \times 2.8^2$ (= 2.46×10^{-3} or 24.6)	C1
	$P = 4.7 \times 10^{-3} \times 2.46 \times 10^{-3}$ = 1.2×10^{-5} W	A1

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Question	Answer	Mark
6(a)(i)	$(I \Rightarrow) 16 / 320 = 0.050 \text{ (A)}$	A1
6(a)(ii)	$R = (25 - 16) / 0.050$ or $R = (9 / 16) \times 320$ or $R = (25 / 0.050) - 320$	C1
	$R = 180 \text{ (}\Omega\text{)}$	C1
	$R_{\text{(LDR)}} = [(1 / 180) - (1 / 240)]^{-1}$ $= 720 \Omega$	A1
	or	
	$I = (25 - 16) / 240$ $(= 0.0375 \text{ A})$	(C1)
	$I_{\text{(LDR)}} = 0.050 - 0.0375$ $(= 0.0125 \text{ A})$	(C1)
	$R_{\text{(LDR)}} = 9.0 / 0.0125$ $= 720 \Omega$	(A1)

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Question	Answer	Mark
6(a)(iii)	$P = V^2 / R$ or $P = VI$ or $P = I^2 R$	C1
	ratio = $(9^2 / 720) / (9^2 / 240)$ or ratio = $(9 \times 0.0125) / (9 \times 0.0375)$ or ratio = $(0.0125^2 \times 720) / (0.0375^2 \times 240)$ ratio = $0.1125 / 0.3375$ = 0.33	A1
6(b)	resistance of LDR decreases	B1
	resistance of parallel combination decreases or total resistance (of circuit) decreases or current in resistor of resistance 320Ω increases or potential difference across parallel combination / LDR / 240Ω resistor decreases	M1
	voltmeter reading increases	A1

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Question	Answer	Mark
7(a)	a (very) small proportion of (alpha) particles are deflected (back) through large angles / angles greater than 90°	B1
	a large proportion of (alpha) particles pass straight through / deflected by small angles	B1
7(b)	electromagnetic wave / electromagnetic radiation	A1
7(c)	neutrino classified as a lepton only <u>and</u> positron classified as a lepton only	B1
	neutron classified as a baryon and a hadron and not as a lepton	B1
7(d)(i)	1.32 u	A1
7(d)(ii)	working states or implies 3 quarks and each quark has a charge of (+) $\frac{2}{3}(e)$	B1
	any combination of 3 quarks comprised of one or more of up / charm / top	B1



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A marks	These are <u>answer</u> marks. They may depend on an M mark or allow a C mark to be awarded by implication.

PUBLISHED

Question	Answer	Marks
1(a)	only electric current and time underlined	B1
1(b)	initial speed / velocity is zero	B1
	(non-zero magnitude of) acceleration is constant / uniform (and in a straight line)	B1
1(c)(i)	• magnitude of acceleration at $t = 8.0$ s is less than that at $t = 14.0$ s	B1
	• direction of acceleration at $t = 8.0$ s is opposite to that at $t = 14.0$ s	B1
1(c)(ii)	$a = \text{gradient}$ or $a = (v - u) / t$ or $a = \Delta v / (\Delta)t$	C1
	$a = \text{e.g. } (20 + 10) / 12$ or $(0 + 10) / 4$ or $(20 - 0) / (12 - 4)$	A1
	$a = 2.5 \text{ m s}^{-2}$	
1(c)(iii)	displacement = $[\frac{1}{2} \times (12 - 4) \times 20] - [\frac{1}{2} \times 4 \times 10]$ or displacement = $(-10 \times 12) + (\frac{1}{2} \times 2.5 \times 12^2)$ or displacement = $(20 \times 12) - (\frac{1}{2} \times 2.5 \times 12^2)$ or displacement = $\frac{1}{2} \times (20 - 10) \times 12$	C1
	displacement = 60 m	A1

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Question	Answer	Marks
2(a)	$65 = \rho g V$ or $65 = mg$ and $m = \rho V$	C1
	$\rho = 65 / (9.81 \times 7.5)$ $= 0.88 \text{ kg m}^{-3}$	A1
2(b)(i)	acceleration = 9.8 m s^{-2}	A1
2(b)(ii)	air resistance (acting on sphere) increases	B1
	resultant force (on sphere) decreases	B1
	(magnitude of) acceleration decreases	B1
2(c)	$F = ma$ $= 4.0 \times 1.9$ $(= 7.6 \text{ N})$	C1
	resistive force = $(4.0 \times 9.81) - (4.0 \times 1.9)$ $= 32 \text{ N}$	A1

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Question	Answer	Marks
3(a)	$E_{(P)} = \frac{1}{2}kx^2$ or $E_{(P)} = \frac{1}{2}Fx$ and $F = kx$	C1
	$0.048 = \frac{1}{2} \times k \times (2.1 \times 10^{-2})^2$ $k = 220 \text{ N m}^{-1}$	A1
3(b)	$E_{(K)} = \frac{1}{2}mv^2$	C1
	$0.048 = \frac{1}{2} \times 7.5 \times 10^{-3} \times v^2$ $v = 3.6 \text{ m s}^{-1}$	A1
3(c)(i)	$(\Delta)E = mg(\Delta)h$	C1
	$0.039 = 7.5 \times 10^{-3} \times 9.81 \times (\Delta)h$ $\Delta h = 0.53 \text{ m}$	A1
3(c)(ii)	$F \times 0.53 = 0.048 - 0.039$	C1
	$F = 0.02 \text{ N}$	A1
3(d)	sketch: curved line from the origin	M1
	curved line has increasing gradient	A1

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Question	Answer	Marks
4(a)(i)	component of momentum = $0.25 \times 3.7 \times \sin 27^\circ$	C1
	= 0.42 N s	A1
4(a)(ii)	$m_{(Z)} \times 5.5 \times \sin 44^\circ = 0.42$ or $m_{(Z)} \times 5.5 \times \sin 44^\circ = 0.25 \times 3.7 \times \sin 27^\circ$ $m_Z = 0.11 \text{ kg}$	A1
4(a)(iii)	magnitudes: equal	B1
	directions: opposite	B1
4(b)	$4 + 6 = 2 + v$ $v = 8 \text{ m s}^{-1}$	A1

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Question	Answer	Marks
5(a)(i)	light intensity has maximum value at 0° , 180° , 360° and zero intensity at 90° , 270°	M1
	'sinusoidally-shaped' curve	A1
5(a)(ii)	$4.2 = 7.6 \cos^2 \theta$	C1
	$\theta = 42^\circ$	A1
5(b)	wave passes (through) an aperture or wave passes (by / through / around) an edge	B1
	wave spreads (into geometrical shadow)	B1
5(c)(i)	$n\lambda = d \sin \theta$	C1
	$d = (3 \times 4.3 \times 10^{-7}) / \sin 68^\circ$ $= 1.4 \times 10^{-6} \text{ m}$	A1
5(c)(ii)	$1.4 \times 10^{-6} \times \sin 68^\circ = 2 \times \lambda$ or $3 \times 4.3 \times 10^{-7} = 2 \times \lambda$	C1
	$\lambda = 6.5 \times 10^{-7} \text{ m}$	A1

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Question	Answer	Marks
6(a)	$R = \rho L / A$	C1
	$\rho = 0.92 \times 5.3 \times 10^{-7}$ $= 4.9 \times 10^{-7} \Omega \text{ m}$	A1
6(b)(i)	(current =) $6.4 / 1600 = 4.0 \times 10^{-3} \text{ (A)}$	A1
6(b)(ii)	charge = $4.0 \times 10^{-3} \times 3.2 \times 60$ (= 0.768 C)	C1
	number = $0.768 / 1.6 \times 10^{-19}$ $= 4.8 \times 10^{18}$	A1
6(b)(iii)	$6.4 / E = 1600 / (1400 + 1600)$ or $E = 6.4 + (4.0 \times 10^{-3} \times 1400)$ or $E = 4.0 \times 10^{-3} (1600 + 1400)$	C1
	$E = 12 \text{ V}$	A1
6(b)(iv)	$P = I^2 R$ or $P = VI$ or $P = V^2 / R$	C1
	ratio = $(6.4^2 / 1600) / [(4.0 \times 10^{-3})^2 \times 1400]$ $= 1.1$	A1
6(c)(i)	increase	B1
6(c)(ii)	increase	B1
6(c)(iii)	decrease	B1

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Question	Answer	Marks
7(a)	only baryon and nucleon underlined	B1
7(b)	number of α -particles = 6	B1
	number of β^- particles = 4	B1
7(c)	charm antiquark (charge) = $-\frac{2}{3}(e)$ or $-\frac{2}{3}(e) + q = -1(e)$	B1
	(other quark $q = -\frac{1}{3}(e)$ so) down / strange / bottom	B1



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- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently, e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

Science-Specific Marking Principles

- 1 Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
- 2 The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to the question should be ignored.
- 3 Although spellings do not have to be correct, spellings of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused (e.g. ethane / ethene, glucagon / glycogen, refraction / reflection).
- 4 The error carried forward (ecf) principle should be applied, where appropriate. If an incorrect answer is subsequently used in a scientifically correct way, the candidate should be awarded these subsequent marking points. Further guidance will be included in the mark scheme where necessary and any exceptions to this general principle will be noted.
- 5 'List rule' guidance
 For questions that require ***n*** responses (e.g. State **two** reasons ...):
 - The response should be read as continuous prose, even when numbered answer spaces are provided.
 - Any response marked *ignore* in the mark scheme should not count towards ***n***.
 - Incorrect responses should not be awarded credit but will still count towards ***n***.
 - Read the entire response to check for any responses that contradict those that would otherwise be credited. Credit should **not** be awarded for any responses that are contradicted within the rest of the response. Where two responses contradict one another, this should be treated as a single incorrect response.
 - Non-contradictory responses after the first ***n*** responses may be ignored even if they include incorrect science.

6 Calculation specific guidance

Correct answers to calculations should be given full credit even if there is no working or incorrect working, **unless** the question states 'show your working'.

For questions in which the number of significant figures required is not stated, credit should be awarded for correct answers when rounded by the examiner to the number of significant figures given in the mark scheme. This may not apply to measured values.

For answers given in standard form (e.g. $a \times 10^n$) in which the convention of restricting the value of the coefficient (a) to a value between 1 and 10 is not followed, credit may still be awarded if the answer can be converted to the answer given in the mark scheme.

Unless a separate mark is given for a unit, a missing or incorrect unit will normally mean that the final calculation mark is not awarded. Exceptions to this general principle will be noted in the mark scheme.

7 Guidance for chemical equations

Multiples / fractions of coefficients used in chemical equations are acceptable unless stated otherwise in the mark scheme.

State symbols given in an equation should be ignored unless asked for in the question or stated otherwise in the mark scheme.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
()	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the context for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
—	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.

Mark categories

B marks	These are <u>independent</u> marks, which do not depend on other marks. For a B mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are <u>method</u> marks upon which A marks later depend. For an M mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an M mark, then the later A mark cannot be awarded either.
C marks	These are <u>compensatory</u> marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a C mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the C mark is awarded. If a correct answer is given to a numerical question, all of the preceding C marks are awarded automatically. It is only necessary to consider each of the C marks in turn when the numerical answer is not correct.
A marks	These are <u>answer</u> marks. They may depend on an M mark or allow a C mark to be awarded by implication.

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Question	Answer	Marks
1(a)	charge and power only ticked	B1
1(b)(i)	%D = 0.4% and %L = 0.6%	A1
1(b)(ii)	$\rho = (4 \times 0.247) / [\pi \times (26.2 \times 10^{-3})^2 \times 0.162]$	C1
	$\rho = 2.83 \times 10^3 \text{ kg m}^{-3}$	A1
1(b)(iii)	percentage uncertainty = $0.4 + (2 \times 0.4) + 0.6$	C1
	= 1.8%	A1

Question	Answer	Marks
2(a)(i)	(time / t =) $9(.0) / 9.5 = 0.95 \text{ (s)}$	A1
2(a)(ii)	$(u_v) = 9.5 \tan 38^\circ$ or $9.5 / \tan 52^\circ$ or $9.5 = u \cos 38^\circ$ and $u_v = u \sin 38^\circ$ or $9.5 = u \cos 38^\circ$ and $u_v = (u^2 - 9.5^2)^{1/2}$	C1
	$u_v = 7.4 \text{ m s}^{-1}$	A1
2(a)(iii)	$s = ut + \frac{1}{2}at^2$ $(h \Rightarrow) 7.4 \times 0.95 - \frac{1}{2} \times 9.81 \times 0.95^2$	C1
	$h = 2.6 \text{ m}$	A1
2(b)	(collision is) inelastic	B1

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Question	Answer	Marks
3(a)	resultant force (in any direction) is zero	B1
	resultant moment / torque (about any point) is zero	B1
3(b)(i)	$F = \rho Vg$ $V = 93\,000 / (1.2 \times 9.81)$ $= 7900 \text{ m}^3$	A1
3(b)(ii)	weight = $93\,000 + 3(.0) \times 10^3$	C1
	$m = (93\,000 + 3.0 \times 10^3) / 9.81$ $= 9800 \text{ kg}$	A1
3(c)(i)	$(\Delta p) = F(\Delta t)$ or $F = \Delta p / (\Delta t)$ or $F = \text{rate of change of momentum}$ or $F = m(v - u) / t$	C1
	$\Delta p = 2800 \times 0.50$ $= 1400 \text{ kg m s}^{-1}$	A1
3(c)(ii)	$(\Delta p =) mv$	C1
	$v = 1400 / 64$ $= 22 \text{ m s}^{-1}$	A1

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Question	Answer	Marks
3(c)(iii)	$E_k = \frac{1}{2}mv^2$	C1
	$= \frac{1}{2} \times 64 \times 22^2$	A1
	$= 15\,000\text{ J}$	
	or	
	$E_k = p^2 / 2m$	(C1)
	$= 1400^2 / (2 \times 64)$	(A1)
	$= 15\,000\text{ J}$	

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Question	Answer	Marks
4(a)(i)	spring constant	B1
4(a)(ii)	area represents the work done (to extend the wire)	B1
	work done (to extend the wire) is equal to elastic potential energy	B1
4(b)(i)	$x_G = 0.39 \text{ mm}$ and $x_H = 0.29 \text{ mm}$	A1
4(b)(ii)	$E = \frac{1}{2}Fx$ or $E = \frac{1}{2}kx^2$ and $F = kx$ or $E = \text{area under graph}$	C1
	for G: $E = \frac{1}{2} \times 2.0 \times (0.39 \times 10^{-3})$ or $\frac{1}{2} \times 5.1 \times 10^3 \times (0.39 \times 10^{-3})^2$ for H: $E = \frac{1}{2} \times 2.0 \times (0.29 \times 10^{-3})$ or $\frac{1}{2} \times 6.9 \times 10^3 \times (0.29 \times 10^{-3})^2$ $E_P = 3.9 \times 10^{-4} + 2.9 \times 10^{-4}$ $= 6.8 \times 10^{-4} \text{ J}$	A1
4(b)(iii)	$E = FL / Ax$ or stress / strain = FL / Ax	C1
	$A_G / A_H = 1 \times (0.29 \times 10^{-3}) / [1.5 \times (0.39 \times 10^{-3})]$	C1
	ratio = 0.50	A1

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Question	Answer	Marks
5(a)(i)	cross labelled Y drawn: at any position where wavefronts cross or centrally in a 'diamond' shape formed between any adjacent wavefronts from A and B	B1
5(a)(ii)	cross labelled Z drawn on a wavefront from one source at a point midway between adjacent wavefronts from the other source	B1
5(b)(i)	$\lambda = ax / D$	C1
	$a = (2.9 \times 10^{-5} \times 140) / (1.2 \times 10^{-2})$	C1
	$= 0.34 \text{ m}$	A1
5(b)(ii)	infrared	A1

Question	Answer	Marks
6(a)	$291 = 251 \times 340 / (340 - v_s)$	C1
	$v_s = 47 \text{ m s}^{-1}$	A1
6(b)(i)	$I \propto A^2$	B1
6(b)(ii)	sketch: line starts at (1.0, 1.0)	B1
	approximately straight line drawn with negative gradient and line ends at (4.0, 0.25)	B1

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Question	Answer	Marks
7(a)	current (through a conductor is directly) proportional to potential difference (across the conductor) or vice versa	M1
	(provided that) temperature (of conductor remains) constant	A1
7(b)(i)	$R = \rho L / A$	C1
	$\rho = (18 \times 7.2 \times 10^{-8}) / 0.94$ $= 1.4 \times 10^{-6} \Omega \text{ m}$	A1
7(b)(ii)	voltmeter reading = 3.1 V	A1
7(b)(iii)	current in the battery: increase	B1
	voltmeter reading: decrease	B1
7(b)(iv)	cross marked on the resistance wire to right of the arrowhead of S, but not touching the right-hand end of the resistance wire	B1
7(c)(i)	$I = Anvq$ $q = 0.93 / [(7.2 \times 10^{-8}) \times (9.0 \times 10^{28}) \times (1.3 \times 10^{-3})]$	C1
	$q = 1.1 \times 10^{-19} \text{ C}$	A1
7(c)(ii)	charge / q (value) is below $1.6 \times 10^{-19} \text{ (C)}$ or charge cannot be below $1.6 \times 10^{-19} \text{ (C)}$ or (the charge carriers / q) should have a charge of $1.6 \times 10^{-19} \text{ (C)}$	B1

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Question	Answer	Marks
8(a)(i)	23: nucleon number or number of neutrons and protons	B1
	12: proton number or number of protons	B1
8(a)(ii)	both numbers correct for X: ${}_{11}^{23}\text{X}$	B1
	both numbers correct for beta-plus: ${}^0_1\beta^+$	B1
8(a)(iii)	lepton(s)	A1
8(b)	(the emitted particles) have a single (kinetic) energy or beta particles / decay have a (continuous) range of (kinetic) energies	B1