

Cambridge International AS & A Level

PHYSICS**9702/41**

Paper 4 A Level Structured Questions

October/November 2025**MARK SCHEME**Maximum Mark: 100

Published

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Mark schemes should be read in conjunction with the question paper and the Principal Examiner Report for Teachers.

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PUBLISHED**Generic Marking Principles**

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 descriptions 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.

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.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	incorrect physics
	incorrect point or mark not awarded
	information missing or insufficient for credit

Annotation	Meaning
MO	mandatory mark not awarded
SEEN	point has been noted, but no credit has been given or blank page seen
POT	power of ten error
TE	transcription error

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>mandatory</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)	velocity and acceleration both have constant magnitude	B1
	velocity is (always) perpendicular to acceleration	B1
1(b)(i)	$v = R\omega$	A1
1(b)(ii)	$a = R\omega^2$ or $a = v^2 / R$	C1
	$a = v\omega$	A1
1(c)(i)	$x = R \sin \theta$	A1
1(c)(ii)	$\theta = \omega t$	A1
1(c)(iii)	clear substitution of $\theta = \omega t$ into $x = R \sin \theta$ leading to $x = R \sin \omega t$	A1
1(c)(iv)	equation is of the form $x = x_0 \sin \omega t$ (so simple harmonic motion)	B1
1(d)(i)	amplitude = $0.46 / 2$ = 0.23 m	A1
1(d)(ii)	$\omega = 2\pi / T$	C1
	period = $2\pi / 1.9$ = 3.3 s	A1

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Question	Answer	Marks
1(d)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 1.9^2 \times 0.23$	A1
	$= 0.83 \text{ m s}^{-2}$	
1(e)	shadow on screen, labelled A, above left-hand edge of the circular path	B1

Question	Answer	Marks
2(a)	work done on / by system	B1
	thermal energy supplied to / removed from system	B1
2(b)(i)	no thermal energy transferred to / from system (due to lack of time)	B1
	work is done on the gas to compress it / to decrease its volume	B1
	internal energy increases so temperature increases	B1
2(b)(ii)	(during vaporisation) molecular separation increases	B1
	(heating causes) potential energy of molecules to increase	B1
	kinetic energy of molecules unchanged so temperature unchanged	B1

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Question	Answer	Marks
3(a)	force per unit mass	B1
3(b)(i)	$F = GMm / x^2$	C1
	$g = F / m$	A1
	$g = [GMm / x^2] / m = GM / x^2$ and G = gravitational constant	
3(b)(ii)	arrow drawn at P pointing directly towards the point mass	B1
3(b)(iii)	fields are in opposite directions	B1
	field strength at Q is four times the field strength at P	B1
3(c)	line starting at $(R, -g_0)$ and ending at $(L - R, +g_0)$	B1
	line passing through $(L / 2, 0)$	B1
	curve becoming shallower from R to $(L / 2)$ and then steeper from $(L / 2)$ to $(L - R)$	B1

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Question	Answer	Marks
4(a)(i)	temperature = $-273.15\text{ }^{\circ}\text{C}$	A1
4(a)(ii)	temperature = 0 K	A1
4(b)(i)	gas is ideal	B1
4(b)(ii)	$pV = NkT$	C1
	$N = 270 / (8.0 \times 10^{-21})$ $= 3.4 \times 10^{22}$	A1
4(b)(iii)	$n = (3.4 \times 10^{22}) / (6.02 \times 10^{23})$ $= 0.056\text{ mol}$	A1
4(c)	$\frac{1}{2} m\langle c^2 \rangle = (3 / 2) kT$	C1
	$\frac{1}{2} \times m \times 1900^2 = 1.5 \times 8.0 \times 10^{-21}$ $(m = 6.65 \times 10^{-27}\text{ kg})$	C1
	$m = (6.65 \times 10^{-27}) / (1.66 \times 10^{-27})$	C1
	$= 4.0\text{ u}$	A1

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Question	Answer	Marks
5(a)	work done per unit charge	B1
	work (done) moving positive charge from infinity (to the point)	B1
5(b)(i)	potential (due to proton) = $(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 10 \times 10^{-12})$ or potential (due to electron) = $(-1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 110 \times 10^{-12})$	C1
	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(10^{-1} - 110^{-1}) \times 10^{12}] = 130 \text{ V}$	A1
5(b)(ii)	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(30^{-1} - 90^{-1}) \times 10^{12}]$	C1
	= (+) 32 V	A1
5(b)(iii)	cross drawn midway between the electron and the proton	B1
5(b)(iv)	line from (10, +130) to (110, -130)	B1
	curve getting shallower until $x = 60 \text{ pm}$, crossing $V = 0$ at (60, 0) and then getting steeper after $x = 60 \text{ pm}$	B1
	curve passing through (30, ± 32) and (90, ± 32)	B1

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Question	Answer	Marks
6(a)	series charges: $Q_s = Q_1 = Q_2$	B1
	series p.d.s: $V_s = V_1 + V_2$	B1
	parallel charges: $Q_s = Q_1 + Q_2$	B1
	parallel p.d.s: $V_s = V_1 = V_2$	B1
6(b)(i)	$E = \frac{1}{2} CV^2$	C1
	p.d. = $[(2 \times 19 \times 10^{-3}) / (470 \times 10^{-6})]^{\frac{1}{2}}$ $= 9.0 \text{ V}$	A1
6(b)(ii)	$E = Q^2 / 2C$ or $C = Q / V$	C1
	$Q = (19 \times 10^{-3} \times 2 \times 470 \times 10^{-6})^{\frac{1}{2}}$ or $Q = 470 \times 10^{-6} \times 9.0$ $Q = 4.2 \times 10^{-3} \text{ C}$	A1
6(b)(iii)	total charge unchanged	C1
	total capacitance = $(470 + 180) \times 10^{-6} \text{ (F)}$	C1
	$E = Q^2 / 2C = (4.23 \times 10^{-3})^2 / (2 \times 650 \times 10^{-6})$ (= 0.014 J) $E = 14 \text{ mJ}$	A1

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Question	Answer	Marks
7(a)	(induced) e.m.f. is (directly) proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
7(b)(i)	flux = e.m.f. $\times$ time	C1
	flux = 0.54×15 = 8.1 Wb	A1
7(b)(ii)	$\Phi = BA$	C1
	area = $8.1 / (38 \times 10^{-6})$ = $2.1 \times 10^5 \text{ m}^2$	A1
7(b)(iii)	area = speed $\times$ time $\times$ width	C1
	$v = (2.1 \times 10^5) / (15 \times 68)$ = 210 m s^{-1}	A1
7(b)(iv)	opposing force (due to current in wings) must be backwards	B1
	from Fleming's left-hand rule, current (in wings) must be from Q to P	B1
	current is from – to + inside an e.m.f. source so P is at higher potential	B1

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Question	Answer	Marks
8(a)	packet / quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
8(b)(i)	$E = c^2 \Delta m$	C1
	$\Delta m = (4.274 \times 10^6 \times 1.60 \times 10^{-19}) / (1.66 \times 10^{-27} \times (3.00 \times 10^8)^2)$ (= 0.00458 u)	C1
	$m = 233.915174 + 4.000407 + 0.00458$ = 237.92016 u	A1
8(b)(ii)	$E = hc / \lambda$ or $E = hf$ and $c = f\lambda$	C1
	$(4.274 - 4.200) \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$	C1
	$\lambda = 1.7 \times 10^{-11} \text{ m}$	A1
8(b)(iii)	(true) energy of gamma photon is smaller so (true) wavelength is larger	B1
8(c)	(anti)neutrinos are emitted during beta decay	B1
	particles emitted during beta decay carry varying amounts of energy, so energy of gamma photon is also variable (between decays)	B1

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Question	Answer	Marks
9(a)	temperature inversely proportional to wavelength	M1
	temperature is thermodynamic temperature of surface of star and wavelength is the wavelength at which maximum emission rate from star occurs	A1
9(b)	<i>Any three points from:</i> • (surface) temperature of star X = 7000 K or star X has a higher temperature than the Sun • star X has a higher luminosity than the Sun • luminosity of star X = 2.7×10^{27} W • radius of star X = 1.3×10^9 m	B3
9(c)	light (from star X) is redshifted	B1
	wavelength of peak emission rate would be greater (using observed data)	B1

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Question	Answer	Marks
10(a)	product of density and speed	M1
	speed of sound in medium (and density of the medium)	A1
10(b)	ultrasound waves cause crystal to vibrate	B1
	vibrations (of crystal) cause induced e.m.f. (across crystal)	B1
10(c)(i)	intensity reflection coefficient= $(40.4 - 1.48)^2 / (40.4 + 1.48)^2$	C1
	= 0.86	A1
10(c)(ii)	Z values are very similar	B1
	(almost) all the ultrasound will be transmitted or (almost) none of the ultrasound will be reflected	B1

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Question	Answer	Marks
1(a)(i)	radius = $6.37 \times 10^6 \times \cos 52.2^\circ = 3.90 \times 10^6 \text{ m}$	A1
1(a)(ii)	period = 24 hours	C1
	$v = 2\pi r / T$ or $v = r\omega$ and $\omega = 2\pi / T$	C1
	$v = (2\pi \times 3.90 \times 10^6) / (24 \times 60 \times 60)$ $= 280 \text{ m s}^{-1}$	A1
1(b)(i)	$F = mv^2 / r$	C1
	$= (58.6 \times 280^2) / (3.90 \times 10^6)$ $= 1.2 \text{ N}$	A1
1(b)(ii)	arrow pointing horizontally to the left	B1
1(b)(iii)	arrow from student pointing along the dotted line, labelled 'weight'	B1
	upwards arrow from student pointing in a direction to the left of normal and above the tangent to the Earth, labelled 'contact force'	B1

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Question	Answer	Marks
2(a)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
2(b)	<i>Any two points from:</i> • molecules are in <u>continuous</u> random motion • molecules have negligible volume compared with volume of gas • collisions (involving molecules) are (perfectly) elastic • collisions (of molecules) are instantaneous	B2
2(c)(i)	$pV = nRT$	C1
	$p = (0.0160 \times 8.31 \times 282) / (1.87 \times 10^{-4})$ $= 2.01 \times 10^5 \text{ Pa}$	A1
2(c)(ii)	number of molecules = $0.0160 \times 6.02 \times 10^{23}$	C1
	separation = $\sqrt[3]{[(1.87 \times 10^{-4}) / (0.0160 \times 6.02 \times 10^{23})]}$ $= 2.7 \times 10^{-9} \text{ m}$ (<i>allow any answer that is $3 \times 10^{-9} \text{ m}$ to one significant figure</i>)	A1
2(d)(i)	$F = 6.67 \times 10^{-11} \times (3.34 \times 10^{-27})^2 / (2.7 \times 10^{-9})^2$	C1
	$= 1.0 \times 10^{-46} \text{ N}$	A1
2(d)(ii)	numerical comparison between 10^{-46} N (F) and 10^{-26} N (the weight of molecule) leading to a conclusion that the assumption is supported	B1

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Question	Answer	Marks
3(a)	same temperature	B1
	no <u>net</u> transfer of thermal energy (between them)	B1
3(b)(i)	density	B1
3(b)(ii)	<i>Any two points from:</i> - large response time / large time to reach equilibrium or cannot measure rapidly changing temperatures - reaching equilibrium requires (significant) transfer of energy or changes temperature of environment being measured or cannot measure temperature of small objects - bulky / difficult to set up or difficult to take readings / scale not calibrated to read temperature or cannot measure temperature of solid objects	B2
3(b)(iii)	substance with large mass or temperature that is constant (over time) or to calibrate other thermometers (in a laboratory)	B1

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Question	Answer	Marks
3(b)(iv)	$0\text{ }^{\circ}\text{C} = 273\text{ K}$	C1
	$T = 273 \times (7.83 - 2.31) / (8.69 - 2.31)$ $(= 236\text{ K})$	C1
	$\theta = 236 - 273$ $= -37\text{ }^{\circ}\text{C}$	A1

Question	Answer	Marks
4(a)	<u>change</u> in internal energy = work done + energy transfer by heating	C1
	<u>increase</u> in internal energy = work done <u>on</u> system + energy transferred <u>to</u> the system by heating	A1
4(b)(i)	$U = (3/2) pV$	A1
4(b)(ii)	$pV = NkT$ <u>and</u> k identified as Boltzmann constant	B1
	$U = (3/2) NkT$	A1
4(c)(i)	$W = (+)8XY$	A1
4(c)(ii)	$W = -20XY$	A1
4(d)	work done during stages BC and DA = 0	B1
	change in internal energy (over complete cycle) = 0	C1
	thermal energy supplied = $20XY - 8XY$ $= (+)12XY$	A1

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Question	Answer	Marks
5(a)(i)	straight line through the origin shows that a is proportional to x	B1
	negative gradient shows that a is always in the opposite direction to x	B1
5(a)(ii)	$a_0 = \omega^2 x_0$	C1
	$\omega = 2\pi / T$	C1
	$T = 2\pi \sqrt{(x_0 / a_0)}$ $= 2\pi \sqrt{(1.2 / 13)}$ $= 1.9 \text{ s}$	A1
5(b)(i)	loss of energy of oscillations	B1
	due to <u>resistive</u> force(s)	B1
5(b)(ii)	line starting from $x = \pm 1.2 \text{ cm}$ at $t = 0$	B1
	line starting from non-zero value of x from $t = 0$ to $t = 2T$ that is entirely either above or below the t -axis	B1
	curve from $t = 0$ starting from non-zero x value, with both magnitude of x value and magnitude of gradient continuously decreasing	B1

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Question	Answer	Marks
6(a)	force per unit positive charge	B1
6(b)(i)	radial lines	B1
	arrows pointing away from the sphere	B1
6(b)(ii)	$C = Q / V$	C1
	$V = 83 / 69$ $= (+)1.2 \text{ V}$	A1
6(b)(iii)	$V = Q / 4\pi\epsilon_0 r$ $r = (83 \times 10^{-12}) / (4\pi \times 8.85 \times 10^{-12} \times 1.2)$	C1
	$= 0.62 \text{ m}$	A1
6(b)(iv)	$E = Q / 4\pi\epsilon_0 r^2$	C1
	$= (83 \times 10^{-12}) / (4\pi \times 8.85 \times 10^{-12} \times 0.62^2)$ $= 1.9 \text{ N C}^{-1}$	A1
6(c)	$26 = 83 \exp [-t / (120 \times 10^6 \times 69 \times 10^{-12})]$	C1
	$t = 9.6 \times 10^{-3} \text{ s}$	A1

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Question	Answer	Marks
7(a)(i)	$T = 2\pi / 40\pi = 0.050 \text{ s}$	A1
7(a)(ii)	$V_{\text{r.m.s.}} = 18 / \sqrt{2}$ $= 13 \text{ V}$	A1
7(b)	sinusoidal curve of period 50 ms from $t = 0$ to $t = 100 \text{ ms}$	B1
	correct phase (V_{MAX} at $t = 0, 50, 100 \text{ ms}$ and $-V_{\text{MAX}}$ at 25, 75 ms etc.)	B1
	maximum and minimum voltages shown as $\pm 18 \text{ V}$	B1
7(c)	<i>Any three points from:</i> - rectification is full-wave - mean power = 14 W - resistance of $R = 12 \Omega$ - peak current in $R = 1.6 \text{ A}$ or r.m.s. current in $R = 1.1 \text{ A}$ - period of <u>output</u> voltage / power = 25 ms or frequency of <u>output</u> voltage / power = 40 Hz or angular frequency of <u>output</u> voltage / power = 250 rad s^{-1}	B3

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Question	Answer	Marks
8(a)	<i>Any three points from:</i> • electrons moving between levels emit a single photon • energy of photon = difference between energy levels • energy of photon depends on frequency • discrete frequencies (in spectrum) so differences between electron energies must be discrete • discrete differences between electron energies means energy levels must be discrete	B3
8(b)(i)	energy = $-(13.6 \times 1.60 \times 10^{-19})$ $= -2.18 \times 10^{-18} \text{ J}$	A1
8(b)(ii)	$\Delta E = hf$	C1
	$= (6.63 \times 10^{-34} \times 2.47 \times 10^{15}) / (1.60 \times 10^{-19}) = 10.2 \text{ eV}$	A1
8(b)(iii)	$n = 2$ energy level = -3.4 eV	A1
	$n = 3$ energy difference = 12.1 eV	A1
	$n = 4$ energy difference = 12.8 eV	A1
	$n = 3$ energy level = -1.5 eV and $n = 4$ energy level = -0.8 eV	A1

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Question	Answer	Marks
9(a)	difference between mass of nucleus and mass of (constituent) nucleons	M1
	when nucleons are separated to infinity	A1
9(b)	$\Delta m = (2 \times 2.013553) - (4.001505) \text{ (u)}$ $(= 0.025601 \text{ u})$	C1
	$E = c^2 \Delta m$	C1
	energy from one He-4 nucleus = $0.025601 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$ $(= 3.82 \times 10^{-12} \text{ J})$	C1
	energy to form 1.00 mol = $3.82 \times 10^{-12} \times 6.02 \times 10^{23}$ $= 2.30 \times 10^{12} \text{ J}$	A1
9(c)(i)	$L = 1.09 \times 10^{11} \times (3.00 \times 10^8)^2$	C1
	$= 9.81 \times 10^{27} \text{ W}$	A1
9(c)(ii)	$L = 4\pi\sigma r^2 T^4$ $9.81 \times 10^{27} = 4\pi \times 5.67 \times 10^{-8} \times (1.19 \times 10^9)^2 \times T^4$	C1
	$T = 9930 \text{ K}$	A1
9(d)	standard candles have known luminosity	B1
	radiant flux intensity (from star) measured (on the Earth)	B1
	distance found from $F = L / (4\pi d^2)$	B1

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Question	Answer	Marks
10(a)	<u>difference</u> in degrees of blackening	B1
10(b)(i)	$I = I_0 \exp(-\mu x)$ $= I_0 \exp(-5.8 \times 0.35) = 0.13 I_0$	A1
10(b)(ii)	use of $\exp\{-(0.35 \times 3.7)\}$ factor	C1
	$0.053 I_0 = I_0 \exp\{-(0.35 \times 3.7) + 2.1\mu\}$	C1
	$\mu = 0.78 \text{ cm}^{-1}$	A1
10(b)(iii)	factor of only 2.5 between the (detected) <u>intensities</u> (so not good contrast)	B1
10(c)	(structure) scanned in (thin) sections	B1
	(many) scans (of each section) taken from different angles	B1
	scanning repeated for all sections and (data) compiled (to form 3D image)	B1

Cambridge International AS & A Level

PHYSICS**9702/43**

Paper 4 A Level Structured Questions

October/November 2025**MARK SCHEME**Maximum Mark: 100

Published

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This document consists of **17** printed pages.

PUBLISHED**Generic Marking Principles**

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 descriptions 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.

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.

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	incorrect physics
	incorrect point or mark not awarded
	information missing or insufficient for credit

Annotation	Meaning
MO	mandatory mark not awarded
SEEN	point has been noted, but no credit has been given or blank page seen
POT	power of ten error
TE	transcription error

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>mandatory</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)	velocity and acceleration both have constant magnitude	B1
	velocity is (always) perpendicular to acceleration	B1
1(b)(i)	$v = R\omega$	A1
1(b)(ii)	$a = R\omega^2$ or $a = v^2 / R$	C1
	$a = v\omega$	A1
1(c)(i)	$x = R \sin \theta$	A1
1(c)(ii)	$\theta = \omega t$	A1
1(c)(iii)	clear substitution of $\theta = \omega t$ into $x = R \sin \theta$ leading to $x = R \sin \omega t$	A1
1(c)(iv)	equation is of the form $x = x_0 \sin \omega t$ (so simple harmonic motion)	B1
1(d)(i)	amplitude = $0.46 / 2$ = 0.23 m	A1
1(d)(ii)	$\omega = 2\pi / T$	C1
	period = $2\pi / 1.9$ = 3.3 s	A1

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Question	Answer	Marks
1(d)(iii)	$a_0 = \omega^2 x_0$	C1
	$= 1.9^2 \times 0.23$	A1
	$= 0.83 \text{ m s}^{-2}$	
1(e)	shadow on screen, labelled A, above left-hand edge of the circular path	B1

Question	Answer	Marks
2(a)	work done on / by system	B1
	thermal energy supplied to / removed from system	B1
2(b)(i)	no thermal energy transferred to / from system (due to lack of time)	B1
	work is done on the gas to compress it / to decrease its volume	B1
	internal energy increases so temperature increases	B1
2(b)(ii)	(during vaporisation) molecular separation increases	B1
	(heating causes) potential energy of molecules to increase	B1
	kinetic energy of molecules unchanged so temperature unchanged	B1

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Question	Answer	Marks
3(a)	force per unit mass	B1
3(b)(i)	$F = GMm / x^2$	C1
	$g = F / m$	A1
	$g = [GMm / x^2] / m = GM / x^2$ and G = gravitational constant	
3(b)(ii)	arrow drawn at P pointing directly towards the point mass	B1
3(b)(iii)	fields are in opposite directions	B1
	field strength at Q is four times the field strength at P	B1
3(c)	line starting at $(R, -g_0)$ and ending at $(L - R, +g_0)$	B1
	line passing through $(L / 2, 0)$	B1
	curve becoming shallower from R to $(L / 2)$ and then steeper from $(L / 2)$ to $(L - R)$	B1

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Question	Answer	Marks
4(a)(i)	temperature = $-273.15\text{ }^{\circ}\text{C}$	A1
4(a)(ii)	temperature = 0 K	A1
4(b)(i)	gas is ideal	B1
4(b)(ii)	$pV = NkT$	C1
	$N = 270 / (8.0 \times 10^{-21})$ $= 3.4 \times 10^{22}$	A1
4(b)(iii)	$n = (3.4 \times 10^{22}) / (6.02 \times 10^{23})$ $= 0.056\text{ mol}$	A1
4(c)	$\frac{1}{2} m \langle c^2 \rangle = (3 / 2) kT$	C1
	$\frac{1}{2} \times m \times 1900^2 = 1.5 \times 8.0 \times 10^{-21}$ $(m = 6.65 \times 10^{-27}\text{ kg})$	C1
	$m = (6.65 \times 10^{-27}) / (1.66 \times 10^{-27})$	C1
	$= 4.0\text{ u}$	A1

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Question	Answer	Marks
5(a)	work done per unit charge	B1
	work (done) moving positive charge from infinity (to the point)	B1
5(b)(i)	potential (due to proton) = $(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 10 \times 10^{-12})$ or potential (due to electron) = $(-1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12} \times 110 \times 10^{-12})$	C1
	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(10^{-1} - 110^{-1}) \times 10^{12}] = 130 \text{ V}$	A1
5(b)(ii)	$V = [(1.60 \times 10^{-19}) / (4\pi \times 8.85 \times 10^{-12})] \times [(30^{-1} - 90^{-1}) \times 10^{12}]$	C1
	= (+) 32 V	A1
5(b)(iii)	cross drawn midway between the electron and the proton	B1
5(b)(iv)	line from (10, +130) to (110, -130)	B1
	curve getting shallower until $x = 60 \text{ pm}$, crossing $V = 0$ at (60, 0) and then getting steeper after $x = 60 \text{ pm}$	B1
	curve passing through (30, ± 32) and (90, ± 32)	B1

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Question	Answer	Marks
6(a)	series charges: $Q_s = Q_1 = Q_2$	B1
	series p.d.s: $V_s = V_1 + V_2$	B1
	parallel charges: $Q_s = Q_1 + Q_2$	B1
	parallel p.d.s: $V_s = V_1 = V_2$	B1
6(b)(i)	$E = \frac{1}{2} CV^2$	C1
	p.d. = $[(2 \times 19 \times 10^{-3}) / (470 \times 10^{-6})]^{\frac{1}{2}}$ $= 9.0 \text{ V}$	A1
6(b)(ii)	$E = Q^2 / 2C$ or $C = Q / V$	C1
	$Q = (19 \times 10^{-3} \times 2 \times 470 \times 10^{-6})^{\frac{1}{2}}$ or $Q = 470 \times 10^{-6} \times 9.0$ $Q = 4.2 \times 10^{-3} \text{ C}$	A1
6(b)(iii)	total charge unchanged	C1
	total capacitance = $(470 + 180) \times 10^{-6} \text{ (F)}$	C1
	$E = Q^2 / 2C = (4.23 \times 10^{-3})^2 / (2 \times 650 \times 10^{-6})$ (= 0.014 J) $E = 14 \text{ mJ}$	A1

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Question	Answer	Marks
7(a)	(induced) e.m.f. is (directly) proportional to rate	M1
	of change of (magnetic) flux (linkage)	A1
7(b)(i)	flux = e.m.f. $\times$ time	C1
	flux = 0.54×15 = 8.1 Wb	A1
7(b)(ii)	$\Phi = BA$	C1
	area = $8.1 / (38 \times 10^{-6})$ = $2.1 \times 10^5 \text{ m}^2$	A1
7(b)(iii)	area = speed $\times$ time $\times$ width	C1
	$v = (2.1 \times 10^5) / (15 \times 68)$ = 210 m s^{-1}	A1
7(b)(iv)	opposing force (due to current in wings) must be backwards	B1
	from Fleming's left-hand rule, current (in wings) must be from Q to P	B1
	current is from – to + inside an e.m.f. source so P is at higher potential	B1

PUBLISHED

Question	Answer	Marks
8(a)	packet / quantum of <u>energy</u>	M1
	of electromagnetic radiation	A1
8(b)(i)	$E = c^2 \Delta m$	C1
	$\Delta m = (4.274 \times 10^6 \times 1.60 \times 10^{-19}) / (1.66 \times 10^{-27} \times (3.00 \times 10^8)^2)$ (= 0.00458 u)	C1
	$m = 233.915174 + 4.000407 + 0.00458$ = 237.92016 u	A1
8(b)(ii)	$E = hc / \lambda$ or $E = hf$ and $c = f\lambda$	C1
	$(4.274 - 4.200) \times 1.60 \times 10^{-13} = (6.63 \times 10^{-34} \times 3.00 \times 10^8) / \lambda$	C1
	$\lambda = 1.7 \times 10^{-11} \text{ m}$	A1
8(b)(iii)	(true) energy of gamma photon is smaller so (true) wavelength is larger	B1
8(c)	(anti)neutrinos are emitted during beta decay	B1
	particles emitted during beta decay carry varying amounts of energy, so energy of gamma photon is also variable (between decays)	B1

PUBLISHED

Question	Answer	Marks
9(a)	temperature inversely proportional to wavelength	M1
	temperature is thermodynamic temperature of surface of star and wavelength is the wavelength at which maximum emission rate from star occurs	A1
9(b)	<i>Any three points from:</i> • (surface) temperature of star X = 7000 K or star X has a higher temperature than the Sun • star X has a higher luminosity than the Sun • luminosity of star X = 2.7×10^{27} W • radius of star X = 1.3×10^9 m	B3
9(c)	light (from star X) is redshifted	B1
	wavelength of peak emission rate would be greater (using observed data)	B1

PUBLISHED

Question	Answer	Marks
10(a)	product of density and speed	M1
	speed of sound in medium (and density of the medium)	A1
10(b)	ultrasound waves cause crystal to vibrate	B1
	vibrations (of crystal) cause induced e.m.f. (across crystal)	B1
10(c)(i)	intensity reflection coefficient= $(40.4 - 1.48)^2 / (40.4 + 1.48)^2$	C1
	= 0.86	A1
10(c)(ii)	Z values are very similar	B1
	(almost) all the ultrasound will be transmitted or (almost) none of the ultrasound will be reflected	B1

Cambridge International AS & A Level

PHYSICS**9702/44**

Paper 4 A Level Structured Questions

October/November 2025**MARK SCHEME**Maximum Mark: 100

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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

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

Annotations guidance for centres

Examiners use a system of annotations as a shorthand for communicating their marking decisions to one another. Examiners are trained during the standardisation process on how and when to use annotations. The purpose of annotations is to inform the standardisation and monitoring processes and guide the supervising examiners when they are checking the work of examiners within their team. The meaning of annotations and how they are used is specific to each component and is understood by all examiners who mark the component.

We publish annotations in our mark schemes to help centres understand the annotations they may see on copies of scripts. Note that there may not be a direct correlation between the number of annotations on a script and the mark awarded. Similarly, the use of an annotation may not be an indication of the quality of the response.

The annotations listed below were available to examiners marking this component in this series.

Annotations

Annotation	Meaning
	arithmetic error
	benefit of the doubt given
	contradiction in response, mark not awarded
	correct point or mark awarded
	error carried forward applied
	error in number of significant figures
	incorrect or insufficient point ignored while marking the rest of the response
	incorrect physics
	incorrect point or mark not awarded
	information missing or insufficient for credit

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Annotation	Meaning
MO	mandatory mark not awarded
SEEN	point has been noted, but no credit has been given or blank page seen
POT	power of ten error
TE	transcription error

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>mandatory</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)	(gravitational) force is (directly) proportional to product of masses	B1
	force (between point masses) is inversely proportional to the square of their separation	B1
1(b)(i)	force = $(6.67 \times 10^{-11} \times 4.0 \times 10^{30} \times 2.0 \times 10^{30}) / (3.3 \times 10^{12})^2$	C1
	= $4.9 \times 10^{25} \text{ N}$	A1
1(b)(ii)	$a = F / m = (4.9 \times 10^{25}) / (4.0 \times 10^{30})$ = $1.2 \times 10^{-5} \text{ m s}^{-2}$	A1
1(b)(iii)	$a = r\omega^2$ and $\omega = 2\pi / T$ or $a = v^2 / r$ and $v = (2\pi r / T)$	C1
	$r = (3.3 \times 10^{12}) / 3$	C1
	$T = 2\pi [(3.3 \times 10^{12}) / (3 \times 1.2 \times 10^{-5})]^{1/2}$ = $1.9 \times 10^9 \text{ s}$	A1
1(b)(iv)	acceleration: B greater than A	B1
	linear speed: B greater than A	B1
	period: B equal to A	B1

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Question	Answer	Marks
2(a)(i)	p = pressure (of gas), V = volume (of gas) and k = Boltzmann constant	B1
	N = number of molecules (in the gas)	B1
	T = thermodynamic temperature (of gas)	B1
2(a)(ii)	$(pV =) NkT = \frac{1}{3}Nm\langle c^2 \rangle$	M1
	$E_K = \frac{1}{2}m\langle c^2 \rangle = \frac{1}{2} \times 3kT = (3/2)kT$	A1
2(b)	(same temperature so) $(\frac{1}{2})m\langle c^2 \rangle$ must be same for both gases	C1
	ratio = $\sqrt{(m_O / m_H)} = \sqrt{(32 / 2)}$ = 4.0	A1

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Question	Answer	Marks
3(a)	total kinetic energy associated with random motion of molecules	B1
	potential energy (of molecules) is zero	B1
3(b)(i)	$pV = NkT$ and $U = (3/2)NkT$	C1
	$U = (3/2)pV$ $= (3/2) \times 2.0 \times 10^5 \times 0.016$ $= 4800 \text{ J}$	A1
3(b)(ii)	temperature = 800 K	A1
3(b)(iii)	volume = 0.032 m ³	A1
3(b)(iv)	straight vertical line labelled X between A and (0.016, 4.0)	B1
	curve from B with continuously decreasing negative gradient, labelled Y	B1
	line labelled Y between (0.016, 4.0) and (0.032, 2.0)	B1

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Question	Answer	Marks
4(a)	<u>number</u> of oscillations per unit time	B1
4(b)(i)	kinetic energy (of object) reaches maximum / minimum / zero twice in a cycle	A1
4(b)(ii)	$\omega = 2\pi / T$ $= 2\pi / 0.80$ or $a_0 = \omega^2 x_0$ $\omega = \sqrt{(1.0 / 0.016)}$	C1
	$\omega = 7.9 \text{ rad s}^{-1}$	A1
4(b)(iii)	<i>Any three points from:</i> - oscillations are simple harmonic <u>amplitude</u> = 0.016 m - maximum speed = 0.13 m s^{-1} - total energy of oscillations = $7.0 \times 10^{-4} \text{ J}$ - mass of object = 0.087 kg - maximum momentum = $0.011 \text{ kg m s}^{-1}$ or 0.011 N s	B3

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Question	Answer	Marks
4(b)(iv)	<i>Any two points from:</i> • kinetic energy is a maximum at zero displacement or kinetic energy is zero at maximum displacement • potential energy is zero at zero displacement or potential energy is a maximum at maximum displacement • kinetic energy is maximum when the potential energy is zero or potential energy is a maximum when the kinetic energy is zero	B2
	kinetic energy + potential energy is constant	B1

Question	Answer	Marks
5(a)	potential is (defined as) zero at infinity	B1
	proton has a positive charge and so repels another positive charge	B1
	work is done on two (positive) charges to move them towards each other or work is done by two (positive) charges as they move apart from each other	B1
5(b)(i)	arrow drawn through Q in a WSW direction directly away from the centre of the sphere	B1
5(b)(ii)	curve in at least one quadrant passing through $(\pm R, \pm E_0)$ and $(\pm 2R, \pm \frac{1}{4}E_0)$	B1
	curve between $-3R$ and $-R$ of increasing magnitude of gradient and curve between R and $3R$ of decreasing magnitude of gradient	B1
	two lines drawn, one in the top right quadrant, the other in the bottom left quadrant	B1
5(c)	$E_P = - (1.60 \times 10^{-19})^2 / [4\pi \times 8.85 \times 10^{-12} \times (5.3 \times 10^{-11})]$	C1
	$= -4.3 \times 10^{-18} \text{ J}$	A1

Question	Answer	Marks
6(a)(i)	conversion of a.c. to d.c.	B1
6(a)(ii)	full-wave (rectification)	B1
6(a)(iii)	three diodes with correct symbols connected into the circuit	B1
	lower-left diode shown pointing towards the right and upper-left and lower-right diodes both shown pointing towards the left	B1
6(b)(i)	$\omega = 18 \text{ (rad s}^{-1}\text{)}$	C1
	$T = 2\pi / 18 = 0.35 \text{ s}$	A1

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Question	Answer	Marks
6(b)(ii)	$V_{\text{r.m.s.}} = 34 / \sqrt{2}$ $= 24 \text{ V}$	A1
6(b)(iii)	sinusoidal 'humps' with minimum $V_{\text{OUT}} = 0$ and non-zero V_{OUT} all same sign	B1
	peak V_{OUT} shown as 34 V or –34 V	B1
	two 'humps' shown, with V_{OUT} always with same sign and $V_{\text{OUT}} = 0$ at $t = 0$, $t = 0.175 \text{ s}$ and $t = 0.350 \text{ s}$ and non-zero in between	B1
6(c)(i)	correct circuit symbol for capacitor, connected in parallel with resistor	B1
6(c)(ii)	time constant = RC	C1
	$= 56 \times 10^3 \times 12 \times 10^{-6}$ $= 0.67 \text{ s}$	A1
6(c)(iii)	$V_{\text{min}} = 34 \exp(-0.14 / 0.67)$	C1
	$= 28 \text{ V}$	A1

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Question	Answer	Marks
7(a)	direction of induced e.m.f.	M1
	such as to (produce effects that) oppose the change that caused it	A1
7(b)(i)	$\Phi = BA$	C1
	$= 0.047 \times 10^{-3} \times \pi \times 12^2$	C1
	$= 0.021 \text{ Wb}$	A1
7(b)(ii)	e.m.f. = flux cut / time	C1
	$= 0.021 / (1 / 85)$	A1
	$= 1.8 \text{ V}$	
7(b)(iii)	force (due to current) cause anticlockwise moment (to oppose rotation)	B1
	(from the LH rule) current is from O to X, so X is at the higher potential	B1

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Question	Answer	Marks
8(a)	(radioactive) substance introduced into the body	B1
	substance absorbed by the tissues being studied	B1
8(b)(i)	$P = 15$ and $R = 0$	A1
	$Q = 7$ and $S = (+)1$	A1
8(b)(ii)	(electron) neutrino	B1
8(c)(i)	<u>number</u> of nuclear disintegrations per unit time	B1
8(c)(ii)	decay constant $= \ln 2 / (2.04 \times 60)$	C1
	$= 5.66 \times 10^{-3} \text{ s}^{-1}$	A1
8(c)(iii)	$N = (2.85 \times 10^{-6}) / (15 \times 1.66 \times 10^{-27})$	C1
	$A = \lambda N$	C1
	rate $= (5.66 \times 10^{-3}) \times (2.85 \times 10^{-6}) / (15 \times 1.66 \times 10^{-27})$	C1
	$= 6.48 \times 10^{17} \text{ s}^{-1}$	A1
8(d)(i)	gamma photons	B1
8(d)(ii)	positron collides with electron (in body)	B1
	annihilation results in their masses becoming photon energy	B1

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Question	Answer	Marks
9(a)	emission of electrons (from a metal surface)	M1
	when electromagnetic radiation is incident (on surface)	A1
9(b)(i)	threshold frequency = $2F$	A1
9(b)(ii)	Planck constant = ϕ / F	A1
9(c)	two diagonal straight lines with positive gradient in the positive E_k region only, starting at non-zero values of f	B1
	line labelled X passing through $(F, 0)$ and line labelled Y passing through $(2F, 0)$ and extending to $3F$ or $+2\phi$	B1
	two diagonal straight lines with equal gradients	B1
	X line extrapolates back to $(0, -\phi)$ and Y line extrapolates back to $(0, -2\phi)$	B1

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Question	Answer	Marks
10(a)	recession of galaxy (from observer) causes emitted light to have	B1
	increase in <u>observed</u> wavelength / decrease in <u>observed</u> frequency	B1
10(b)	(distant) galaxies show redshift <u>so</u> galaxies are moving apart	B1
	galaxies moving apart <u>means</u> universe must be expanding	B1
10(c)	the speed of recession is proportional to the distance of the galaxies from each other or more distant galaxies are receding faster	B1
	<i>Any two points from:</i> • more distant galaxies represent further back in time • a long time ago, all matter in the universe must have been very close together • a long time ago, all matter in the universe must have been moving apart very fast	B2