Cambridge Assessment International Education

Cambridge Pre-U

PHYSICS **9792/03**

Paper 3 Written Paper 3 **May/June 2023**

MARK SCHEME

Maximum Mark: 140

Published

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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

Cambridge International will not enter into discussions about these mark schemes.

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This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

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 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.

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	<u>'List rule' guidance</u> 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.

Question	Answer	Marks
1(a)(i)	angle subtended at the centre of a circle by an arc of length equal to the radius	**1**
1(a)(ii)	arrow at X pointing vertically up the page	**1**
1(b)(i)	*either*: $\omega = v / r$ <u>and</u> $\theta = \omega t$ *or*: $s = \theta r$ <u>and</u> $v = s / t$	**1**
	leading to $\boldsymbol{t = \theta r / v}$	**1**
1(b)(ii)	<u>vector diagram shows</u>: • arrow labelled v_Y pointing about 10° left of vertical, and • arrow labelled v_X pointing upwards, and • short arrow labelled Δv arrow pointing about 5° off left	**1**
1(b)(iii)	(provided θ is small) $\Delta v = \theta v$	**1**
	$= (vt / r) \times v = v^2 t / r$	**1**
	$\boldsymbol{a = \Delta v / t = v^2 / r}$ OR $a = \Delta v / t = \theta v / t = \theta v / (\theta r / v) = v^2 / r$	**1**
1(c)	*either*: T = 24 hours <u>and</u> $\omega = 2\pi / T$ *or*: T = 24 hours <u>and</u> $v = 2\pi r / T$ acceleration = $r\omega^2 = 6.4 \times 10^6\ \text{m} \times \left(2\pi / (24 \times 60 \times 60\ \text{s})\right)^2$ acceleration = $v^2 / \text{r} = \left(2\pi \times 6.4 \times 10^6\ \text{m} / (24 \times 60 \times 60\ \text{s})\right)^2 / (6.4 \times 10^6\ \text{m})$	**1**
	= $\mathbf{0.034\ m\ s^{-2}}$	**1**

Question	Answer	Marks
2(a)	any two points from: • mass of water (in tube) *or* volume of water (in tube) • initial temperature (of water) • capacitance (of capacitor) • resistance • IGNORE externals e.g. pressure on water, temp of room • IGNORE things that wouldn't change e.g. material of tube, leads	**2**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td>2(b)</td><td><u>any two points from</u>: PRECAUTIONS
• insulate small tube (from heat losses) or put lid on
• use a resistor with a small resistance (so discharge is quick)
• use a physically very small resistor (so small heat capacity)
• use voltmeter to monitor when capacitor sufficiently discharged or charged
• check for systematic error in voltmeter (or voltmeter zeroed)
• resistor cool fully
• stir or vibrate
• put resistor at bottom of tube (for convection)
• IGNORE just use a digital thermometer
• IGNORE use same power source
• Measure temp at eye level to avoid parallax
• Ensuring resistor is cool before next experiment
• IGNORE use same thermometer
• IGNORE safety precautions
• Ensuring resistor is submerged
• Ensure temp taken before it starts to fall
• Ensure leads have low resistance e.g. as short as possible
• Disconnect voltmeter during discharge
• Ensure no liquid escapes
• Record series of temps to be sure of maximum
• Ensure at least 5 time constants have passed
• IGNORE use pure distilled water
• Use <u>smaller</u> quantity of water
• Ensure elements of the circuit are waterproof
• IGNORE infra-red thermometer
• Use high resistance voltmeter with reason</td><td>2</td></tr>
<tr><td rowspan="2">2(c)</td><td>evidence of correct comparison of two sets of data involving V^2 and change in temperature</td><td>1</td></tr>
<tr><td>correct use of the data comparison to justify a conclusion about the validity of the relationship</td><td>1</td></tr>
</table>

Question	Answer	Marks
2(d)(i)	$mc\Delta\theta = kV^2$	**1**
	12.3 g × 4.20 J g^{-1} K^{-1} × (27.3 – 23.2) K = k × (840 V)^2	**1**
	k = **3.0 × 10^{-4} F**	**1**
2(d)(ii)	$k = ½C$ $C = 2k$ = 2 × 3.0 × 10^{-4} F = **6.0 × 10^{-4} F**	**1**
2(e)	any three points from: • take more than three sets of readings • greater range of V • use multiple capacitors connected in parallel or bigger • use a thermocouple thermometer • use a liquid with a lower specific heat capacity (than water) Since all liquids at RT have lower shc than water accept just different liquid • use a temperature sensor connected to a data logger to obtain a temperature-time graph • clear description of a precision improvement e.g. T to 0.01 °C • IGNORE different something without explanation • Use low resistance leads • Repeat with different C or R (but not 2 for both) • IGNORE ‘in a vacuum’ unless fully explained • Insulate tube if not already used in **(a)** or **(b)** • Use smaller volume of water IGNORE different volumes	**3**

Question	Answer	Marks
3(a)(i)	(change in) tension in one spring = kx	**1**
	one spring pulls with force $F_1 = -(T + kx)$ (T is initial tension in both) the other spring pulls with force $F_2 = +(T - kx)$ so $F_{res} = F_1 + F_2 = -(T + kx) + (T - kx) = -2kx$ OR Take movement to right as positive Force on trolley by (compressed)RH spring is kx to left i.e. $-kx$ Force on trolley by (stretched) LH spring is kx to left i.e. $-kx$ So resultant force = $-2kx$	**1**
3(a)(ii)	*either*: $F = -m\omega^2 x$ <u>and</u> ω, x are both constant <u>so</u> SHM *or*: $a = -\omega^2 x$ (so SHM) <u>must be *a*</u> not $F = -m\omega^2 x$	**1**
	$\omega^2 = 2k / m$ <u>and</u> $\omega = 2\pi / T$ leading to $T = \pi\sqrt{(2m / k)}$	**1**
3(b)(i)	(light) damping	**1**
3(b)(ii)	values of x_0 correct to 2 decimal places in second column of table	**2**
3(b)(iii)	values of ln (x_0 / 4.0) calculated correctly and given to 2 or 3 decimal places in third column of table.	**1**
3(c)(i)	all seven points plotted correctly (to within 1 small square)	**2**
	line of best-fit	**1**
3(c)(ii)	gradient = **–0.27 ($\mathbf{s^{-1}}$)**	**1**
3(d)	$\ln(x_0 / 4.00) = -Rt / 4m$	**1**
	so gradient = $-R / 4m$	**1**
	$R = 0.27\ \text{s}^{-1} \times 4 \times 0.170\ \text{kg}$ = **0.18 kg $\mathbf{s^{-1}}$**	**1**
3(e)	damping becomes heavy or over damping	**1**

Question	Answer	Marks
4(a)	<u>similarity – any one point from</u>: • magnitude is inversely proportional to distance (from point) <u>squared</u> • direction is radial (accept field lines identical) • IGNORE force per charge and force per mass • IGNORE they do not need a medium • Both are conservative fields • Both have potentials proportional to 1/r	**1**
	<u>difference – any one point from</u>: • electric field can be towards or away from the point • gravitational field can only be towards the point • IGNORE electric much bigger or vice versa • Gravity attracts electric can repel	**1**
4(b)	$F_G = GMm / x^2$ and $F_E = Q^2 / (4\pi\varepsilon_0 x^2)$ so ratio $F_G / F_E = (GMm \times 4\pi\varepsilon_0) / Q^2$	**1**
	ratio = (6.67 × 10^{-11} N kg^{-2} m^2 × 1.67 × 10^{-27} kg × 9.11 × 10^{-31} kg × 4π × 8.85 × 10^{-12} Fm^{-1}) / (1.60 × 10^{-19} C)^2	**1**
	= **4.41 × 10^{-40}**	**1**
4(c)(i)	gravitational PE = (–)GMm / x = (–)(6.67 × 10^{-11} N kg^{-2} m^2 × 1.67 × 10^{-27} kg × 9.11 × 10^{-31} kg) / 5.00 × 10^{-11} m = (–)2.03 × 10^{-57} J	**1**
	electric PE = gravitational PE / (4.41 × 10^{-40})	**1**
	= (–)**4.60 × 10^{-18} J**	**1**
4(c)(ii)	½ mv^2 = (–) electric potential energy	**1**
	½ × 9.11 × 10^{-31} kg × v^2 = 4.60 × 10^{-18} J escape speed = **3.2 × 10^6 m s^{-1}**	**1**

Question	Answer	Marks
5(a)(i)	$\frac{1}{2}m\,c_{RMS}^2 = {}^3/_2\,kT$	1
	6.68×10^{-27} kg $\times\ c_{RMS}^2 = 3 \times 1.38 \times 10^{-23}$ J K^{-1} $\times$ (25 + 273) K	1
	c_{RMS} = **1.4 × 10^3 m s^{-1}**	1
5(a)(ii)	*either*: kinetic energy of one atom = $1.5 \times 1.38 \times 10^{-23} \times (25 + 273)$ J *or*: 1.00 mol contains 6.02×10^{23} atoms	1
	total kinetic energy = $6.02 \times 10^{23} \times (1.5 \times 1.38 \times 10^{-23} \times 298)$ J **= 3710 J**	1
5(a)(iii)	internal energy = total kinetic energy + total potential energy (of atoms)	1
	potential energy (of atoms in an ideal gas) is zero	1
5(b)	<u>sketch</u>: straight line with positive gradient between θ = –269 °C and 25 °C	1
	line with positive gradient, passing through (25, 3710), and (if necessary, when extrapolated) passing through (–273, 0)	1
5(c)	volume of gas so low that volume of molecules is not negligible (in comparison)	1
	either: particles so slow-moving that intermolecular forces become significant *or*: particles so close together that intermolecular forces become significant	1

Question	Answer	Marks
6(a)(i)	line starting at (1, 0), rising to a peak and then decreasing less quickly than it increased	**1**
	Peak at 56 OR peak anywhere above 'Fig 6.1' OR gentle enough fission slope (Peak is 8.8 MeV with U about 7.5 MeV) a drop of 15%. Allow a drop of 33% a third	**1**
6(a)(ii)	fusion involves nuclei with small A joining together <u>and</u> fission involves nuclei with large A splitting into two smaller ones	**1**
	in both processes, binding energy <u>per nucleon</u> increases	**1**
	greater binding energy per nucleon means energy released	**1**
6(b)	Δm = [235.043930 – (143.922953 + 88.917636 + (2 × 1.008665))] u = 0.186011 u	**1**
	$E = \Delta m\, c^2$ <u>and</u> Δm=mass in u x value of mass u OR $E = 0.186011 \times 1.66 \times 10^{-27}\ \text{kg} \times (3.00 \times 10^{8}\ \text{m s}^{-1})^2$ OR $E = 2.78 \times 10^{-11}\ \text{J}$	**1**
	Number of atoms = N_A x mass of sample/ molar mass or mass of sample/ mass of 235 nucleons $N = 15.0\ \text{kg} / (235 \times 1.66 \times 10^{-27}\ \text{kg})$ OR $N = (15\,000\ \text{g} \times 6.02 \times 10^{23}) / 235\ \text{g}$ $N = 3.85 \times 10^{25}$	**1**
	energy released = $3.85 \times 10^{25} \times 2.78 \times 10^{-11}$ J = $\mathbf{1.1 \times 10^{15}\ J}$	**1**

Question	Answer	Marks
7(a)(i)	three vertical parallel lines to the left of the printed line, such that the spacing of the four lines increases from left to right	**1**
7(a)(ii)	evidence (from application of $13.6 / n^2$ equation or otherwise) that the line is caused by the $n = 3$ to $n = 2$ transition	**1**
	evidence of conversion from eV to J by multiplying by 1.60×10^{-19}	**1**
	energy = $[(13.6 / 2^2) - (13.6 / 3^2)] \times 1.60 \times 10^{-19}$ J = $3.02(22) \times 10^{-19}$ J 3.40 eV 1.51 eV	**1**
7(a)(iii)	$E = hf$ <u>and</u> $\lambda = c / f$ OR $\lambda = hc / E$	**1**
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (3.02 \times 10^{-19})$ = $\mathbf{6.59 \times 10^{-7}}$ **m**	**1**
7(b)(i)	$v = H_0 d$	**1**
	= 2.3×10^{-18} s^{-1} $\times 1.2 \times 10^{25}$ m = $\mathbf{2.8 \times 10^{7}}$ **m s^{-1}**	**1**
7(b)(ii)	redshift (or Doppler) causes the apparent wavelength (to be greater)	**1**
7(b)(iii)	$\Delta\lambda = (6.59 \times 10^{-7}$ m$)(2.8 \times 10^{7}$ m s$^{-1}) / (3.0 \times 10^{8}$ m s$^{-1})$ = 0.62×10^{-7} m	**1**
	$\lambda_0 = (6.59 + 0.62) \times 10^{-7}$ m = $\mathbf{7.21 \times 10^{-7}}$ **m**	**1**

Question	Answer	Marks
8(a)	harder (owtte) to start flywheel rotating	**1**
	harder to stop flywheel rotating	**1**
8(b)(i)	Rate of change of angular velocity (with time) Rate of change of rate of rotation Newton II relating $F=ma$ to $\Gamma = I\alpha$	**1**
8(b)(ii)	α = change in angular velocity/time change in angular velocity = (8.0 m s^{-1} – 2.5 m s^{-1}) / 0.35 m	**1**
	α = 15.71 rad s^{-1} / 36 s	**1**
	= **0.44 rad s^{-2}** (0.4365)	**1**
8(c)(i)	$\omega = v / r$ <u>and</u> energy = ½ $I\omega^2$	**1**
	ω = (12 m s^{-1}) / (0.35 m) = 34 rad s^{-1} energy = 0.5 × 0.200 kg m^2 × (34 rad s^{-1})^2	**1**
	= **118 J**	**1**
8(c)(ii)	ke = ½ mass × speed^2 = 0.5 × 75 kg × (12.0 m / s)^2 **= 5400 J**	**1**
8(d)	Identifying the element to integrate as a thin ring of mass $\rho 2\pi x dx$	**1**
	Integrating d$I = \rho 2\pi x$ dx x^2.to $I = \rho 2\pi r^4 / 4$.	**1**
	Recognising mass is $\rho\pi r^2$.	**1**
	so $I = Mr^2 / 2$.	**0**

Question	Answer	Marks
8(e)(i)	Sliding ½ $mv^2 = mgh$ or ½ $v^2 = gh$	**1**
	v (max speed) = sq root $(2 \times 9.81\text{ m s}^{-2} \times 1.5\text{ m} \times \sin(5.0^{\circ})) = 1.6016\text{ m s}^{-1}$	**1**
	time = 1.5 m / (½ × 1.602 m s^{-1}) = **1.9 (1.873) s**	**1**
8(e)(ii)	Rolling ½ (½ $MR^2\omega^2 + Mr^2\omega^2$) = Mgh	**1**
	½ (½ R^2 / r^2 + 1) $r^2\omega^2 = gh$	**1**
	(450 + 1) $v^2 = 2\,gh$ R / r = .150 m / 0.005 m = 30	**1**
	v (max v) = 0.0754 m s^{-1} so time = 1.5 m / (0.5 × 0.0754 m s^{-1}) time = **40 (39.78 or 39.79) s**	**1**
	OR Rolling ½ (½ $MR^2v^2 / r^2 + Mv^2$) = Mgh	**(1)**
	½ (½ R^2 / r^2 + 1)$v^2 = gh$	**(1)**
	(450 + 1) $v^2 = 2\,gh$	**(1)**
	v = 0.0754 m s^{-1} so time = 1.5 m / (0.5 × 0.0754 m s^{-1})	**(1)**

Question	Answer	Marks
9(a)(i)	Work E or W $W = \int_{\infty}^{r} F\mathrm{d}r$ $W = \int_{\infty}^{r} k\dfrac{Q_1Q_2}{r^2}\,\mathrm{d}r$	**1**
	correct limits	**1**
	Evidence of integration for example -1 or square	**1**
9(a)(ii)	Potential energy = $\dfrac{(8.99\times10^{9}\ \mathrm{mF^{-1}})(1.60\times10^{-19}\ \mathrm{C})^2}{(3.0\times10^{-10}\ \mathrm{m})}$ = $\mathbf{7.67\times10^{-19}\ J}$	**1**
9(b)(i)	de Broglie wavelength = 1.6 nm	**1**
	momentum = 6.63×10^{-34} J s / 1.6×10^{-9} m = $\mathbf{4.1\times10^{-25}\ kg\ m\ s^{-1}}$	**1**
9(b)(ii)	$E = p^2/2m$ or from mv and ½ mv^2 = ½ $(4.14\times10^{-25}\ \mathrm{kg\ m\ s^{-1}})^2/(9.11\times10^{-31}\ \mathrm{kg})$	**1**
	= 9.41×10^{-20} J	**1**
	= **0.5897 eV**	**1**
9(b)(iii)	Wavelength is an eighth so energy 64 × bigger or 38 eV	**1**
9(c)(i)	LH side is mass x centripetal acceleration (“centripetal force”) <u>and</u> RH side is force of electrostatic attraction	**1**
	Force of attraction provides (or is) centripetal force (or equals mass x acceleration). It must be clear that there is only one force acting.	**1**

Question	Answer	Marks
9(c)(ii)	angular velocity = v/r <u>and</u> moment of inertia = mr^2 angular momentum = $v/r \times mr^2 = mvr$ OR $L = nh/2\pi$ and $\lambda=2\pi r/n$ $L=2\pi rh/2\pi\lambda. = rh/\lambda = rp = rmv$	**1**
9(c)(iii)	$L^2 = n^2h^2/4\pi^2$ $L^2 = m^2v^2r^2$	**1**
	$\dfrac{n^2h^2}{4\pi^2} = \dfrac{r^3mmv^2}{r} == \dfrac{r^3me^2}{4\pi\varepsilon_0 r^2} = \dfrac{rme^2}{4\pi\varepsilon_0}$	**1**
	Evidence of rearrangement to $r = n^2h^2\varepsilon_0/\pi me^2$	**1**
9(c)(iv)	Energy = $\dfrac{½e^2}{4\pi\varepsilon_0 r}$	**1**
	= $\dfrac{½e^2\pi me^2}{n^2h^2\varepsilon_0 4\pi\varepsilon_0}$	**1**
	= $\dfrac{me^4}{n^2h^2 8\varepsilon_0{}^2}$	**0**
9(c)(v)	Energy = $\dfrac{(9.11\times10^{-31}\,\text{kg})(1.60\times10^{-19}\,\text{C})^4}{8\times(6.63\times10^{-34}\,\text{Js}\times8.85\times10^{-12}\,\text{Fm}^{-1})^2}$	**1**
	= **-2.17×10^{-18}** J (2.1677)	**1**

Question	Answer	Marks
10(a)(i)	At least 2 clockwise on magnetic lines and at least 4 radial away from charge in a variety of directions to make it clear all are away from charge	**1**
10(a)(ii)	B force is at right angles (to line) E force along line	**1**
10(b)(i)	Capacitance = charge / potential difference	**1**
	Clear idea of charge (+)Q on one plate and (–)Q on other	**1**
10(b)(ii)	Flux density = flux / area = (q / ε_0) / A	**1**
	$E = q / \varepsilon_0 A$	**0**
10(b)(iii)	$(C = q / V)$ $V = Ez$ or $E = V / d$	**1**
	$C = q\varepsilon_0 A / zq = \varepsilon_0 A / z$	**1**
10(b)(iv)	Capacitance = $(8.85 \times 10^{-12}\ \text{F m}^{-1})(0.0200\ \text{m}^2) / (5.00 \times 10^{-4}\ \text{m})$ = **354 pF**	**1**
10(c)	It is the speed of light	**1**
10(d)(i)	Current I = extra charge / t = extra capacitance × V / t	**1**
	Area = xw and use in capacitor equation $= \dfrac{\varepsilon_0 xw V}{z t}$	**1**
10(d)(ii)	Speed $v = x / t$	**1**
	$x = \dfrac{Izt}{\varepsilon_0 wV}$	**1**
	$v = \dfrac{Iz}{\varepsilon_0 wV}$	**0**

Question	Answer	Marks
10(d)(iii)	Magnetic flux = flux density x area or formula in any arrangement Extra area at right angles to $B = xz$	**1**
	Change in magnetic flux = $\frac{\mu_0 I}{w}$	**1**
	Change in magnetic flux = $\frac{\mu_0 I xz}{W}$	**0**
10(d)(iv)	Induced voltage V = change in magnetic flux / t = $\frac{\mu_0 I xz}{w\boldsymbol{t}}$	**1**
	= $\mu_0 I vz / w$	**0**
10(d)(v)	Electric $V / I = z / \varepsilon_0 wv$ magnetic $V / I = zv\mu_0 / w$ or substituting for I or V in the other equation	**1**
	$z / \varepsilon_0 wv = zv\mu_0 / w$ or evidence of eliminating z and w $v^2 = 1 / \mu_0 \varepsilon_0$	**1**
10(d)(vi)	$v^2 = 1 / (8.85 \times 10^{-12}\ \mathrm{F\ m^{-1}})(1.26 \times 10^{-6}\ \mathrm{T\ m\ A^{-1}})$ **v = 2.99 × 10^8 m s^{-1}**	**1**
10(d)(vii)	The leading edge of the charge area is moving at the speed of electromagnetic waves	**1**
	An electromagnetic pulse is travelling along system (waveguide)	**(1)**

Question	Answer	Marks
11(a)(i)	time = 2 x 200.00 m / 340.00 m s^{-1} = **1.1765 s**	1
11(a)(ii)	time = $x / (c + v) + x / (c - v)$	1
	OR time = $\dfrac{2xc}{(c^2 - v^2)}$	(1)
11(a)(iii)	time difference = $x / (c + v) + x / (c - v) - 2x / c$ time with wind = $2xc / (c^2 - v^2)$ time difference = $(2x / c) / (1 - v^2 / c^2) - 2x / c$	1
	= $(2x / c)(1 + v^2 / c^2) - 2x / c$ time difference = $2x\, v^2 / c^3$	1
11(a)(iv)	time difference = $2 \times 200 \times 20^2 / 340^3$ s	1
	= **4.1×10^{-3} s** (4.070832 ms)	1
	or time difference = 200 / 360 + 200 / 320 – 400 / 340 seconds	(1)
	= 0.5555555 + 0.6250000 – 1.17647 = 4.08496×10^{-3} so **4.1 ms**	(1)
11(b)(i)	(The luminiferous) aether or ether	1
11(b)(ii)	time difference = $(2 \times 22\ \text{m})(60 \times 10^3\ \text{m s}^{-1})^2 / (300 \times 10^6\ \text{m s}^{-1})^3$	1
	= **5.867×10^{-15} s**	1

Question	Answer	Marks
11(b)(iii)	Period = 1 / frequency = 1 / 520 THz	**1**
	= 1.9×10^{-15} s (1.923)	**1**
	5.867 / 1.923 = 3.0	**0**
11(b)(iv)	The laws of Physics are the same in all (inertial) frames	**1**
	Motion cannot be internally detected	**(1)**
11(c)(i)	Speed = 9.17 km / 31.2 micros = **294 x 10^{6} m s^{-1}**	**1**
11(c)(ii)	31.2 / 1.56 = 20 so 20 half lives	**1**
	$100 \times 10^{6} / 2^{20}$	**1**
	= **95**	**1**
	OR decay constant = ln 2 / 1.56×10^{-6} s = 4.44×10^{5} s^{-1}	**(1)**
	number = $100 \times 10^{6} \times \exp(-4.44 \times 10^{3} \times 31.2 \times 10^{-6})$	**(1)**
	= **95**	**(1)**

Question	Answer	Marks
11(c)(iii)	Muon is travelling close to speed of light so time is different 'in muon'	**1**
	Speed of muon = 294 / 300 c = 0.98 c $(1 - v^2 / c^2)^{½} = 0.20$ or $(1 - v^2 / c^2)^{-½} = 5.0$	**1**
	Muons clock run at 1 / 5 the speed so it is only 4 half lives	**1**
	$100 \times 10^6 / 2^4 = \mathbf{6.25 \times 10^6}$.	**1**
	OR decay constant = ln 2 / ($5 \times 1.56 \times 10^{-6}$ s) = 88.7×10^3 s^{-1}	**(1)**
	number = $100 \times 10^6 \times \exp(-88.7 \times 10^3 \times 10^3 \times 31.2 \times 10^{-6}) = \mathbf{6.25 \times 10^6}$.	**(1)**
	OR decay constant = ln 2 / 1.56×10^{-6} s = 4.44×10^5 s^{-1}	**(1)**
	time = 31.2 microseconds × 0.20 number = 100 x 10^6 ×x $\exp(-4.44 \times 10^3 \times 6.24 \times 10^{-6}) = \mathbf{6.25 \times 10^6}$	**(1)**

Question	Answer	Marks
12(a)(i)	The energy supplied (by heating) to turn unit mass of water (at 100 °C into vapour at 100 °C)	**1**
12(a)(ii)	energy per mole = 0.0180 kg × 2 260 000 J kg^{-1} = 40 680 J	**1**
	energy per molecule = 40 680 J / 6.02×10^{23} **=** $\mathbf{6.76 \times 10^{-20}}$ **J**	**1**
12(a)(iii)	warming ice = 273 × 2090 = 570 570 melting ice = 33 400 warming water = 100 × 4180 = 418 000 Total = 1 021 970 Both shc calculation correct	**1**
	Latent heat correct	**1**
	Total $\mathbf{1.02 \times 10^6}$ **J** correct	**1**

Question	Answer	Marks
12(a)(iv)	energy per molecule = 1.02×10^{6} J $\times$ 0.0180 kg / 6.02×10^{23} **= 3.06×10^{-20} J**	**1**
12(a)(v)	Molecules have a wide range of energies or mention of distribution curve	**1**
	Only molecules with energy above that needed are involved	**1**
12(a)(vi)	Number at 100 / number at 90 = $\dfrac{\exp(-E\,/\,k373\,\text{K})}{\exp(-E\,/\,k363\,\text{K})}$	**1**
	= $\exp(-(6.76 \times 10^{-20}\ \text{J} / 1.38 \times 10^{-23}\ \text{J K}^{-1})(1/373-1/363))$ **= 1.43**	**1**
12(b)	Conversion to kelvin	**1**
	30.5 / 4.8 = $\dfrac{\exp(-\text{energy} \times 1.6 \times 10^{-19} \times (1/278 - 1 \times 298))}{1.38 \times 10^{-23}}$	**1**
	J eV conversion wherever done	**1**
	energy in eV = $\dfrac{-1.38 \times 10^{-23}\ \ln(30.5/4.8)}{(1.6 \times 10^{-19})(1/278 - 1/298)}$	**1**
	= 0.66 eV	**0**
12(c)	Molar to molecular conversion or using *R* instead of *k*	**1**
	warm life / cold life = $\dfrac{\exp(-40.7\,\text{kJmol}^{-1} \times (1/398 - 1/255))}{8.31\,\text{Jmol}^{-1} - \text{K}}$	**1**
	=0.0626 So cold life = 1 year / 0.0626 =16 years	**1**
	So 15 years longer	**0**

Question	Answer	Marks
12(d)	Creep in a polymer Enzyme catalysis Cooking eg pressure cookers Photographic development	**1**
12(e)	There is not a range of energies but defined quanta	**1**

Question	Answer	Marks
13(a)(i)	Use of period square is proportional to radius cubed	**1**
	Period = square root of 100 cubed	**1**
	= 1000 years	**1**
13(a)(ii)	Law of gravity quoted or implied	**1**
	Force ratio = 27 000 000 / 394^2 = **174**	**1**
13(a)(iii)	The number of objects in Universe is huge	**1**
	Each would need calculating power with every other	**1**
	Intelligence bigger than universe	**(1)**
	observational information would need more space than universe	**(1)**
	System is chaotic	**(1)**
	No exact value of G or any other relevant measurement	**(1)**
	Heisenberg argument	**(1)**
13(b)(i)	HUP says 'we cannot measure / know the exact position <u>and</u> the exact momentum for a particle at any given time.' We can only know / calculate the product of the position <u>and</u> the momentum for a particle to a minimum given uncertainty	**1**

Question	Answer	Marks
13(b)(ii)	Range of speed = 0.1 *c* = 30 000 000 m / s Range of momentum = 9.1×10^{-31} kg × 3.0×10^{7} m / s = 27.3×10^{-24} kg m / s Range of position > $\dfrac{6.63 \times 10^{-34}\ \text{J s}}{2\pi(27.3 \times 10^{-24}\ \text{kg m / s})}$	**1**
	3.9 × 10^{-12} m	**1**
13(b)(iii)	We cannot know all information about a single particle	**1**
	We cannot know everything about everything	**(1)**
	So no – quantum mechanics does not support Demon	**0**
13(c)(i)	It happens unpredictably.	**1**
	You cannot know when it will happen	**(1)**
	You cannot change conditions to make it happen – fixed probability	**(1)**
	You cannot know which atom will decay	**(1)**
	Totally spontaneous	**(1)**
13(c)(ii)	mass = 25.00 mg × exp(–ln(2) × 10 / 400)	**1**
	= **24.57 mg**	**1**
13(c)(iii)	(Very) large number of random events	**1**
	Very large number leads to an almost certain outcome (or repeatable probability)	**1**
13(d)(i)	It is more likely energy will go from atoms with more to atoms with less	**1**
	So energy goes from hot to cold because it is the most likely outcome	**1**

Question	Answer	Marks
13(d)(ii)	It is very likely things will become more disordered.	**1**
	This gives arrow of time or words to that effect	**1**
	Second law gives arrow of time	**(1)**