Cambridge Assessment International Education

Cambridge Pre-U

PHYSICS **9792/03**

Paper 3 Written **May/June 2022**

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.

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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.

This document consists of **22** printed pages.

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)	charge / potential difference	**1**
1(b)	$E = ½CV^2$	**1**
	4.5×10^{-3} J = ½ × (250×10^{-6} F) × V^2 leading to V = 6.0 V (0.0045) (0.00025)	**1**
1(c)(i)	$I = I_0 \exp(-t /)$ so ln $(I / I_0) = -t / \tau$ or when t = 1 s time constant, ln $(I / I_0) = -1.0$	**1**
	Values from graph	**1**
	so (reading from graph), time constant = **3.6 s**	**1**
1(c)(ii)	(R =) τ / C or (R =) (3.6 s / (250×10^{-6} F))	**1**
	= **14 000 Ω**	**1**
1(c)(iii)	line with decreasing negative gradient starting at (any) non-zero I when t = 0	**1**
	line starts at I = 0.42 mA (or 0.43 mA) when t = 0	**1**
	line passes through I = 0.15 mA when t = 3.6 s or other appropriate point e.g. 2 half lives, two eeth lives	**1**
	At t = 8 s line between 0.02 and 0.06 mA (between 1 and 3 squares)	**1**

Question	Answer	Marks
2(a)	general formula of form $F = Gm_1m_2 / x^2$	**0**
	Evidence of 3D or 2M being used in it	**1**
	$F = (G \times M \times 2M) / (3D)^2$ so **$F = 2GM^2 / 9D^2$**	**1**
2(b)	$F = mr\omega^2$ <u>and</u> F is the same for both stars	**1**
	$M \times 2D \times \omega_X^2 = 2M \times D \times \omega_Y^2$ and so $\omega_X = \omega_Y$ $(=\omega)$	**1**
2(c)(i)	$2MD\omega^2 = 2GM^2 / 9D^2$ and so $\omega^2 = GM / 9D^3$	**1**
	$E_K = ½mv^2$ and $v = r\omega$	**1**
	$E_X = ½ \times M \times (2D \times \omega)^2 = 2MD^2 \times GM / 9D^3$	**1**
	$= 2GM^2 / 9D$	**0**
2(c)(ii)	$E_Y = ½ \times 2M \times (D \times \omega)^2 = MD^2 \times GM / 9D^3$ $= GM^2 / 9D$	**1**
	$E_P = (–)\ 2GM^2 / 3D$	**1**
	$E = (2GM^2 / 9D) + (GM^2 / 9D) – (6GM^2 / 9D) = – 3GM^2 / 9D$ so **$E = – GM^2 / 3D$**	**1**
2(d)	force (between two objects) must be attractive (for them to orbit around their common centre of gravity)	**1**
	force between identical charges is repulsive, so not possible	**1**

Question	Answer	Marks
3(a)(i)	$F / l = BI(\sin\theta) = 0.34 \times 10^{-3}\ \mathrm{T} \times 5.6\ \mathrm{A}$	**1**
	= $\mathbf{1.9 \times 10^{-3}\ N\ m^{-1}}$	**1**
3(a)(ii)	radial arrows	**1**
	arrows pointing outwards	**1**
3(b)(i)	area = $\pi r^2 = \pi \times (9.3 \times 10^{-2}\ \mathrm{m})^2$	**1**
	flux linkage = $(N)BA$	**1**
	$= (1) \times 0.34 \times 10^{-3}\ \mathrm{T} \times \pi \times (9.3 \times 10^{-2}\ \mathrm{m})^2$ = $\mathbf{9.2 \times 10^{-6}}$ **……….Wb**	**1**
3(b)(ii)	$E = \Delta\Phi / t$	**1**
	$= (2 \times 9.2 \times 10^{-6}) / (0.20 \times 10^{-3})$	**1**
	= **0.092 V**	**1**

Question	Answer	Marks
4(a)(i)	Pressure	**1**
	amount of gas	**1**
4(a)(ii)	pressure: piston is free to move in and out, (so gas remains at atmospheric pressure throughout).	**1**
	amount of gas: cap stops gas leaving or entering the syringe and / or effective piston seal	**1**
4(b)(i)	temperature values are not on thermodynamic / absolute temperature scale	**1**

Question	Answer	Marks
4(b)(ii)	evidence of correct conversion of at least two temperature to Kelvin	**1**
	evidence of correct comparison of ratios to deduce (tentatively) that the results do (support Charles' law)	**1**
4(c)	<u>any three points from:</u> • lubricate syringe to ensure free movement of plunger • *either* heat more slowly to allow more time for gas temperature to equilibrate with water *or* use thermometer inside gas • monitor atmospheric pressure (using barometer) • use thinner syringe / raise water level to top of syringe • take further sets of measurements as system cools • Dry air • Different gas e.g. hydrogen or argon • Stirring water • Greater range of temperatures • More sensitive thermometer • Use of ice • Avoid parallax of volume or thermometer or eye level • Avoid volume of tube on syringe on value of volume • Different liquid to go to higher temps • Measure pressure to ensure it is constant • Different starting volumes	**3**
4(d)	molecules move with more kinetic energy	**1**
	collisions with walls involve greater change in momentum	**1**
	for same pressure, collisions with walls must be less frequent and so molecules must travel further between collisions. Fewer collisions per unit area.	**1**

Question	Answer	Marks
5(a)	number of disintegrations per unit time (or accept per second)	**1**
5(b)(i)	let $N_X = N$ at time zero after 4 half-lives, N_X has halved 4 times, and so $N_X = N / 16$	**1**
	$N_X + N_Y$ must always equal N, so after 4 half-lives, $N_Y = N - N / 16 = 15\,N / 16$	**1**
	so $N_Y / N_X = (15\,N / 16) / (N / 16) = 15$	**1**
5(b)(ii)	using the same reasoning as applied in **(b)(i)**: *either*: at 1 half-life, $N_Y / N_X = 1$ *or*: at 2 half-lives, $N_Y / N_X = 3$	**1**
	reading from graph, half-life = **1.6 s**	**1**
5(b)(iii)	$\lambda = \ln 2 / t_{½}$ $= \ln 2 / 1.6$ s	**1**
	= **0.43 ……………… s^{-1}**	**1**
5(b)(iv)	$N_0 = 2.0 \times 6.02 \times 10^{23}$	**1**
	$A = \lambda N\ A_0 = 0.43$ s$^{-1} \times 2.0 \times 6.02 \times 10^{23}$	**1**
	= **5.2 × 10^{23} Bq**	**1**

Question	Answer	Marks
6(a)	(astronomical) object of known luminosity (for reason other than distance) or absolute magnitude	**1**
6(b)	<u>any two points from:</u> • observations of emission / absorbtion spectrum or spectral lines • comparison of wavelengths in light from object and comparing with known wavelengths from same spectrum on Earth • use of Doppler shift equation $\Delta\lambda / \lambda = v / c$	**2**
6(c)	all five values of lg (L / F) calculated correctly to 2 decimal places	**1**
	all five values of lg (v) calculated correctly to 2 decimal places	**1**
6(d)	all six points plotted correctly (to within ½ small square)	**2**
	line of best-fit	**1**
6(e)	m = **2.0 or 2**	**1**
	c = **36.4**	**1**
6(f)(i)	$v = Kd$ <u>and</u> $F = L / 4\pi d^2$	**1**
	<u>*either*</u>:	
	$\lg(v) = \lg K + \lg(d)$ <u>and</u> $\lg(L/F) = \lg(4\pi) + 2\lg(d)$	**1**
	algebra showing elimination of d to get $\lg(L/F) = \lg(4\pi) - 2\lg K + 2\lg(v)$	**1**
	<u>*or*</u>:	
	elimination of d to get $F = L / 4\pi(v / K)^2$	**(1)**
	algebra showing taking logs and then rearranging to get $\lg(L/F) = \lg(4\pi) - 2\lg K + 2\lg(v)$	**(1)**
6(f)(ii)	(K is the) Hubble constant	**1**

Question	Answer	Marks
6(g)	lg (4π) – 2lg K = 36.4	**1**
	K = **2.2 × 10^{-18} s^{-1}**	**1**

Question	Answer	Marks
7(a)(i)	–13.6 eV / 2^2 = – 3.40 eV	**1**
7(a)(ii)	Balmer (series)	**1**
7(b)	transition is from n = 2 (or –3.40 eV)	**1**
	$\Delta E = hf$ and $c = f\lambda$	**1**
	(13.6 – 3.4) × 1.60 × 10^{-19} = (6.63 × 10^{-34} × 3.00 × 10^{8}) / λ	**1**
	λ = 1.2 × 10^{-7} m = **120 nm**	**1**

Question	Answer	Marks
8(a)(i)	Mom of inertia = 1 / 12 (1.4 m)^3(5.0 × 10^{-4} m^2)(800 kg m^{-3})	**1**
	= 0.09147	**1**
8(a)(ii)	Angular acceleration = Γ / I <u>and</u> angular velocity = ang acc × time	**1**
	Angular acceleration = (0.20 N)(1.4 m / 2) / (0.09147 kg m^2) = 1.531 s^{-2}	**1**
	Angular velocity = (0.50 s)(1.531 s^{-2}) = 0.7653 s^{-1} (0.77 2 sf)	**1**
	or	
	Torque × time = (change in) angular momentum ($I\omega$)	**(1)**
	angular velocity = (0.20 N)(0.70 m)(0.50 s) / (0.09147 kg m^2)	**(1)**
	=0.77 (0.7653) s^{-1}	**(1)**
8(a)(iii)	Rot ke = ½ $I\omega^2$	**1**
	Rot ke = 0.5 (0.09147 kg m^2)(0.7653 s^{-1})^2 = 0.027 J (0.02678 J)	**1**
8(a)(iv)	Integrating $\rho A r^2$ dr from 0 to L or equivalent and	**1**
	using $m = \rho AL$ leading to	**1**
	I = 1 / 3 mL^2.	**1**
	or viewing rod as half of the rod length 2 L rotating about centre	**(1)**
	Allowing for double mass leading to	**(1)**
	I = 1 / 3 mL^2.	**(1)**

Question	Answer	Marks
8(a)(v)	Showing or stating moment of inertia of pencil is **smaller** than longer rod	**1**
	Calculation or explanation than moment of inertia is **MUCH** smaller (Volume or mass 1 / 100 and L^2 1 / 100 so momentum of I 1 / 10 000)	**1**
	A force (or torque) will produce bigger angular velocity for pencil ora	**1**
	Not time to react **or** any correcting force unlikely to be right size **or** A small force can more easily topple the pencil	**1**
8(b)(i)	Mass = $\rho\pi r2l$ so $r = (m / (\pi\ l\rho)^{½}$ $r = (0.193\text{ kg} / (\pi \times 0.06\text{ m} \times 4000\text{ kg m}^{-3})^{½}$ $=1.6 \times 10^{-2}$ m	**1**
	or mass of P = mass of outer bit of Q + mass of inner bit of Q Mass of P = 1.528 kg $= 4000\text{ kg m}^{-3} \times L \times \pi \times r^2 + 11\,000\text{ kg m}^{-3} \times L \times \pi \times ((0.030\text{ m})^2 - r^2)$ $9 \times 30^2 = 4 \times r^2 + 11(30^2 - r^2)$ $7\ r^2 = 2 \times 900\ r = (2 / 7)^{½}\ 30 = 16.03$	**(1)**
8(b)(ii)	M of I of inner = $½ \times 0.193\text{ kg} \times (0.016\text{ m})^2 = 2.4704 \times 10^{-5}\text{ kg m}^2$	**1**
	M of I of sleeve $= ½ \times 1.\ 335\text{ kg} \times ((0.03\text{ m})^2 + (0.016\text{ m})^2)$ $= 7.716 \times 10^{-4}\text{ kg m}^2$	**1**
	Total $= 8.0 \times 10^{-4}\text{ kg m}^2$ $(7.963 \times 10^{-4}\text{ kg m}^2)$	**1**
8(b)(iii)	Reference to both Rotational and Translational kinetic energy	**1**
	Same energy change to ke but Q has a lower proportion of translational ke or it has more rotational ke	**1**

Question	Answer	Marks
9(a)(i)	The work done per unit charge in moving a(infinitesimal) charge	1
	(Charge) from infinity to the point	1
9(a)(ii)	A scalar quantity(has size or magnitude) but NOT direction	**1**
9(a)(iii)	(Electric field strength which is a vector quantity) because it has direction.	**1**
9(b)	Idea of integrating $-F\mathrm{d}r$ from *a* to *b* and it involves integral of $r^{-2}\,\mathrm{d}r$ $W = -\int_a^b F dr = -\int_a^b k\frac{Q_1Q_2}{r^2}\mathrm{d}r$	**1**
	Correct integration to (–)1 / *r*	**1**
	$W = -kQ_1Q_2((-1/b) - (-1/a)) = -kQ_1Q_2((1/a) - (1/b)) = kQ_1Q_2(1/b - 1/a)$ Putting in limits with correct signs so rearrangement is $(a-b)/ab$ or $(b-a)/ab$	**1**
9(c)(i)	Recognising it is sum of three potentials	**1**
	Pot$l$ = $8.99 \times 10^9 \times ((2 \times 4 \times 10^{-9} / 0.040) - (4 \times 10^{-9} / 0.08 \sin 60))$ V	**1**
	or using $AM^2 = (80\text{ mm})^2 - (40\text{ mm})^2$	**(1)**
	= 1279 V = 1.3 kV Evidence of calculation	**1**
9c(ii)	Anywhere between A and N but not A or N	**1**
9(d)(i)	Distances to charges all the same so potential due to A(–8.0 nC) is same size as sum of potentials due to B and C. Opposite sign so sum is zero.	**1**

Question	Answer	Marks
9(d)(ii)	$E = 9 \times 10^9 \times 8 \times 10^{-9} / (0.0462)^2$ V m^{-1}	1
	$= 33.7 \times 10^3$ Vm^{-1}	1
	Direction up the page	1
9(d)(iii)	Half answer to **(ii)** 16.9×10^3 V m^{-1}	**1**
	$E = 9 \times 10^9 \times 4 \times 10^{-9} / (0.0462)^2$ V m^{-1} $= 16.9 \times 10^3$ V m^{-1}	**(1)**
9(d)(iv)	Recognising vertical component of answer to **(iii)** is ½ or cos 60° × size so E from B and C is 16.9×10^3 V m^{-1}	**1**
	Field strength at N is $3 \times 16.9 \times 10^3$ V m^{-1}	**1**
	Force = 50.7×10^3 V m^{-1} $\times 1.0 \times 10^{-9}$ C = 5.1×10^{-5} N	**1**
	Up	**1**

Question	Answer	Marks
10(a)(i)	$a = F / m$ or $v = u + at$ (or $v = at$)	**1**
	$(v =)\ Ft / m$	**1**
10(a)(ii)	$W = Fs$ and $s = \frac{1}{2} at^2$ (or $v^2 / 2a$)	1
	$(W = F\ \frac{1}{2}\ (F / m)\ t^2 =)\ \frac{1}{2} F^2t^2 / m$	1
10(a)(iii)	$(W = \frac{1}{2} F^2t^2 / m$ and$)\ v^2 = F^2t^2 / m^2$	**1**
	Answer **(a)(ii)** multiplied by m / m to give $(m / 2)(F^2t^2 / m^2)$ and substitute in for $F^2t^2 / m^2 = v^2$ $= \frac{1}{2} mv^2$	**1**

Question	Answer	Marks
10(b)	Not all bricks are lifted to height h so less than *mgh* or centre of mass is not at the top	**1**
	Average height lifted is ½ h or centre of mass is at ½ h	**1**
10(c)(i)	Force = 0.20 kg × 9.81 N kg^{-1} Extension, x = 0.20 kg × 9.81 N kg^{-1} 80 N m^{-1} =0.0245 m (0.025 m)	**1**
	Elastic pot$l$ energy = ½ kx^2 = 0.024 J (0.02406 J, 24 mJ, 2.4 × 10^{-2} J)	**1**
10(c)(ii)	New total = ½ × 80 N m^{-1} × (0.0245 m + 0.015 m)^2 = 0.06248 or 62 mJ	**1**
	(62 mJ – 24 mJ = 38 mJ) Change in elastic energy = 0.038 (38 mJ , 3.8 × 10^{-2} J)	**1**
10(c)(iii)	Change in gpe = 0.20 kg × 9.81 N kg^{-1} × 0.015 m	**1**
	= 0.02943 J 29 mJ	**1**
10(c)(iv)	Res force = 80 N m^{-1} × (0.0245 m + 0.015 m) – 1.962 N = 1.2 N (1.198 N)	**1**
10(c)(v)	angular velocity^2= F_{res} / mx , or a = –angular velocity$^2 x$ and $F = ma$ or angular velocity^2 = k / m or equivalent	**1**
	$\underline{\omega^2}$= 400 s^{-2}	**(1)**
	ω = 20 s^{-1}	**1**
10(c)(vi)	Energy = ½ $m A^2 \omega^2$ = 0.5 × 0.20 kg × (0.015 m)^2(20 s^{-1})^2 J	**1**
	= 0.0090 J 9.0 mJ = 9 × 10^{-3} J	**1**
10(c)(vii)	On starting oscillation elastic energy goes up 38 mJ and gpe goes down 29 mJ So energy to oscillation is 38 mJ –29 mJ = 9 mJ = 9 × 10^{-3} J	**1**

Question	Answer	Marks
11(a)(i)	Circles with wire at centre with clockwise arrows OR circles closer together near wire	**1**
	Circles with wire at centre with clockwise arrows AND circles closer together near wire	**1**
11(a)(ii)	Magnetic field lines are loops (because there are no monopoles)	**1**
11(a)(iii)	The direction of the field changes	**1**
	The field gets stronger and weaker	**1**
11(b)(i)	(current is) zero	**1**
11(b)(ii)	(the electric field) is changing size (magnitude)	**1**
	(the electric field) is changing direction	**1**
	The field is uniform (across the space)	**(1)**
11(b)(iii)	The emf induced is proportional to the rate of change	**1**
	of the magnetic flux (linked by the circuit)	**1**
	correct reference to Lenz's Law e.g. the induced emf is opposite to change causing it	**(1)**
11(b)(iv)	Electric field, $E = V / x$	**1**
11(b)(v)	The changing electric field	**1**
11(c)(i)	The (luminiferous)aether	**1**
11(c)(ii)	The speed of em waves is the same regardless of the frame of reference in which it is measured or speed is invariant	**1**
	The laws of physics are the same in any inertial frame of reference	**1**
11(d)	$(1 - (130/300)^2)^{½} = 0.901$	**1**
	Frequency = 5×0.901 Hz = 4.506 Hz	**1**

Question	Answer	Marks
11(e)	u/c is very small $L = L_0(1 - (u/c)^2)^{½}$ so $L \approx L_0(1 - ½\,(u/c)^2)$	**1**
	change in L = 4.0 m (½ (30 / 3 × 10^8)^2)	**1**
	Change in length = 4.0 m × ½ × 10^{-14} = 2.0 × 10^{-14} m	**1**

Question	Answer	Marks
12(a)(i)	The temperature of the gas does not change	**1**
	The average speed / ke of the molecules does not change	**1**
12(a)(ii)	The pressure will decrease (halve)	**1**
	The molecules are hitting any area less frequently	**1**
12(a)(iii)	The entropy of the gas will increase	**0**
	There are more possible arrangements in the larger space	**1**
12(b)	The entropy would need to decrease or contrary to 2 Law of TD	**1**
12(c)(i)	(The temperature increases) because speed / ke increases because	**1**
	The molecules speed increases on hitting the moving piston	**1**
12(c)(ii)	(The pressure increases) because the molecules hit walls harder	**1**
	and more frequently	**1**
12(c)(iii)	The entropy increases	**1**
	Because (though fewer spatial arrangements) higher speed / energy means more arrangements in total	**1**

Question	Answer	Marks
12(d)(i)	$\Delta S = 6.0 \times 10^{3}$ J / 300 K = 20 J K^{-1}.	**1**
12(d)(ii)	293 and 253 seen	**1**
	4 J / 293 K – 4 J / 253 K =(–)2.16 × 10^{-3} J K^{-1}	**1**
	minus sign correct	**1**
12(d)(iii)	From B to A so that total entropy increases	**1**
12(d)(iv)	Energy into room is 60 000 J	**1**
	Entropy increase of room = 60 000 J / 293 K = 204.778 J K^{-1} <u>and</u> Entropy decrease of freezer = 50 000 J / 253 K = 197.628	**1**
	Size of entropy change is 7.15 + J K^{-1}. (204.778 – 197.628)	**0**
	Sign of entropy change of whole system is positive so possible	**1**

Question	Answer	Marks
13(a)(i)	Time = 141 mm / 3.00 × 10^8 m s^{-1} + 141 mm / 2.00 × 10^8 m s^{-1} =	**1**
	= 1.175 ns to 1.179 ns From 141 mm from 100 root2	**1**
13(a)(ii)	Dist air = $(0.100^2 + 0.150^2)^{½}$ m = 0.180 m <u>or</u> dist glass = $(0.100^2 + 0.050^2)^{½}$ m = 0.112 m	**1**
	Time = 180 mm / 3.00 × 10^8 m s^{-1} + 112 mm / 2.00 × 10^8 m s^{-1} =	**1**
	= 1.16 ns	**1**
13(a)(iii)	sin θ *1*= 150 / 180 = 0.833 <u>and</u> sin θ 2 = 50 / 112 = 0.446	**1**
	Ratio = 1.86	**1**
	Refractive index = 3 × 10^8 / 2 × 10^8 = 1.5	**1**
	1.87 not equal to refractive index of 1.5	**1**
	So not shortest time route	**(0)**
	or *i* = $\tan^{-1}$(150 / 100) = 56.3 sin 56.3 = 0.83 *r* = $\tan^{-1}$ (50 / 100) = 26.6 sin 26.6 = 0.45	**(1)**
13(b)(i)	<u>Two</u> stripes	**1**

Question	Answer	Marks
13(b)(ii)	Many fringes	**1**
	Gradual change in brightness. Sketch or graph	**1**
	Fringe separation = wavelength × distance / slit separation	**1**
	Fringe separation = 600 nm × 3.0 m / 0.40 mm = 4.5 mm	**1**
	Reference to diffraction envelope (sketch)	**(1)**
13(c)(i)	Copenhagen- wave function (collapses)	**1**
	(The act of observation causes) collapse	**1**
13(c)(i)	Feymann – All routes taken	**1**
	Routes superpose (other than classical route they cancel)	**1**
13(c)(iii)	All possible events happen in a multitude of universes	**1**
	We only see what happens in one	**1**