2224 – 6709M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2024

Physics

Higher level

Paper 3

30 pages

Subject Details: Physics HL Paper 3 Markscheme

Candidates are required to answer **all** questions in Section A and **all** questions from **one** option in Section B. Maximum total = **45 marks**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative wording is indicated in the "Answers" column by a slash (*/*). Either wording can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading ***ALTERNATIVE 1*** *etc*. Either alternative can be accepted.

8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.

9. Words that are underlined are essential for the mark.

10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

11. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

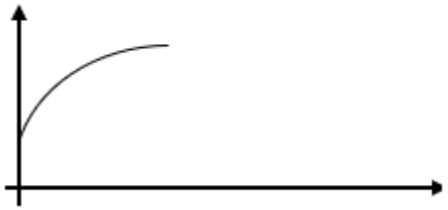
12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script. "ECF acceptable" will be displayed in the "Notes" column.

14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

Section A

Question			Answers	Notes	Total
1.	a	i	identifies *m* as a controlled variable ***OR*** recognizes that «the variation of» *m* affects *T* ***OR*** identifies d as the independent variable **OR** relationship between d and T could not be found if m changes ***OR*** acknowledges that only one variable is to be changed at a time ***OR*** highlights the need of the same conditions throughout the experiment ✓	*OWTTE.*	**1**
	a	ii	no, as the fit does not go through the origin ✓		**1**
	a	iii	amplitude/angle of release / use of small angle ***OR*** number of oscillations ***OR*** any measurable feature of the cable, e.g. length or diameter ***OR*** any measurable feature of the rod **OR** cable holding the rod at its mid-point ***OR*** shape of masses ✓	*Do not accept **same** cable/rod/ spheres without any other reference.* *Do not accept any environmental reference as e.g. temperature.*	**1**
	b		«identifies 3.4 = A*m* so» A = 85 ✓ unit is $s^2\ kg^{-1}\ m^{-2}$ ✓	*Ignore unit and award [1] max for a final answer of 0.085.*	**2**

	c		correct shape of graph ✓  intercept on *T* axis is not zero ✓		**2**

Question			Answers	Notes	Total
2.	**a**		uncertainties are small / negligible ***OR*** variables can be measured precisely ✓	*Award [1] if the answer specifically refers to the specific heat capacity of water as known/constant value.*	**1**
	b		(25 ± 1 so) 4% ✓		**1**
	c		$0.095 \times 4200 \times 25 = 0.025 \times (L + 4200 \times 20)$ ✓ $L = \frac{0.095x4200x25}{0.025} - 4200x20$ ***OR*** $L = 315000$ «Jkg^{-1}» ✓	*MP2 scores MP1* *Do not apply ECF from MP1.* *Answer given, so award MP2 if candidates show a correct full expression for L **OR** the value with an extra significant figure.*	**2**
	d		0.064 x 3.2x10^5 ***OR*** 0.064 x 3.15x10^5 ***OR*** 20480 ***OR*** 20160» ✓ 2 x10^4 «Jkg^{-1}» ✓	*For MP2, accept two significant figures for the answer, i.e. 2.0x10^4* *For MP2, accept a final answer of 20000.* *MP2 scores MP1*	**2**
	e		there is more thermal energy/mass/extra term in the L.H.S of the equation/thermal energy provided by the container ***OR***	*MP1 can be expressed in a variety of ways.*	**2**

			mass of container has made the final temperature higher/ΔT smaller ✓ *L* should be greater than calculated / is an underestimate ✓	*Award [1] max if they interpret that the container takes thermal energy, assuming it was at room temperature, regardless of the conclusion* *Do not accept MP2 if no reason given.* *Do not apply CON and award [1] if conclusion inconsistent with correct MP1*	

Section B

Option A — Relativity

Question			Answers	Notes	Total
3.	**a**		there is no relative velocity/change in position between Y and the electron ***OR*** both move at the same velocity ✓		**1**
	b		«electron experiences changing» magnetic field approaching thus creating a «changing» electric field ✓ no magnetic force on a stationary electron ✓ electric force on the electron ✓		**2 max**
	c	**i**	correct use of relativistic addition of velocities formula e.g. $v = \frac{1.8\times10^8 - 1.5\times10^8}{1-\frac{1.8\times10^8\times1.5\times10^8}{(3\times10^8)^2}}$ or $v = \frac{0.6\,c - 0.5\,c}{1-\frac{0.6\,c\times0.5\,c}{c^2}}$ ✓ $= 0.14c$ ✓	*Award [2] for a BCA* *Ignore sign for MP2* *Do not apply ECF for MP2*	**2**
	c	**ii**	time/length is no longer absolute/depends on the frame of reference ***OR*** speed of light «in vacuum» is constant/ independent of the velocity of the source ***OR*** relative velocity between objects cannot be larger than *c* ✓		**1**

Question			Answers	Notes	Total
4.	**a**		$\gamma = \frac{1}{\left(1-0.4^2\right)^{0.5}}$ ***OR*** γ = 1.09 ✓ *d* = «2.0 × 10^8/1.09 =»1.8 × 10^8 «km» ✓	*Allow ECF for MP2* *Allow BCA*	**2**
	b	**i**	$c\Delta t = d + v\Delta t$, «so $\Delta t = \frac{d}{c-v}$» ✓ $\Delta t = \frac{3\times10^9}{0.6\times3\times10^8}$ «s» **OR** 16.7 «s» ✓	*Answer of 17 s given, so award MP2 if candidates show a correct full substitution **OR** the value with an extra significant figure.*	**2**
	b	**ii**	use of $\Delta t' = \gamma\left(\Delta t - \frac{v\Delta x}{c^2}\right)$ ✓ $\Delta t' = 1.09\times\left(16.7 - \frac{0.4c\times c\times16.7}{c^2}\right) =$ 11 «s» ✓	*Award [2] for a BCA*	**2**

Question			Answers	Notes	Total
5.	**a**	**i**	use of inverse of gradient of *ct'* axis ✓ v = 0.6c ✓	*Award [2] for a BCA*	**2**

	a	**ii**	draws axis *x'* through B and D ✓		**1**
	b		A and D ✓		**1**
	c		line shown parallel to *x'* ✓ through C ✓	*Accept answer C without working for MP2*	**2**
	d		shows 45° lines from A and D ✓ that meet on the *ct'* axis ✓		**2**

Question			Answers	Notes	Total
6.	a		total energy **OR** sum of rest and kinetic energy ✓		1
	b		attempt to use $E^2 = p^2c^2 + m_o^2c^4$ for any of the pions ✓ $(210 + 140)^2 = (pc)^2 + 140^2$ ***OR*** «p = » 321 « $MeVc^{-1}$» ***OR*** $(48 + 135)^2 = (pc)^2 + 135^2$ ***OR*** «p = » 124 «$MeVc^{-1}$» ✓ «applies conservation of momentum so» 312 - 124 «$MeVc^{-1}$» ***OR*** 197 «$MeVc^{-1}$» ✓		3
	c		attempt to use $E^2 = p^2c^2 + m_o^2c^4$ for the kaon ✓ «Rest energy of kaon» $= (533^2 - 197^2)^{0.5}$ ***OR*** 495 « $MeVc^{-2}$ » ✓ «$= \frac{495\times10^6\times1.6\times10^{-19}}{(3\times10^8)^2}$ =»	*MP2 can be 495 or 494* *Award [3] for a BCA*	3

			8.8×10^{-28} «kg» ✓	*Allow ECF from MP2 to MP3*	

Question			Answers	Notes	Total
7.	**a**		accelerated frames of reference are equivalent to frames in a gravitational field ✓	*OWTTE*	**1**
	b		mention of gravitational red shift ***OR*** clocks are at different positions «from a massive body » ***OR*** at a higher potential «than on Earth» ✓ there is a frequency/period shift ***OR*** clocks will run differently «than on Earth» ***OR*** clocks need to be adjusted ✓		**2**

Option B — Engineering physics

Question			Answers	Notes	Total
8.	**a**	**i**	quotes $I = \Sigma mr^2$ with r = «perpendicular» distance to axis ***OR*** resistance to change in rotation ***OR*** ratio of torque «applied» to angular acceleration ***OR*** analog to mass in rotational mechanics ✓	*In MP1, accept r = radius.* *In MP2, do not accept resistance to rotation.* *In MP3 accept the expression as a formula if both symbols identified.*	**1**
	a	**ii**	Net torque/moment is zero ✓		**1**
	a	**iii**	$\frac{1}{12}2M\,(2L)^2 = \text{«}\frac{8}{12}ML^2 = \frac{2}{3}ML^2\text{»}$ ✓		**1**
	b		$\frac{2}{3}\times 2.2\times 0.6^2$ ***OR*** $\frac{1}{12}\times 4.4\times 1.2^2$ ***OR*** 0.53 «kg m^2» ✓	*Answer of 0.5 kg m^2 given, so award the mark if candidates show a correct full substitution **OR** the value with an extra significant figure*	**1**
	c	**i**	«angular acceleration = $\frac{torque}{I}$ =»	*Allow ECF from MP1* *Award [2] for a BCA*	**2**

			$\frac{140}{0.53}$ ***OR*** 264 «rad/s» ✓ t = «$\frac{\text{angular velocity}}{\text{angular acceleration}} = \frac{750}{264}$ = » 2.8 «s» ✓		
	c	**ii**	«$\omega^2 = 2\alpha\theta$» $\theta = \frac{750^2}{2\times 264}$ ***OR*** 1065 «rad» ***OR*** «r$\theta = \frac{\omega}{2}\times t$» = $\frac{750}{2}\times 2.8$ ***OR*** 1050 «rad» ✓ n = $= \frac{1065}{2\pi}$ = 170 ✓	*Follow the calculations as there can be other slight changes in the results, e.g. if they use 2.7 s.* *Allow ECF from MP1 and from c) i)* *Accept alternative methods through other rotational kinematics equations.*	**2**
	d		«$\alpha =$» $\frac{750}{5}$ ***OR*** 150 «rad/s^2»\ ***OR*** «L = » 0.53 x 750 ***OR*** 398 «kg m^2/s » ✓ «torque = 0.53 x 150 =» 80 «Nm» ***OR*** « Rate of change in angular momentum =» 398/5 = 80 «Nm» ✓	*Follow the calculations as there can be other slight changes in the results.* *Ignore sign of final answer*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>9.</td><td>a</td><td></td><td>V = $\frac{0.007\times8.31\times200}{120000}$ OR 9.7x10^{-5} «m^3»✓</td><td>Answer given, so award the mark if candidates show a correct full substitution OR the value with an extra significant figure</td><td>1</td></tr>
<tr><td></td><td>b</td><td></td><td>T = $\frac{1.3\times10^{-4}\times200}{9.7\times10^{-5}}$

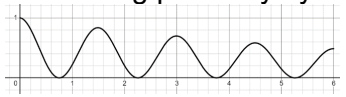
OR
T = $\frac{120\times10^{3}\times1.3\times10^{-4}}{0.007\times8.31}$

OR
268 «K» ✓</td><td>Accept 260 if 1x10^{-4} used

Answer of 270 K given, so award the mark if candidates show a correct full substitution OR the value with an extra significant figure</td><td>1</td></tr>
<tr><td></td><td>c</td><td></td><td>uses PV$^{5/3}$ = constant ✓
V = 4.9x10^{-5} «m^3» ✓</td><td>Accept 4.95 or 5</td><td>2</td></tr>
<tr><td></td><td>d</td><td>i</td><td><table><tr><td></td><td>Change in Q</td><td>Change in U</td><td>W</td><td></td></tr><tr><td>A - B</td><td>+</td><td>+</td><td>+</td><td>✓</td></tr><tr><td>B - C</td><td>0</td><td>+</td><td>-</td><td>✓</td></tr><tr><td>C - D</td><td>-</td><td>-</td><td>-</td><td>✓</td></tr><tr><td>D - A</td><td>0</td><td>-</td><td>+</td><td>✓</td></tr></table></td><td>One mark per line</td><td>4</td></tr>
<tr><td></td><td>d</td><td>ii</td><td>cycle is anticlockwise so work is negative
OR
work in BCD is larger than work in DAB
OR
work is negative so Q is negative/released «as delta U = 0 » ✓</td><td></td><td>1</td></tr>
</table>

	e		Q released to surroundings so S increases ***OR*** entropy of Universe must increase so S increases ***OR*** since S increases then disorder increases ✓		**1**

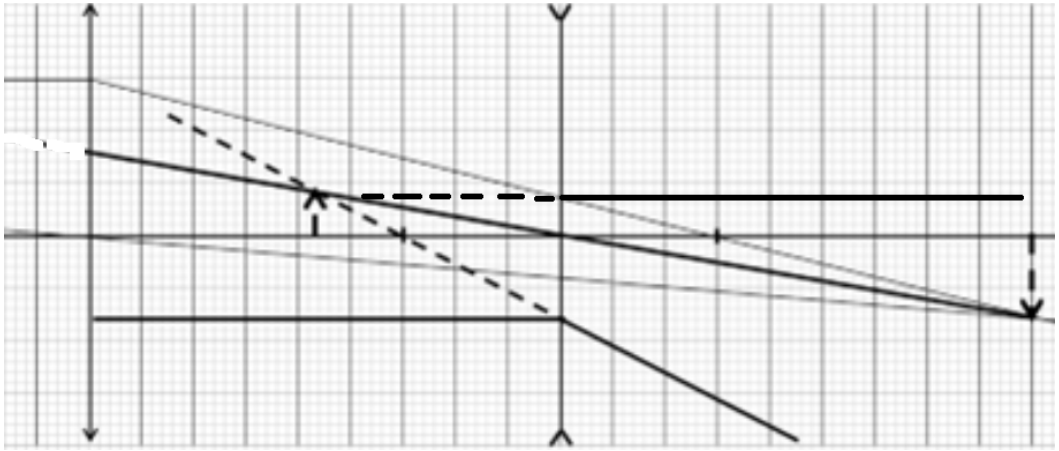
Question			Answers	Notes	Total
10.	**a**		$6\pi R\eta v = \frac{4}{3}\pi R^3 \rho g$ ✓ manipulation to show ✓		**2**
	b		correct substitution ✓ 0.0032 «Pa s» ✓	*Award [1] if there is a POT error in the calculation* *Apply ECF from MP1*	**2**
	c		Reynolds number = 33 or 35 ✓ «comparison with limit for laminar flow» is laminar ✓	*Allow ECF from b).* *Allow use of diameter in calculation of Reynolds number (R) so R is double.* *Allow ECF for MP2 with consistent conclusion.*	**2**

Question			Answers	Notes	Total
11.	**a**		$Q = 2\pi \frac{1}{1-0.7} = 21$ ✓		**1**
	b	**i**	periodic curve with maxima every 1.5 s ✓ decreasing height of peaks ✓	Example of the expected graph. Allow decreasing peaks by eye. 	**2**
	b	**ii**	0.7^5 = 0.17 «m» ✓	*Award [1] for a BCA*	**1**

Option C — Imaging

Question			Answers	Notes	Total
12.	**a**	**i**	«for the image to be smaller in a converging lens it must be inverted so» $\text{«}M = \frac{h_i}{h_o} = -\text{»}\ \frac{v}{u} = \text{« - »}\ \frac{1}{2}$ ***OR*** $\frac{1}{f} = \frac{1}{u} + \frac{2}{u}$ ✓ $u = 3f$ ✓	*MP1 for v =* $\frac{u}{2}$ *or its use in the lens equation.* *MP2 scores MP1*	**2**
	a	**ii**	one ray correct with object further than $2f$ ✓ second ray drawn and image found smaller and inverted ✓		**2**
	b	**i**	erect ***OR*** virtual ***OR*** diminished ***OR*** image always on the same side as the object ***OR***	*Award [0] if more than one feature stated and any one is wrong.*	**1**

			v smaller than f ***OR*** v smaller than u ✓		
	b	**ii**	«M = » $\frac{1}{2} = -\frac{v}{u}$ ***OR*** v = $\frac{-u}{2}$ ✓ «- » $\frac{1}{5} = \frac{1}{u} - \frac{2}{u}$ ***OR*** «- » $\frac{1}{f} = \frac{1}{u} - \frac{2}{u}$ ***OR*** u = 5 «cm» ***OR*** u = f ✓	*Ignore sign for MP2* *u = 5 scores MP2 only if MP1 scored.* *Answer is given in the question so check working carefully.*	**2**
	b	**iii**	object at the focus, one ray correctly diverged ✓ another ray and image found of half the height ✓		**2**
	c		new ray drawn towards the intermediate image through centre of diverging lens		**2**

			OR uses the ray coming from distant object originally entering parallel to principal axis, diverging it from the diverging lens parallel to principal axis and extends it back ***OR*** draws a new ray aiming at intermediate image, parallel to principal axis and diverged away from the focus and extends it back ✓ Another one of the above rays drawn ***OR*** image identified within the central square (about half-way between the lenses) and not taller than 1 square ✓ 		

Question			Answers	Notes	Total
13.	a		M «= angular magnification» = $\frac{0.34}{\theta_{moon}}$ ***OR*** $\frac{0.34}{\frac{3500}{380000}}$ ***OR*** M = 37 ✓ « = $M = \frac{f_o}{f_e} = \frac{1100}{f_e} = 37$ so » f_e = 30 «mm» ✓	*Allow ECF for MP2*	**2**
	b	i	have increased our ability to collect information of «celestial» objects ***OR*** detect «celestial» objects not visible «to the naked eye» ***OR*** allow for the analysis of light/radiation to determine distance/luminosity/temperature/velocity/structure of «celestial» objects ***OR*** Mention of any large astronomical reflecting telescope, e.g. Hubble/James Webb/Planck/WMAP ✓	*For MP1, MP2 and MP3 accept the reference to any specific celestial object* *For MP4 accept an example of a telescope working on any wavelength.* *Accept other sensible answers*	**1**
	b	ii	there is dispersion / chromatic aberration at the lenses in refracting telescope ***OR*** there is no dispersion/chromatic aberration at the mirror ***OR*** there is only dispersion/chromatic aberration at eyepiece of reflecting telescope ***OR*** no refraction in mirror telescopes ✓		**1**
	b	iii	Cassegrain: rays are reflected «towards the eyepiece» by a convex mirror ***OR*** rays are axial to mirror/exit along mirror axis **OR**	*Allow a sketch which illustrates either telescope.*	**1**

			rays exit «primary» concave mirror through a hole in its center ***OR*** Newtonian: rays are reflected «towards the eyepiece» by a flat/tilted mirror ***OR*** rays are reflected 90º to mirror axis/exit at side ✓		

Question			Answers	Notes	Total
14.	**a**		refractive index/velocity varies with wavelength ***OR*** wavelengths/colors arrive at different times ***OR*** mentions pulse broadening or chromatic dispersion ✓	*Allow reference to change in critical angle so increased refractive losses*	**1**
	b		uses transit time = «= $\frac{d}{\left(\frac{c}{n}\right)}$ » ✓ $t = \frac{10\,000\left(1.45298 - 1.45264\right)}{3 \times 10^8} = 11 \text{ ns}$ ***OR*** t = 10000x1.45298/3x10^8 = 4.84327x10^{-5} ***OR*** t = 10000x1.45264/3x10^8 = 4.84213x10^{-5} ✓ $11 \text{ ns} + 1 \text{ ns} = 12$ «ns» ✓		**3**

Question			Answers	Notes	Total
15.	**a**		20 keV attenuation/coefficients quite different «for muscle and bone» ***OR*** 100 keV attenuation/coefficients almost the same ✓ «hence » better contrast with 20 keV ✓	*Accept reverse conclusion*	**2**
	b		$d = \frac{\ln 2}{7.2}$ ***OR*** 0.096 «cm» ***OR***	*Answer of 1 mm given, so award the mark if candidates show a correct full substitution **OR** the value with an extra significant figure*	**1**

			$\frac{I}{I_0} = e^{-0.1\times7.2}$ ***OR*** $\frac{I}{I_0} = 0.49$ ✓		
	c	**i**	one decay expression correct i.e. $e^{-2\times0.24}$ or $e^{-2\times0.21}$ ✓ « $\frac{I}{I_0} = e^{2(-0.24-0.21)}$ = $\frac{I}{I_0}$ = » 0.41 ***OR*** « $\frac{I}{I_0}$ = » 41% ✓		**2**
	c	**ii**	two exponential decays «with the overall change in the first 2 cm section smaller than the second 2 cm section by eye» ✓		**1**

Question			Answers	Notes	Total
16.	**a**		high frequencies have better resolution ✓ high frequencies have lower penetration ✓ high frequencies are more attenuated ✓	*Or reverse argument for low frequencies*	**2 max**
	b		gel removes/fills air gap/cancels acoustic differences/makes densities similar ✓ prevents reflection/improves transmission ✓	*OWTTE*	**2**

Option D — Astrophysics

Question			Answers	Notes	Total
17.	**a**		mention of spectrum/spectral lines ✓ lines/wavelengths/transitions are specific for an element ✓	*OWTTE*	**2**
	b		502 «nm» ✓	*Accept 501 or 500* 5.02×10^{-7} *scores [1] if unit (m) stated.*	**1**
	c		(most) orbits of planets are nearly circular/slightly elliptical ***OR*** orbits of comets highly/more elliptical ✓	*OWTTE*	**1**
	d		stellar nucleosynthesis/fusion in stars «for elements up to iron» ✓ supernovae/neutron capture for elements heavier than iron ✓	*OWTTE*	**2**

Question			Answers	Notes	Total
18.	**a**		addition of Alpha Centauri B to the luminosity/brightness of the binary star system ***OR*** combined luminosity/brightness of the binary stars ✓	*OWTTE*	**1**
	b	**i**	$d = \frac{1}{0.76}$ ***OR*** 1.3 «pc» ✓ $d = \frac{3.26 \times 9.46 \times 10^{15}}{0.76}$ ***OR*** d = 4.1x10^{16} «m» ✓	*MP2 scores MP1.* *Answer given, so award MP2 if candidates show a correct full substitution **OR** the value with an extra significant figure*	**2**
	b	**ii**	«$b = \frac{5.7 \times 10^{26}}{4\pi(4.1x10^{16})^2}$ =»2.7×10^{-8} «W/m» ✓	*Accept use of* 4×10^{16}	**1**
	b	**iii**	Use of L = M$^{3.5}$ ✓ $M = \left(\frac{5.7}{3.8}\right)^{\frac{1}{3.5}} M_{\odot}$ ***OR*** $M = 1.12M_{\odot}$ ✓	*Answer given, so award MP2 if candidates show a correct full substitution **OR** the value with an extra significant figure*	**2**
	c	**i**	position of A correct (just above and to the left of the Sun) ✓	*Allow a position from the Sun up to the second drawn star to its left.*	**1**
	c	**ii**	loop via red giants to white dwarves ***OR*** line towards red giants, then white dwarves ✓ red giants and white dwarves' approximate regions labelled ✓	*Allow areas on the upper right-hand and lower left-hand region.*	**2**
	d		«L = E/t and E proportional to M so» t inversely proportional to $M^{2.5}$ ***OR***	*Award [1] for a correct but incomplete reason, e.g. larger luminosity, or smaller mass, with the correct conclusion.*	**2**

			$\frac{t_P}{t_\alpha} = \left(\frac{1.12}{0.12}\right)^{2.5}$ ***OR*** faster fusion rate to hydrogen available in Alpha Centauri A ✓ Proxima Centauri stays longer on main sequence ***OR*** $t_P = 270\, t_\alpha$ ✓		
	e		type I a supernovae form when a white dwarf in a binary star system accretes mass from companion ✓		**1**
	f		reference to standard candles ***OR*** mention of constant/peak luminosities ✓ «allow calculation of distance from apparent brightness»		**1**

Question			Answers	Notes	Total
19.	**a**		isotropic/uniform/homogeneous/appears to come from everywhere ✓ tiny fluctuations «in temperature» ✓ black body radiation «spectrum» ✓ «radiation of a body at» 3 K/2.7(6)K ✓ «radiation with a» wavelength of 2 mm ✓	*OWTTE*	**1 max**
	b		Big Bang model predicted the existence of CMB radiation ✓ «discovery of» CMB radiation provides evidence for the BB model ✓ CMB radiation left by the BB/originated when Universe was hot/small ✓ wavelength increased/T decreased as Universe expanded/cooled down ✓		**2 max**
	c		red-shift ✓ as space is being stretched / «distant» galaxies are moving away ✓ ***OR*** «relative» abundance of elements/H/He ✓ as Big Bang model predicts the ratio «of H/He as observed in all stars» ✓ ***OR*** «large scaled» structure of universe ✓ as Big Bang model predicts influence of gravity to create structures/relates structures to anisotropies ✓		**2**

Question			Answers	Notes	Total
20.			$\frac{R}{R_0} = z + 1 = 8.5$. ✓ $R_0 = \frac{1}{8.5} R$ ***OR*** 0.118 ***OR*** 11.8% ✓	*Allow reverse argument, from 12% to a z value of 7.33* *Answer 12% given, so award MP2 if candidates show a correct full substitution **OR** the value with an extra significant figure*	**2**

Question			Answers	Notes	Total
21.	**a**		corresponds to the critical density/flat «model» ✓ density of the Universe = critical density ***OR*** the curve becomes asymptotic to time axis ***OR*** Universe expands to limiting value ***OR*** expansion slows down ✓	*OWTTE*	**2**
	b		D ✓ identified as accelerated Universe ***OR*** stretching of space/expansion speeding up mentioned **OR** need for energy not observed identified **OR** dark energy postulated to account for this «model/observations» ✓		**2**