Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2023

Physics

Higher level

Paper 3

28 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		height «of drop» ***OR*** velocity «of ball» ***OR*** kinetic energy «of ball» ***OR*** temperature/mass/radius/surface area/volume of ball ✓	*Allow reference to controlling spin on the ball* *Do **not** accept bald temperature, mass, surface area or volume.*	**1**

Question			Answers	Notes	Total
1.	b		refers to 2 non-adjacent points ✓ suitable calculation to analyze the proportionality ✓ identifies variation/difference in calculated values, **«**thus hypothesis not supported**»** ✓	*Award **full marks** if more than two points used appropriately.* *Allow **[2 max]** if they use at least three points to show that two increments in force are not consistent with the corresponding increments in pressure and therefore it is not a straight line.*	**3**

Question			Answers	Notes	Total
1.	c	i	N^2m^2 ***OR*** $kg^2m^4s^{-4}$ ***OR*** $N^3\,Pa^{-1}$ ✓	***Award [0]*** *if they convert to base units incorrectly.*	**1**
1.	c	ii	point plotted at (40 kPa, $49x10^5\,N^3$) ✓	*Allow for the point to be plotted from 46 to 56 x10^5 N^3 at 40* kPa*, as candidates may calculate or may plot from a graphical analysis.*	**1**
1.	d	i	15 % seen anywhere ✓ «$\Delta(F^3)$ =» 39.4 x 10^5 x 0.15= 5.9 x10^5 ✓ $\pm 6 \times 10^5$ ✓	***MP1*** *is for the propagation of 5%. It can be shown differently, e.g. 3x5% Allow students to use* 40×10^5 *(from the graph).* *Award* ***MP3*** *for* ***any*** *uncertainty rounded to 1 significant digit* ***Award [3]*** *for a* ***BCA****.* *Allow* ***ECF*** *from* ***MP1*** *and* ***MP2***	**3**
1.	d	ii	error bar drawn at 30 kPa from 34x10^5 to 46x10^5 N^3 ✓	*Allow ± half square on each side of the bar or one square overall (± 2x10^5)* *Allow* ***ECF*** *from* ***d(i).***	**1**
1.	d	iii	a «straight» line can be drawn that passes through origin ✓		**1**

Question			Answers	Notes	Total
2.	a		final temperature of equilibrium/water/cube ***OR*** mass of water/cube ✓	*Do **not** award mark if any additional incorrect measurement is included* *Accept temperature change if water or cube specified*	**1**
2.	b		smaller mass of cube ***OR*** hotter cube ***OR*** more mass of water ***OR*** colder water ***OR*** more precise thermometer ✓	*Accept reference to repeating the experiment and taking mean values.* *Accept any reasonable answer that increases change in temperature of the cube.* *Do **not** accept more accurate thermometer*	**1**
2.	c		cube specific heat will be too large/increased value/overestimate ✓ additional «thermal» energy transferred ***OR*** temperature rise of water will be larger ***OR*** temperature drop of cube will be smaller ✓		**2**

Section B

Option A — Relativity

Question			Answers	Notes	Total
3.	**a**		set of coordinates/axes to record position and time **«**of an event**»** ***OR*** a coordinate system which is at rest/not moving relative to the observer ✓	*Some mention of time **and** position for **MP1*** *Allow "set of clocks and rulers" as per **MP1***	**1**
3.	**b**	**i**	magnetic ✓ **«**observer O sees**»** moving charge in a magnetic field ✓	*Do **not** allow electromagnetic* ***OWTTE***	**2**
3.	**b**	**ii**	electric / electrostatic ✓ positive lattice ions are length contracted relative to e ***OR*** electrons sees positive wire ✓		**2**

Question			Answers	Notes	Total
4.	**a**		4.8 **«**light years**»** ✓		**1**
4.	**b**		**«-»** 0.48c ✓	*Ignore sign*	**1**
4.	**c**		$\gamma = 1.6$ ✓ $D = \frac{4.8}{1.6}$ = 3 **«**ly**»** ✓	*Allow **ECF** from **MP1***	**2**
4.	**d**		$= \frac{0.3c - 0.78c}{1 - \frac{0.78c \times 0.3c}{c^2}}$ ✓ **«–»**0.63*c* ✓	***Award [2]** if **MP1** correct and correct answer given to 1 significant figure.*	**2**
4.	**e**		$\Delta t_p = \frac{3\text{ly}}{(0.78 - 0.627)c}$ ***OR*** $\Delta t_P = 1.6(\frac{4.8\text{ly}}{0.3c} - \frac{0.78c \times 4.8\text{ly}}{c^2})$ ✓ = 19 ***OR*** 20 **«**years**»** ✓	*Award **[2]** for **BCA***	**2**
4.	**f**		shuttle measures proper time ✓ as the events occur at the same place for the shuttle / shuttle is at both events ✓		**2**

Question			Answers	Notes	Total
5.	**a**		0.6 c ***OR*** = 1.8 x 10^8 «ms^{-1}» ✓		**1**
5.	**b**		Line drawn at 45° from ct = 2 km to hit spaceship world line at ct = 5 km ***OR*** c t = 1.2/(c-0.6c) + 2 = 5 **«**km**»**·✓ $t = \frac{5000}{c}$ = 1.7x10^{-5} «s» ✓	*Award **[2]** for **BCA***	**2**
5.	**c**		$(ct')^2 - 0 = 5^2 - 3^2$ ***OR*** $\gamma = 1.25$ ✓ *ct'* = 4 **«**km**»** ***OR*** *t'* =13 **«**μs**»** ✓	*Allow **ECF** from **(b)*** *Allow **ECF** from **MP1***	**2**

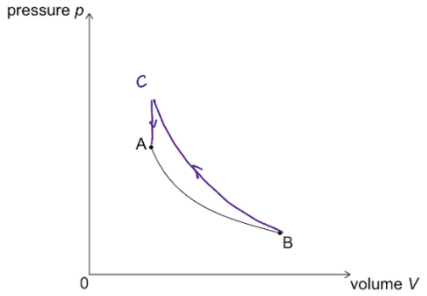
Question			Answers	Notes	Total
6.	**a**		227 **«**MeVc^{-1}**»**		**1**
6.	**b**		$E_{\pi^+} = \sqrt{140^2 + 340^2}$ ***OR*** = 368 **«**MeV**»**	***Award [1]*** *for correct substitution or value determined to 3 SF*	**1**
6.	**c**		E Pion minus = root of (140^2 + 113^2) = **«**180 MeV**»** ✓ Rest Energy of $K^0 = \sqrt{(368+180)^2 - (340-113)^2}$ ✓ = 499 **«**MeV**»** ✓	*Award* ***[3]*** *for* ***BCA***	**3**

Question			Answers	Notes	Total
7.	a		some photon energy is used to do work against the gravitational field ***OR*** mention of gravitational redshift ✓	***OWTTE***	**1**
7.	b		$\frac{1.2\times10^{-4}}{3.2\times10^{10}} = \frac{g\times20}{c^2}$ ✓ = 16.9 **«**m s^2**»** ✓	***Award [2]*** *for* ***BCA***	**2**
7.	c		gravitational effects cannot be distinguished from inertial effects ✓ **«**apparent**»** acceleration within rocket is greater than *g* ***OR*** there is a stronger gravitational field ***OR*** the receiver is moving further away ✓	***OWTTE***	**2**

Option B — Engineering physics

Question			Answers	Notes	Total
8.	**a**		$\sum \Gamma = 50 \times 0.5 + 40 \times 0.2$ ***OR*** 33 **«**Nm**»** ✓	*Accept opposite rotational sign convention*	**1**
8.	**b**		**«** $\alpha = \frac{20}{5}$ **=»** 4 **«**rad s^{-2}**»** ✓		**1**
8.	**c**		$I = \frac{\Gamma}{\alpha}$ ***OR*** $33 = I \times 4$ ✓ $I = 8.25$ **«**kg m^2**»** ✓	*Allow **ECF** from **(a)** and **(b)*** *Award **[2]** for a **BCA***	**2**

Question			Answers	Notes	Total
8.	d	i	moment of inertia increases ✓ Angular momentum is conserved ✓	*Allow algebraic expressions e.g.* $\omega = \frac{L}{I}$ *so ω decreases* *for* ***MP2***	**2**
8.	d	ii	E_k «$= \frac{1}{2} I\omega^2 =$» $\frac{1}{2}(I\omega)\omega = \frac{1}{2} L\omega$ ✓	*Accept equivalent methods*	**1**
8.	d	iii	«E_k =» ½ L ω_1 = ½ $L\omega_2$ ***OR*** $\frac{E_{k1}}{E_{k2}} = \frac{\omega_1}{\omega_2}$ ***OR*** «L is constant so» E_k is proportional to ω ✓ 40 % «energy loss» ✓	***MP1*** *is for understanding that angular momentum is constant so change in rotational kinetic energy is proportional to change in angular velocity* ***Award [0]*** *if* $E = 0.5\, I\, \omega^2$ *is used with the same I value for both values of E* *Award* ***[2]*** *for* ***BCA***	**2**
8.	e		one example specified *eg* friction, air resistance, mass distribution not modelled ✓	***Award [1]*** *for any reasonable physical parameter that is not consistent with the model*	**1**

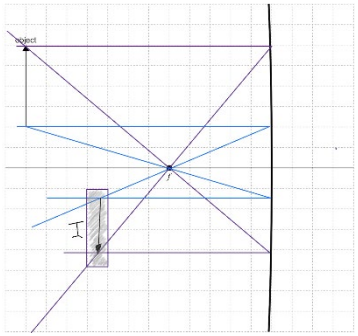
Question			Answers	Notes	Total
9.	a		use of pV = constant ✓ $P_B = 43$ «kPa» ✓	***Award [2]*** *for* ***BCA***	**2**
9.	b		concave curved line from B to locate C with a higher pressure than A ✓ vertical line joining C to A ✓	*Allow* ***ECF*** *from* ***MP1*** *i.e.,* ***award [1]*** *for first process locating C at a lower pressure than A, then vertical line to A.* *Arrows on the processes are not needed.* *Point C need not be labelled.*  	**2**
9.	c		***ALTERNATIVE 1*** *use of* $TV^{\frac{2}{3}}$ = constant «so $300(3V_A)^{\frac{2}{3}} = T_C(V_A)^{\frac{2}{3}}$» ✓ T_C = 624 «K» ***OR*** $T_C = 351$ «°C» ✓ ***ALTERNATIVE 2*** use of $pV^{\frac{5}{3}}$ to get either $p_c = 43(3)^{\frac{5}{3}}$ ***OR*** p_c = 268 «kPa» ✓ « T_c = 268x300/129 = so » T_C = 624 «K» ***OR*** $T_C = 351$ «°C» ✓		**2**

Question			Answers	Notes	Total
9.	**d**		***ALTERNATIVE 1*** «the process is adiabatic so» $\Delta Q = 0$ ✓ ***ALTERNATIVE 2*** The compression is reversible «so $\Delta S = 0$»✓	***OWTTE***	**1**
9.	**e**		area under curve AB is less than area under curve BC ✓	*Do **not** allow **ECF** from part **(b)***	**1**
9.	**f**		«W = 0 so» Q = ΔU ✓ «$\Delta U = \frac{3}{2}$ x 53.2 x R x (351 – 27) so » $\Delta U = 2.15 \times 10^5$ «J» ✓	***Award [2]** for **BCA***	**2**

Question			Answers	Notes	Total
10.	**a**		calculates P_{bottom} «= 850 x 9.8 x 4 = P_{bottom} «$= 850 \times 9.8 \times 4$» $= 33\,320$ Pa » ***OR*** calculates weight of oil« $\text{Weight}_{oil} = 850 \times \left(\frac{0.1^2\pi}{4}\right) \times 4 \times 9.8$ » ✓ Add the weight of the stopper « $F_{min} = 33\,320 \times \left(\frac{0.1^2 \times \pi}{4}\right) + 2.5 \times 9.8$ » ✓ $F_{min} = 286$ N ✓	*Alternative method may include finding the volume and then weight of oil above the stopper* ***Award [2 max]*** *if the weight of stopper is ignored to give 262* N ***Award [2 max]*** *if plug is taken as a square base to give 358* N *Allow **ECF** from **MP1***	**3**
10.	**b**		the pressure «at the valve opening and at the top of the oil in the tank» is constant ✓ the velocity «of oil surface» at the top «of the tank» is zero / negligible ✓ no energy/head losses «as the oil flows through the valve» ✓ no turbulence/ laminar flow occurs «as the oil flows through the valve» ✓ fluid not compressible ✓ ideal fluid ✓ no viscosity ✓		**2 max**
10.	**c**		Use of Re = 1000 ***OR*** states Re = $\frac{\sqrt{2g(4-0.5)} \times r \times 850}{0.25}$ ✓ « $1000 = \frac{\sqrt{2g(4-0.5)} \times r \times 850}{0.25}$ so » r = 3.6 «cm» ✓	***Award [2]*** *if r is taken to be the diameter this gives r = 1.8* cm	**2**

Question			Answers	Notes	Total
11.	**a**		Q decreases so damping increases ✓ amplitude is lower **«**everywhere**»** ***OR*** peak shifts left / to lower frequency ✓		**2**
11.	**b**		$\frac{2\pi}{30}$ **«**$= \frac{\text{energy dissipated per cycle}}{\text{energy stored}}$**»** $= 0.21$ or $21\,\%$ ✓	*Accept in exact form as* $\frac{2\pi}{30}$ *or* $\frac{\pi}{15}$	**1**

Option C — Imaging

Question			Answers	Notes	Total
12.	**a**		one ray drawn correctly reflected ✓ bottom and top of image located within the accepted region ✓	 *Allow the image to be within 1 square wide in the shaded region in the diagram above. The bottom not closer than 1 square from the main axis.*	**2**
12.	**b**		real ***OR*** inverted ***OR*** smaller image or magnification<1 ✓	*Must have any **two** correct to score **[1]*** *Features to be consistent with **(a)***	**1**
12.	**c**		spherical aberration ***OR*** rays do not meet at common focus ***OR*** blurred image ✓ parabolic **«**shape**»** ✓		**2**

Question			Answers	Notes	Total
13.	a		M = «$\frac{25}{8}$ =» 3.1 ✓		1
13.	b	i	$\frac{1}{8} = \frac{1}{14} + \frac{1}{v}$ ***OR*** v = 18.7 ✓ $M = \frac{18.7}{14}$ ***OR*** M = 1.33 ***OR*** M = 1.34 ✓	*Do **not** allow **ECF** for wrong value for v*	2
13.	b	ii	$\frac{1}{8}$ = 1 / (25-18.66) + 1/v ***OR*** v = -30.4 ✓ m = «m_1 x m_2 = 1.33 x $\frac{30.4}{(25-18.66)}$ = 1.33 x 4.8 =» 6.4 ✓	*Allow **ECF** from **MP1*** *Allow **ECF** from **b(i)***	2
13.	c	i	better resolution «than the eye» ✓	*Allow reference to brighter, sharper or clearer image.*	1
13.	c	ii	no magnification ***OR*** m=1 ✓		1
13.	d		international means base line can be across countries/continents ✓ greater distances increase the effective diameter of the dish ✓ great diameter improves resolution ✓	***OWTTE***	2 max

Question			Answers	Notes	Total
14.	**a**		attenuation = 10 $\log_{10}(0.015)$ ***OR*** = -18.2 ✓ length = $\frac{-18.2}{-0.3}$ ***OR*** 60.8 **«**km**»** ✓	*Allow **ECF** from **MP1*** *Ignore signs*	**2**
14.	**b**		$\Delta t = 14 \times 10^{-5}$ s ✓ **«**$\frac{27 \times 10^{3}}{14 \times 10^{-5}} = \frac{3 \times 10^{8}}{n}$**»** : $n = 1.56$ ✓	*Award **MP1** if $\Delta t = 14 \times 10^{-5}$ s is seen anywhere* *Allow **ECF** for **MP2**, if candidates use Δt= 18 – 3 **OR** Δt= 20 – 4, accepting* *n = 1.67 or = 1.78*	**2**
14.	**c**		refractive index of fibre is less at the edges ✓ reduces time taken for the longer path signals ✓	***OWTTE***	**2**

Question			Answers	Notes	Total
15.	**a**		$\frac{\ln 2}{0.348}$ ***OR*** 1.99 **«**cm**»** ✓	*Allow 2.0* **«**cm**»**	**1**
15.	**b**		$\frac{I}{I_0} = e^{-0.173 \times 4}$ ✓ $= 0.50$ ✓	***Award [2]*** *for* ***BCA***	**2**
15.	**c**		$I_{\text{muscle}} \times I_{\text{bone}} \times I_{\text{muscle}} = \left(\frac{1}{2}\right)^3$ ✓ $I = 0.125\ I_0$ ✓	***Award [2]*** *for* ***BCA*** *Watch for* ***ECF*** *from* ***(b)*** *Allow* ***ECF*** *from* ***MP1***	**2**
15.	**d**		more contrast with 1 keV ***OR*** less sharp with 1 keV correct explanation for one of them, i.e. **«**more contrast with 1 keV**»** as coefficients have greater ratio ***OR*** **«**less sharp with 1 keV**»** as the X-rays will be scattered more ✓	*Accept reverse argument in each case for 10* keV.	**2**
15.	**e**	**i**	A scan is one dimensional ✓ B scan is two dimensional ✓ B scan computed from multiple images ✓		**1 max**
15.	**e**	**ii**	gradient field is added to initial strong magnetic field ✓ varies linearly across/along the patient ✓ the flip/Larmor frequency varies linearly across the patient **«**hence position of proton frequency known**»** ✓		**2 max**

Option D — Astrophysics

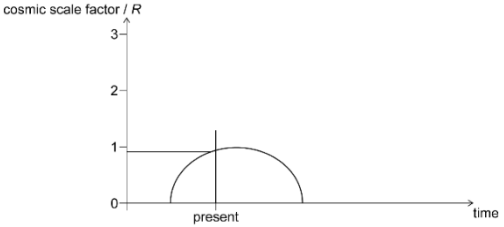
Question			Answers	Notes	Total
16.	**a**	**i**	cloud/body of dust and gas ✓	***Award [1]*** *for a reference to dust* ***OR*** *gas.* *Ignore further references to origin of cloud.*	**1**
16.	**a**	**ii**	observation of light from/passing through nebula ✓ part of the model of stellar evolution ✓	***MP1*** *is for any suitable comment that refers to making inferences from the radiation received, including measurement of luminosity or comparison to radiation on Earth to e.g., obtain chemical composition or wavelength shift.*	**1 max**
16.	**b**	**i**	Star Y ✓ because parallax angle is greater ***OR*** star Y is closer «and that means movement relative to distant stars is greater» ✓	*Allow reverse argument for star X*	**2**
16.	**b**	**ii**	**«** $\text{distance} = \left(\frac{1}{0.019}\right) \times 3.26 \times 9.46 \times 10^{15}$ **»** 1.6×10^{18} «m» ✓		**1**
16.	**b**	**iii**	$\frac{\text{Luminosity of Star X}}{\text{Luminosity of Star Y}} = \frac{b_x d_x^2}{b_y d_y^2}$ ✓ $= 10.8 \approx 11$ ✓	*Award* ***MP1*** *if ratio shown with distance or parallax angle.* *Award* ***MP1*** *for any correct substitution into ratio expression* ***Award [2]*** *for* ***BCA*** *Allow* ***ECF*** *for incorrect distances from* ***b(i)*** *or* ***b(ii)****.*	**2**

Question			Answers	Notes	Total
17.	**a**		Hydrogen ✓		**1**
17.	**b**		stars have same/similar *L* ***AND*** star B has lower *T* ✓ correct reference to luminosity formula ($L\alpha AT^4$) ✓	***MP1*** *Allow reverse argument i.e., star A has higher T*	**2**
17.	**c**		Any evidence of correct identification that three dots bottom left represent white dwarfs ✓ line passing through all 3 white dwarfs ***OR*** line continuing from 3 white dwarfs with approximately same gradient, in either direction ✓	*Award* ***MP2*** *if no line drawn through the three dots but just beyond them in either direction*	**2**
17.	**d**		«inward» gravitational force/pressure ✓ balanced by **«**neutron**»** degeneracy pressure/force ✓	*Allow force or pressure* ***OWTTE***	**2**

Question			Answers	Notes	Total
18.	a		***ALTERNATIVE 1*** v = 0.13 x 3x10^8 ***OR*** 0.39x10^8 «m s^{-1}» ***OR*** 0.13 x 3x10^5 ***OR*** 0.39x10^5 «km s^{-1}» ✓ $d = «\frac{0.39 \times 10^8}{73 \times 10^3} =»530$ «Mpc» ✓ ***ALTERNATIVE 2*** $d = \frac{cz}{H}$ ✓ $«3 \times 10^8 \times \frac{0.13}{73 \times 10^3} =»530«$Mpc» ✓	***Award [2]*** *for* ***BCA***	**2**

Question			Answers	Notes	Total
18.	b	i	***ALTERNATIVE 1*** $\frac{R}{R_0} = 1 + z = 1.13$ ✓ $\frac{R}{R_0} = \frac{t}{t_0} = 1.13$ ✓ t_0 = «$\frac{13.4 \times 10^9}{1.13}$ =» 11.9x10^9 «years» ✓ ***ALTERNATIVE 2*** «distance light travelled from galaxy = » 530x10^6 x 3.26 ***OR*** 1.7x10^9 «ly» ✓ light emitted from galaxy 1.7x10^9 «years ago» ✓ age when light was emitted «13.4x10^9 - 1.7x10^9 =» 11.7x10^9 «years ago» ✓	***MP1*** *can be awarded if* ***MP2*** *is clearly seen For* ***MP2*** *allow* $H_{now} / H_{then} = 1.13$ *then* $H_{then} = 1/t_0$ ***Award [3]*** *for* ***BCA*** *Allow* ***ECF*** *for* ***MP3*** *Accept* 1.6×10^{25} *m for* ***MP1***	**3**
18.	b	ii	evidence from type Ia supernovae show an accelerating universe ✓	*Accept distant galaxies are further away than expected*	**1**

Question			Answers	Notes	Total
19.	a		$M > M_j$ ***OR*** minimum mass for interstellar matter to collapse into a star ***OR*** «interstellar» potential energy > kinetic energy ✓	*Do **not** penalize if they compare gravitational force with kinetic, thermal or internal energy.*	**1**
19.	b	i	***ALTERNATIVE 1*** $T \propto \frac{M}{L}\ L \propto \frac{M}{T}$ ✓ «and L proportional to $M^{3.5}$ then» $T \propto \frac{M}{M^{3.5}}$ ✓ ***ALTERNATIVE 2*** L proportional $\frac{E}{T}$ ***AND*** L proportional M ✓ «and L proportional to $M^{3.5}$ then» T proportional $\frac{M}{M^{3.5}}$ ✓	***MP2** can be awarded if **MP1** is not.*	**2**
19.	b	ii	« $T_{20}M_{20}^{2.5} = T_{sun}M_{sun}^{2.5}$ ***OR*** $T_{20} = 10^{10} \times \left(\frac{1}{20}\right)^{2.5}$ » «$T_{20 =}$» 1.8×10^9 «s» ***OR*** 5.6×10^6 «y» ✓	*Accept 5.6* My *if unit stated*	**1**

Question			Answers	Notes	Total
20.	**a**		H«$= \frac{73 \times 10^3}{3.26 \times 10^6 \times 9.46 \times 10^{15}}$» $= 2.37 \times 10^{-18}$ «s^{-1}» ✓ $\rho_c =$ «$\frac{3 \times \left(2.37 \times 10^{-18}\right)^2}{8\pi \times 6.67 \times 10^{-11}}$ =»1.0×10^{-26} «kg m^{-3}» ✓	***Award [2]*** *for* ***BCA*** *Allow* ***ECF*** *from* ***MP1*** ***Award [1]*** *for* 9.5×10^{18} *or* 9.5×10^{12}	**2**
20.	**b**		any irregular semicircular shape that returns to zero ✓ must pass through present and $\frac{R}{R_0}$ = 1 ✓	 *Allow* ***MP2*** *for any line reasonably going through (present, 1)*	**2**
20.	**c**		presence of dark energy accelerates the expansion of the universe ✓ this increases the rate of cooling ✓		**2**