Markscheme

November 2017

Physics

Higher level

Paper 3

26 pages

Section A

Question			Answers	Notes	Total
1.	a		single smooth curve passing through all data points ✓	*Do not accept straight lines joining the dots* *Curve must touch some part of every x*	1
1.	b	i	tangent drawn at 80 °C ✓		3
			gradient values separated by minimum of 20 °C ✓	*Do not accept tangent unless "ruler" straight.* *Tangent line must be touching the curve drawn for MP1 to be awarded.*	
			9.0×10^{-4} «$kJ\,kg^{-1}K^{-2}$» ✓	*Accept values between 7.0×10^{-4} and 10×10^{-4}.* *Accept working in J, giving 0.7 to 1.0*	
1.	b	ii	$kJ\,kg^{-1}K^{-2}$ ✓		1
1.	c	i	«$0.1\times4.198\times10=$» 4.198 «kJ» ***or*** 4198 «J» ✓	*Accept values between 4.19 and 4.21*	1
1.	c	ii	percentage uncertainty in $\Delta T = 10\%$ ✓	*Allow fractional uncertainties in MP1 and MP2* *Watch for ECF from (c)(i)* *Watch for ECF from MP1* *Watch for ECF from MP2* *Do not accept an answer without justification*	3
			«$2\%+5\%+10\%=$» 17% ✓		
			absolute uncertainty = «$0.17\times4.198=$» 0.7 «kJ» therefore 2 sig figs ***OR*** absolute uncertainty to more than 1 sig fig and consistent final answer ✓		

Question			Answers	Notes	Total
2.	a		«$\varepsilon = IR + Ir$»	*No mark for stating data booklet equation*	**2**
			$\frac{1}{I} = \frac{R}{\varepsilon} + \frac{r}{\varepsilon}$ ✓ identifies equation with $y = mx + c$ ✓ «hence $m = \frac{1}{\varepsilon}$»	*Do not accept working where r is ignored or $\varepsilon = IR$ is used* *OWTTE*	
2.	b		«$-$» r ✓	*Allow answer in words*	**1**

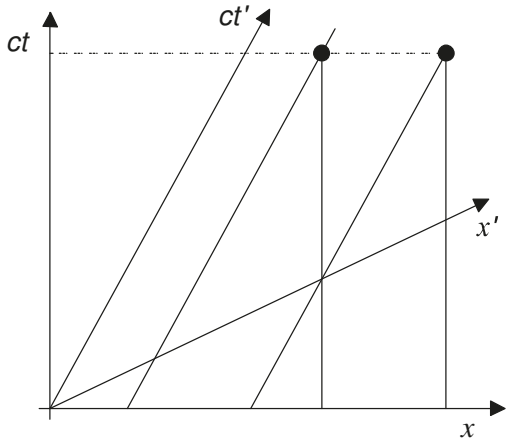
3.	a		«to reduce» random errors ✓ to reduce absolute uncertainty ✓ to improve precision ✓	*OWTTE* *Do not accept just "to find an average" or just "reduce error"* *Ignore any mention to accuracy*	**1 max**
3.	b		as the literature value is within the range «9.7 – 11.1» ✓	*OWTTE*	**2**
			hence it is accurate ✓	*MP2 must be correctly justified*	

Section B

Option A — Relativity

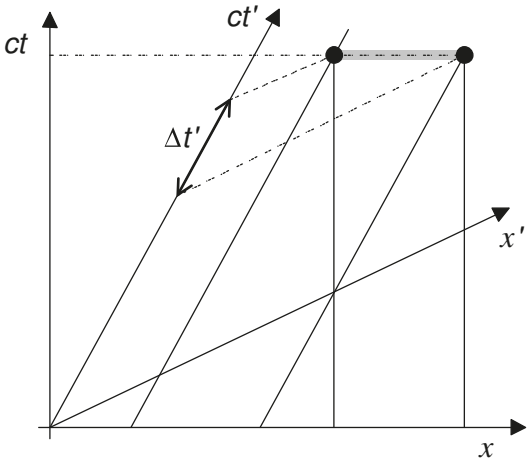
Question			Answers	Notes	Total
4.			light is an EM wave ✓		**2**
			speed of light is independent of the source/observer ✓		

5.	**a**		a co-ordinate system in which measurements «of distance and time» can be made ✓	*Ignore any mention to inertial reference frame.*	**1**
5.	**b**		closing speed $= c$ ✓		**2**
			2 «s» ✓		
5.	**c**		*u* and *v* are velocities with respect to the same frame of reference/Earth ***AND*** *u′* the relative velocity ✓	*Accept 0.4c and 0.6c for u and v*	**1**
5.	**d**		$\frac{-0.4-0.6}{1+0.24}$ ✓		**2**
			«–» $0.81c$ ✓		
5.	**e**	**i**	$\gamma = 1.25$ ✓		**2**
			so the time is $t = 1.6$ «s» ✓		
5.	**e**	**ii**	gamma is smaller for B ✓		**2**
			so time is greater than for A ✓		

Question			Answers	Notes	Total
6.	a		the length of an object in its rest frame ***OR*** the length of an object measured when at rest relative to the observer ✓		1
6.	b		world lines for front and back of tunnel parallel to *ct* axis ✓ world lines for front and back of train ✓ which are parallel to *ct'* axis ✓		3
6.	c		realizes that gamma = 1.25 ✓ 0.6*c* ✓		2

(continued…)

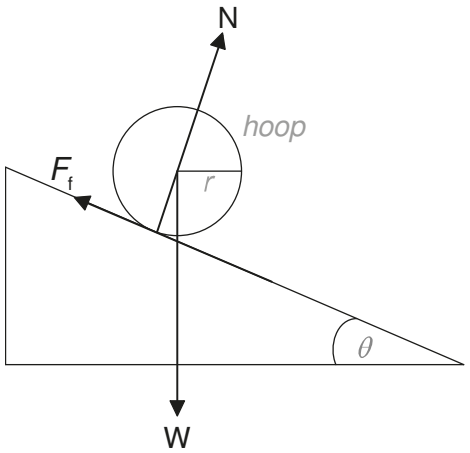
(Question 6 continued)

Question			Answers	Notes	Total
6.	d		***ALTERNATIVE 1*** indicates the two simultaneous events for *t* frame ✓ marks on the diagram the different times «for both spacetime points» on the *ct′* axis «shown as $\Delta t'$ on each diagram» ✓ ***ALTERNATIVE 2: (no diagram reference)*** the two events occur at different points in space ✓ statement that the two events are not simultaneous in the *t′* frame ✓		**2**

Question			Answers	Notes	Total
7.	a		Λ momentum $= 900$ ✓		4
			$E_{\text{proton}} = \text{«}\sqrt{pc^2 + (mc^2)^2} = \sqrt{630^2 + 938^2}\text{»}$ 1130 «MeV» ✓		
			$E_{\text{pion}} = \text{«}\sqrt{270^2 + 140^2}\text{»}$ 304 «MeV» ✓		
			so rest mass of $\Lambda = \text{«}\sqrt{(1130 + 304)^2 - 900^2}\text{»}$ 1116 «MeV c^{-2}» ✓		
7.	b		$\text{«}E = \gamma mc^2$ so» $\gamma = \text{«}\frac{1434}{1116}\text{»}$ 1.28 ✓		2
			to give $0.64c$ ✓		

Question			Answers	Notes	Total
8.	a		this is gravitational time dilation ***OR*** black hole gives rise to a «strong» gravitational field ✓		**2 max**
			clocks in stronger field run more slowly ***OR*** the clock «signal» is subject to gravitational red-shift ✓		
			the clock is subject to gravitational red shift ***OR*** the clock has lost gravitational potential energy in moving close to the black hole ✓		
8.	b				**2**
			ALTERNATIVE 1 (10 ks is in observer frame):		
			$\Delta t' = 10000\sqrt{1-\frac{6.0\times10^5}{7.0\times10^8}}$ ✓	*Allow 9996* *Allow ECF if 10 is used instead of 10000*	
			9995.7 so 9995 «ticks» ✓		
			ALTERNATIVE 2 (10 ks is in rocket frame):		
			$\Delta t = \frac{10000}{\sqrt{1-\frac{6.0\times10^5}{7.0\times10^8}}}$ ✓	*Allow ECF if 10 is used instead of 10000*	
			10004 «ticks» ✓		

Option B — Engineering physics

Question			Answers	Notes	Total
9.	**a**		weight, normal reaction and friction in correct direction ✓ correct points of application for at least two correct forces ✓	*Labelled on diagram.*  *Allow different wording and symbols* *Ignore relative lengths*	**2**

(continued…)

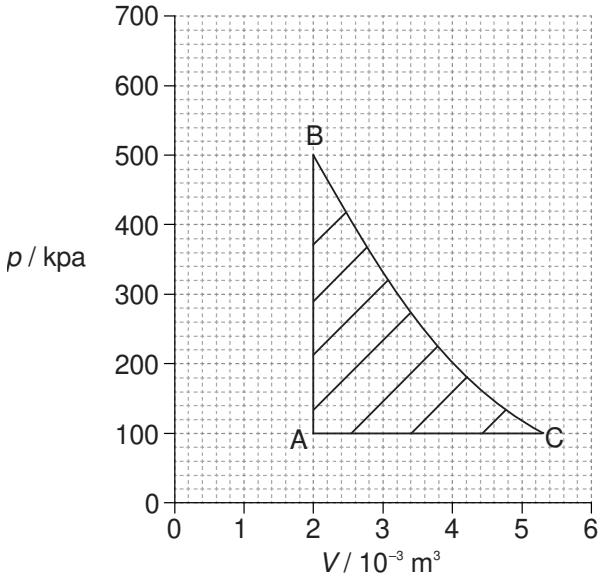
(Question 9 continued)

Question			Answers	Notes	Total
9.	b		***ALTERNATIVE 1***	*Can be in any order*	
			$ma = mg\sin\theta - F_f$ ✓		
			$I\alpha = F_f \times r$		
			OR	*Accept answers using the parallel axis theorem (with $I = 2mr^2$) only if clear and explicit mention that the only torque is from the weight*	
			$mr\alpha = F_f$ ✓		
			$\alpha = \frac{a}{r}$ ✓		
			$ma = mg\sin\theta - mr\frac{a}{r} \rightarrow 2a = g\sin\theta$ ✓		**4**
			ALTERNATIVE 2		
			$mgh = \frac{1}{2}I\omega^2 + \frac{1}{2}mv^2$ ✓	*For alternative 2, MP3 and MP4 can only be awarded if the previous marking points are present*	
			substituting $\omega = \frac{v}{r}$ «giving $v = \sqrt{gh}$» ✓		
			correct use of a kinematic equation ✓		
			use of trigonometry to relate displacement and height «$s = h\sin\theta$» ✓		

(continued…)

(Question 9 continued)

Question			Answers	Notes	Total
9.	**c**		1.68 «$m\,s^{-2}$» ✓		**1**
9.	**d**		***ALTERNATIVE 1*** $N = mg\cos\theta$ ✓ $F_f \leq \mu mg\cos\theta$ ✓ ***ALTERNATIVE 2*** $F_f = ma$ «from 9(b)» ✓ so $F_f = \frac{mg\sin\theta}{2}$ ✓		**2**
9.	**e**		$F_f = \mu mg\cos\theta$ ✓ $\frac{mg\sin\theta}{2} = mg\sin\theta - \mu mg\cos\theta$ ***OR*** $mg\frac{\sin\theta}{2} = \mu mg\cos\theta$ ✓ algebraic manipulation to reach $\tan\theta = 2\mu$ ✓		**3**

Question			Answers	Notes	Total
10.	a		$500\,000 \times (2 \times 10^{-3})^{\frac{5}{3}} = 100\,000 \times V^{\frac{5}{3}}$ ✓ $V = 5.25 \times 10^{-3}$ «m^3» ✓	*Look carefully for correct use of $pV^{\gamma} =$ constant*	**2**
10.	b		correct vertical and horizontal lines ✓ curve between B and C ✓	*Allow tolerance ±1 square for A, B and C* *Allow ECF for MP2* *Points do not need to be labelled for marking points to be awarded*  	**2**
10.	c		use of $PV = nRT$ ***OR*** use of $\frac{P}{T} =$ constant ✓ $T =$ «$5 \times 290 =$» 1450 «K» ✓		**2**

(continued…)

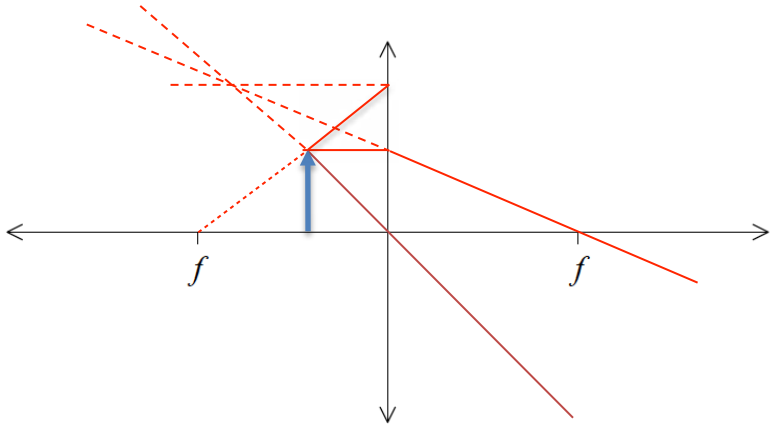
(Question 10 continued)

Question			Answers	Notes	Total
10.	**d**		area enclosed ✓ work is done by the gas during expansion ***OR*** work is done on the gas during compression ✓ the area under the expansion is greater than the area under the compression ✓		**2 max**

Question			Answers	Notes	Total
11.	a	i	density $= 785$ «kg m^{-3}» ✓ «$\frac{4}{3}\pi(0.03)^3 \times 785 \times 9.8 =$» 0.87 «N» ✓	*Accept answer in the range 784 to 786*	**2**
11.	a	ii	$\frac{0.87}{\frac{4}{3}\pi(0.03)^3 \times 1080 \times 9.8}$ ***OR*** $\frac{0.87}{1080 \times 1.13 \times 10^{-4}}$ ***OR*** $\frac{785}{1080}$ ✓ 0.727 ***or*** 73 % ✓	*Allow ECF from (a)(i)*	**2**
11.	b		use of drag force to obtain $\frac{4}{3}\pi r^3 \times 0.04 \times g = 6 \times \pi \times 0.0011 \times r \times v$ ✓ $v = 0.071$ «ms^{-1}» ✓		**2**

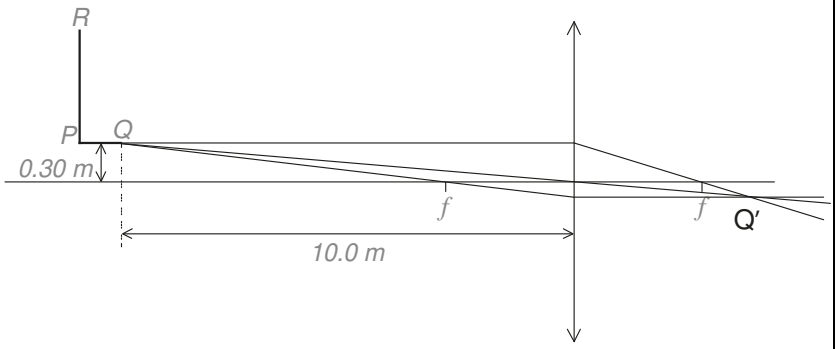
Question			Answers	Notes	Total
12.	a		***ALTERNATIVE 1*** the time between undulations is $\frac{3}{5.6} = 0.536$ «s» ✓ $f = \frac{1}{0.536} = 1.87$ «Hz» ✓ «frequencies match» <u>resonance</u> occurs so amplitude of vibration becomes greater ✓ ***ALTERNATIVE 2*** $f = \frac{v}{\lambda} = \frac{5.6}{3}$ ✓ $f = 1.87$ «Hz» ✓ «frequencies match» <u>resonance</u> occurs so amplitude of vibration becomes greater ✓	*Must see mention of "resonance" for MP3* *Must see mention of "resonance" for MP3*	**3**
12.	b		«to increase damping» reduce Q ✓		**1**

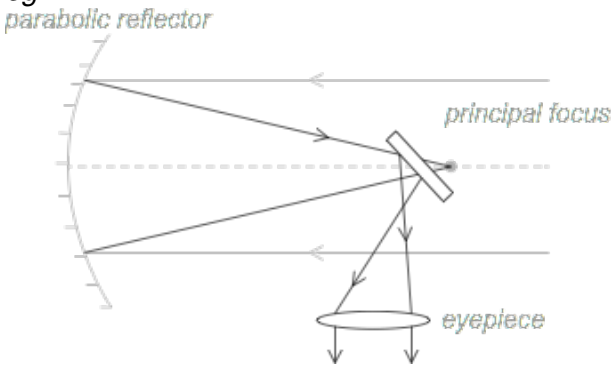
Option C — Imaging

Question			Answers	Notes	Total
13.	a	i	with object placed between lens and focus ✓ two rays correctly drawn ✓  thin converging lens	*Backwards extrapolation of refracted rays can be dashes or solid lines* *Do not penalize extrapolated rays which would meet beyond the edge of page* *Image need not be shown*	2
13.	a	ii	«just less than» the focal length ***or*** f ✓		1
13.	b	i	$\frac{1}{10}+\frac{1}{v}=\frac{1}{2}$ ✓ $v = 2.5$ «m» ✓		2
13.	b	ii	real, smaller, inverted ✓	*All three required — OWTTE*	1

(continued…)

(Question 13 continued)

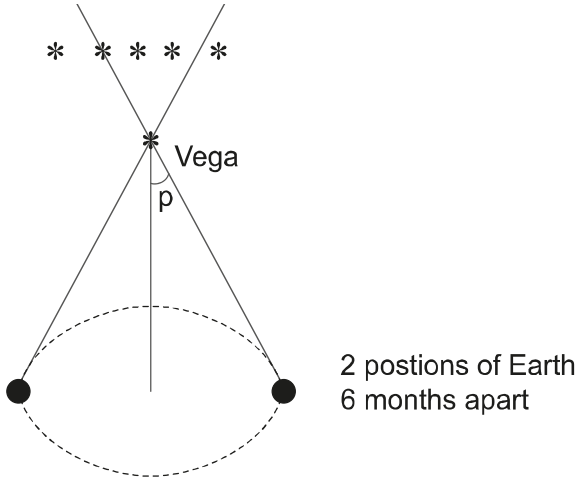
Question			Answers	Notes	Total
13.	**c**	**i**	two correct rays coming from Q ✓	*Allow any **two** of the three conventional rays.*	**2**
			locating Q′ below the main axis ***AND*** beyond f to the right of lens ***AND*** at intercept of rays ✓		
13.	**c**	**ii**	$\frac{h}{h'} = \frac{-x}{x'}$ ***OR*** 2.5 ***or*** 10×0.3 «m» ✓		**2**
			«–» 0.075 «m» ✓		
13.	**c**	**iii**	towards Q ✓	*Accept move to the left*	**1**
13.	**c**	**iv**	spherical aberration ✓		**2**
			top of the shape «R» is far from axis so no paraxial rays ✓	*For MP2 accept rays far from the centre converge at different points*	

Question			Answers	Notes	Total
14.	**a**		plane mirror to the left of principal focus tilted anti-clockwise ✓ two rays which would go through the principal focus ✓ two rays cross between mirror and eyepiece ***AND*** passing through the eyepiece ✓	*eg*:  	**3**
14.	**b**		$\frac{2\times1737}{363300}=\frac{0.0120}{f}$ ✓ $f=1.25$ «m» ✓	*Allow ECF if factor of 2 omitted answer is 2.5 m*	**2**
14.	**c**		$M=\frac{1.25}{0.05}=25$ ✓		**1**
14.	**d**		parabolic/convex mirror instead of flat mirror ✓ eyepiece/image axis same as mirror ✓		**1 max**

Question			Answers	Notes	Total
15.	**a**		realization that θ min is the critical angle ✓		**3**
			$\theta = \text{«}\sin^{-1}\frac{1.48}{1.5}\text{=»}\ 80.6\ \text{«}^\circ\text{»}$ ✓	*Accept 1.4 rad* *Accept 0.16 rad*	
			$\beta = \text{«}90 - 80.6 = \text{»}\ 9.4\ \text{«}^\circ\text{»}$ ✓		
15.	**b**		because the critical angle is nearly 90° ✓		**3**
			then only rays that are «almost» parallel to the fibre pass down it ✓		
			so pulse broadening is reduced ✓	*OWTTE*	

16.	**a**		evidence of finding the gradient ✓		**2**
			$\mu = \text{«} - \text{gradient} = \text{»}\ 59.9\ \text{«cm}^{-1}\text{»}$ ✓		
16.	**b**		$I = \frac{I_0}{25000}$ ✓		**2**
			$\text{«}\ln 25000 = \mu x\text{»}\ x = 0.17\ \text{«}cm\text{»}$ ***or*** 1.7 «mm» ✓		

Option D — Astrophysics

Question			Answers	Notes	Total
17.	**a**	**i**	«nuclear» fusion ✓	*Do not accept "burning"*	**1**
17.	**a**	**ii**	brightness depends on luminosity and distance/ $b = \frac{L}{4\pi d^2}$ ✓ Vega is much further away but has a larger luminosity ✓	*Accept answer in terms of Jupiter for MP2*	**2**
17.	**b**	**i**	a group of stars forming a pattern on the sky ***AND*** not necessarily close in distance to each other ✓	*OWTTE*	**1**
17.	**b**	**ii**	the star's position is observed at two times, six months apart, relative to distant stars ✓ parallax angle is half the angle of shift ✓ 	*Answers may be given in diagram form, so allow the marking points if clearly drawn*	**2**

(continued…)

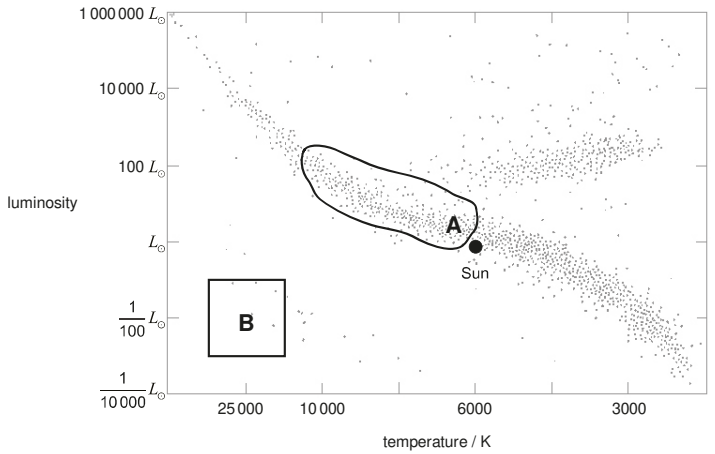
(Question 17 continued)

Question			Answers	Notes	Total
17.	**b**	**iii**	$\frac{1}{0.13} = 7.7$ «pc» ✓ so $d = 7.7 \times 3.26 = 25.1$ «ly» ✓		**2**

18.	**a**		two stars orbiting a common centre «of mass» ✓	*Do not accept "stars which orbit each other"*	**1**
18.	**b**		«$\lambda \times T = 2.9 \times 10^{-3}$» $T = \frac{2.9 \times 10^{-3}}{115 \times 10^{-9}} = 25217$ «K» ✓		**1**
18.	**c**		use of the mass-luminosity relationship ***or*** $\left(\frac{M_{\text{Sirius}}}{M_{\text{Sun}}}\right)^{3.5} = 1$ ✓ if Sirius B is on the main sequence then $\left(\frac{L_{\text{SiriusB}}}{L_{\text{Sun}}}\right) = 1$ «which it is not» ✓	*Conclusion is given, justification must be stated* *Allow reverse argument beginning with luminosity*	**2**

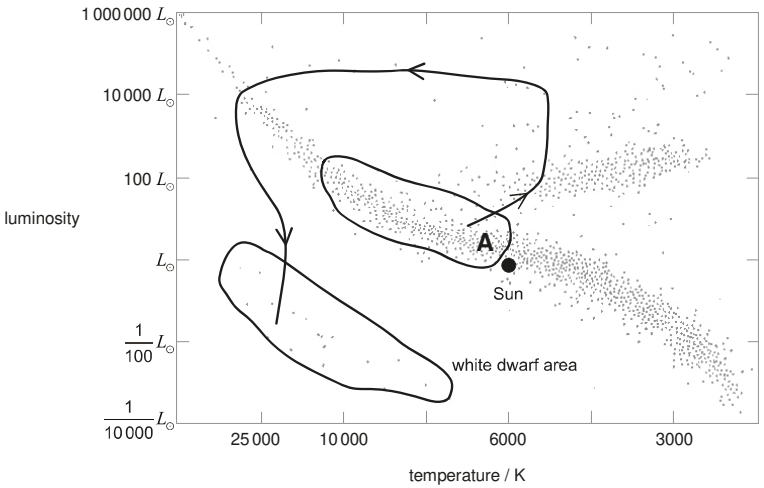
(continued…)

(Question 18 continued)

Question			Answers	Notes	Total
18.	**d**	**i**	$\left(\frac{L_{\text{SiriusB}}}{L_{\text{Sun}}}\right) = 0.025$ ✓ $r_{\text{Sirius}} = \text{«}\sqrt{0.025 \times \left(\frac{5800}{25000}\right)^4} = \text{»}\ 0.0085\ r_{\text{Sun}}$ ✓		**2**
18.	**d**	**ii**	white dwarf ✓		**1**
18.	**e**	**i**	Sirius A on the main sequence above and to the left of the Sun ***AND*** Sirius B on white dwarf area as shown ✓	*Both positions must be labelled* *Allow the position anywhere within the limits shown.*  	**1**

(continued…)

(Question 18 continued)

Question			Answers	Notes	Total
18.	**e**	**ii**	arrow goes up and right and then loops to white dwarf area ✓		**1**

19.	**a**		galaxies are moving away ***OR*** space «between galaxies» is expanding ✓	*Do not accept just red-shift*	**1**
19.	**b**		« $\frac{\Delta\lambda}{\lambda} =$ » $\frac{1.04}{115} = \frac{v}{c}$ ✓ $0.009c$ ✓	*Accept* 2.7×10^6 *«m s*$^{-1}$*»* *Award* ***[0]*** *if 116 is used for* λ	**2**

Question			Answers	Notes	Total
20.	**a**		interstellar gas/dust «from earlier supernova» ✓ gravitational attraction between particles ✓ if the mass is greater than the Jean's mass/M_j the interstellar gas coalesces ✓ as gas collapses temperature increases leading to nuclear fusion ✓	*MP3 can be expressed in terms of potential and kinetic energy*	**4**
20.	**b**		fluctuations in CMB due to differences in temperature/mass/density ✓ during the inflationary period/epoch/early universe ✓ leading to the formation of galaxies/stars/structures ✓ gravitational interaction between galaxies can lead to collision ✓		**3 max**

(continued…)

(Question 20 continued)

Question			Answers	Notes	Total
20.	**c**		***ALTERNATIVE 1*** kinetic energy of galaxy $\frac{1}{2}mv^2 = \frac{1}{2}mH^2r^2$ «uses Hubble's law» ✓ potential energy $= \frac{GMm}{r} = G\frac{4}{3}\pi r^3\rho\frac{m}{r}$ «introduces density» ✓ KE = PE to get expression for critical ρ ✓ ***ALTERNATIVE 2*** escape velocity of distant galaxy $v = \sqrt{\frac{2GM}{r}}$ ✓ where $H_0 r = \sqrt{\frac{2GM}{r}}$ ✓ substitutes $M = \frac{4}{3}\pi r^3\rho$ to get result ✓		**3**