Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2016

Physics

Standard level

Paper 3

19 pages

Subject Details: Physics SL Paper 3 Markscheme

Mark Allocation

Candidates are required to answer ALL questions in Section A [15 marks] and all questions from ONE option in Section B [20 marks]. Maximum total = [35 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.

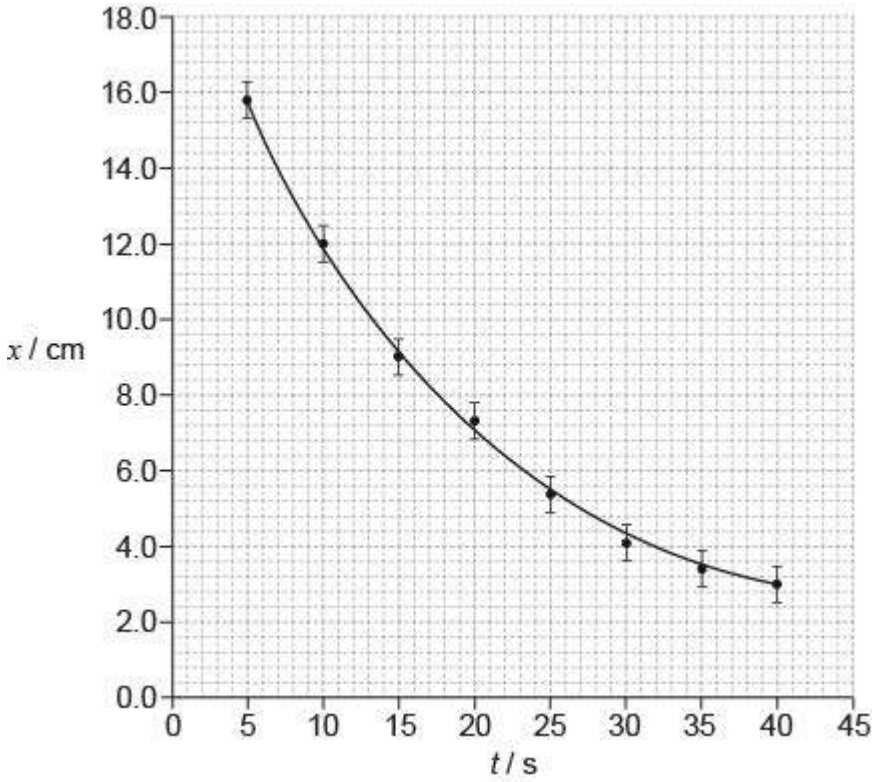
6. An alternative answer is indicated in the "Answers" column by "***OR***" between the alternatives. Either answer can be accepted.

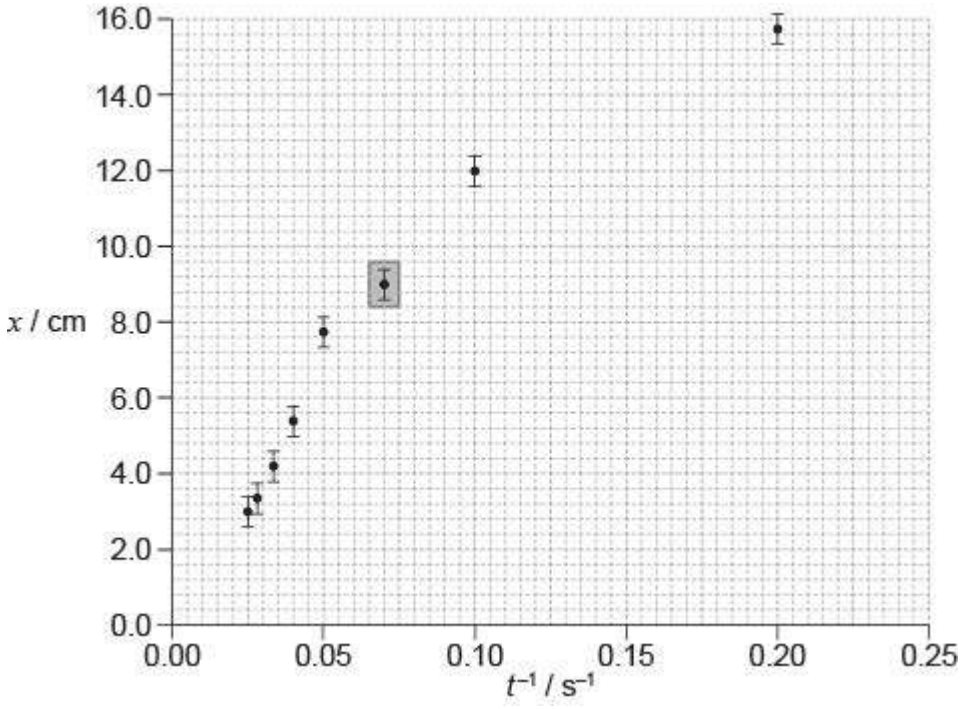
7. Words in angled brackets **« »** in the "Answers" column are not necessary to gain the mark.

8. Words that are <u>underlined</u> are essential for the mark.

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

Section A

Question			Answers	Notes	Total
1	a		smooth curve passing through all error bars ✓  		1
	b		$x = 2.5\,\text{cm} \pm 0.2\,\text{cm}$ ***AND*** $\Delta x = 0.5\,\text{cm} \pm 0.1\,\text{cm}$ ✓ $\text{«}\frac{0.5}{2.5}\text{=»}\ 20\%$ ✓	*Accept correctly calculated value from interval 15 % to 25 %.*	2

Question			Answer	Notes	Total
1	c	i	plotted point (0.07, 9.0) as shown ✓ 	*Allow any point within the grey square. The error bar is not required.*	**1**

Question			Answer	Notes	Total
1	c	ii	***ALTERNATIVE 1*** t^{-1} from 0.025 s^{-1} to 0.04 s^{-1} ✓ giving t from 25 to 40 ✓ ***ALTERNATIVE 2*** the data do not support the hypothesis ✓ any relevant support for the suggestion, *eg* straight line cannot be fitted through the error bars and the origin ✓	*Do not allow ECF from MP1 to MP2.*	**2**

Question			Answers	Notes	Total
2	a	i	refractive index = 1.5 ✓	*Both correct value and 2SF required for **[1]**.*	**1**
	a	ii	fractional uncertainty $x_3 - x_1 = \frac{0.04}{1.15} = 0.035$ ***AND*** $x_3 - x_2 = \frac{0.04}{0.76} = 0.053$ ✓ sum of fractional uncertainty $= 0.088$ ✓ «uncertainty = their RI × 0.088» = 0.1 ✓	*Accept correct calculation using maximum and minimum values giving the same answer.*	**3**
	b	i	systematic error ✓	*Accept "zero error/offset".*	**1**
	b	ii	calculated refractive index is unchanged ✓ because both numerator and denominator are unchanged ✓	*Accept calculation of refractive index with 0.05 subtracted to each x value.*	**2**
	c		numerator and denominator will be 10 times larger so refractive index is unchanged ✓ relative/absolute uncertainty will be smaller ✓	*"Constant material" is not enough for MP1.*	**2**

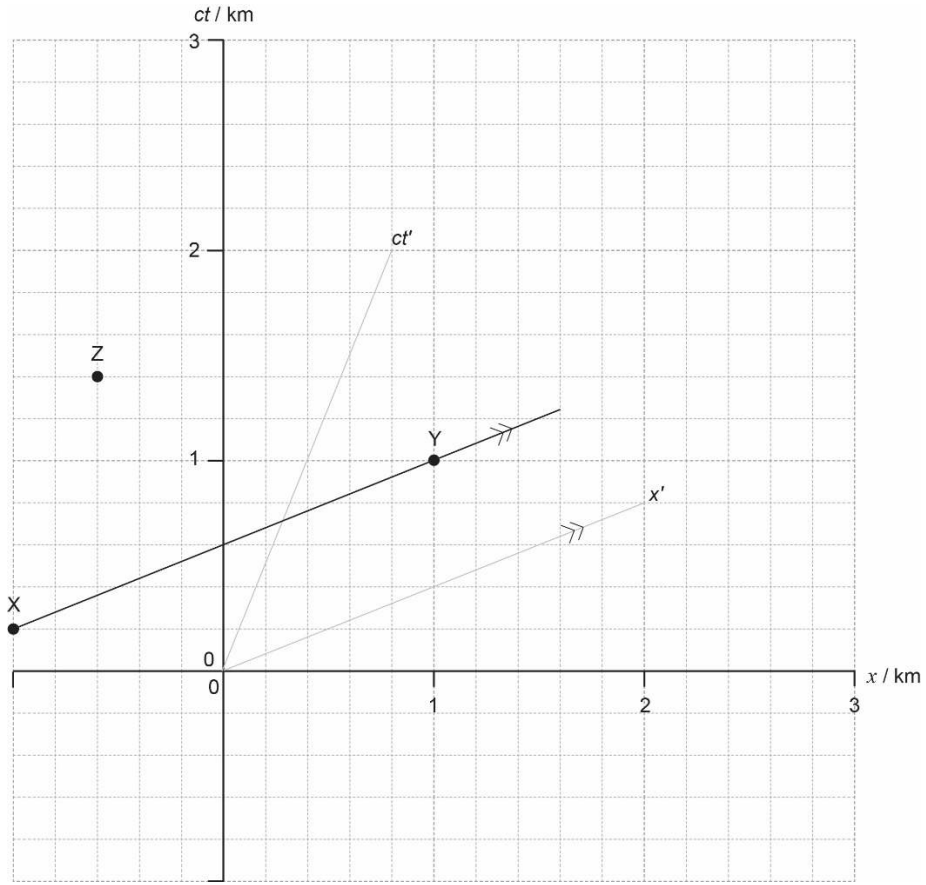
Section B

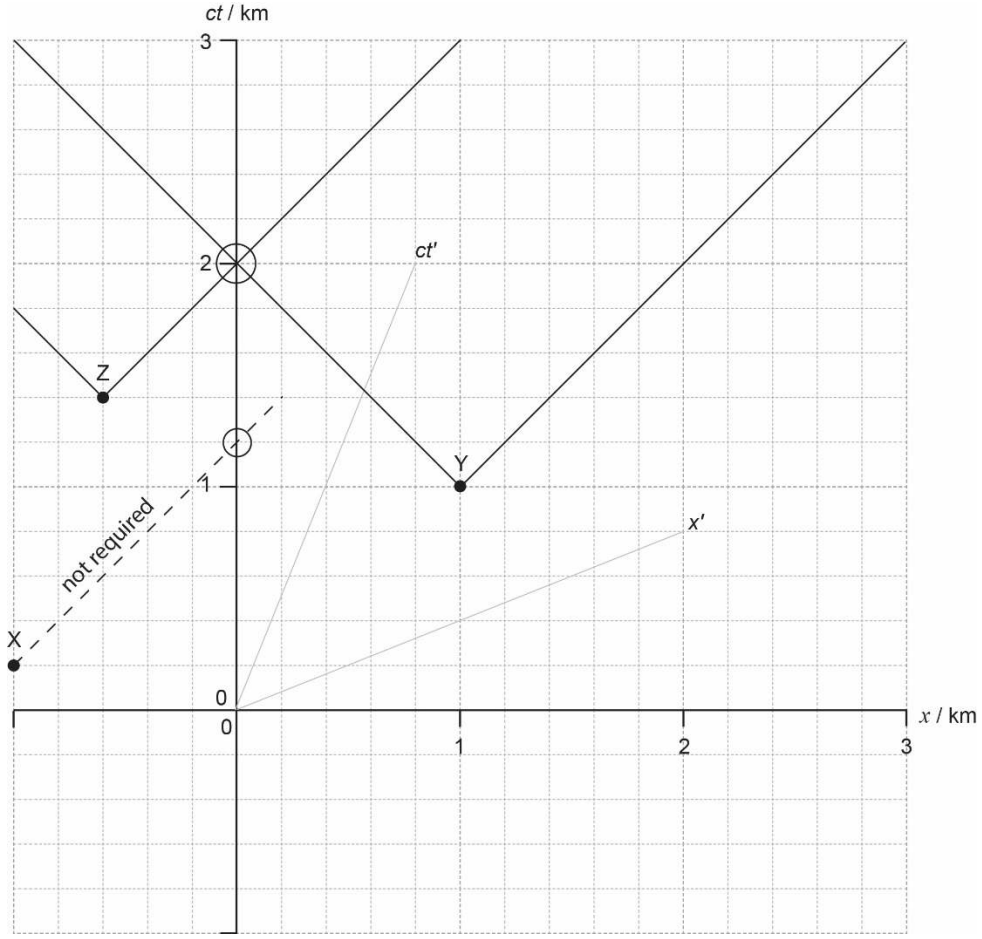
Option A — Relativity					
Question			**Answers**	**Notes**	**Total**
3	**a**		not being accelerated ***OR*** not subject to an unbalanced force ***OR*** where Newton's laws apply ✓		**1**
	b	**i**	c ✓		**1**
	b	**ii**	$c+v$ ✓		**1**

4			Y measures electrostatic <u>repulsion</u> only ✓ protons are moving relative to X «but not Y» ***OR*** protons are stationary relative to Y ✓ moving protons create magnetic fields around them according to X ✓ X also measures an <u>attractive</u> magnetic force ***OR*** relativistic/Lorentz effects also present ✓		**4**

Question			Answers	Notes	Total
5	a		$\gamma = 4.503$ ✓ $\text{«}\frac{0.800}{4.50}\text{=»}$ 0.178 m ✓		2
	b		$\text{time} = \frac{0.800}{2.94 \times 10^8}$ ✓ 2.74 ns ✓		2
	c		$\frac{2.74}{4.5}$ ***OR*** $\frac{0.178}{2.94 \times 10^8}$ ✓ 0.608 ns ✓		2
	d		it is measured in the frame of reference in which both events occur at the same position ***OR*** it is the shortest time interval possible ✓		1

6	a		$\Delta ct = 2.0$ km ***AND*** $\Delta x = 0.8$ km ✓ $v = \text{«}\frac{\Delta x}{\Delta ct} = \frac{0.8}{2.0}\text{=»}$ 0.4*c* ✓	*Allow any correct read-off from graph.* *Accept answers from 0.37c to 0.43c.*	2

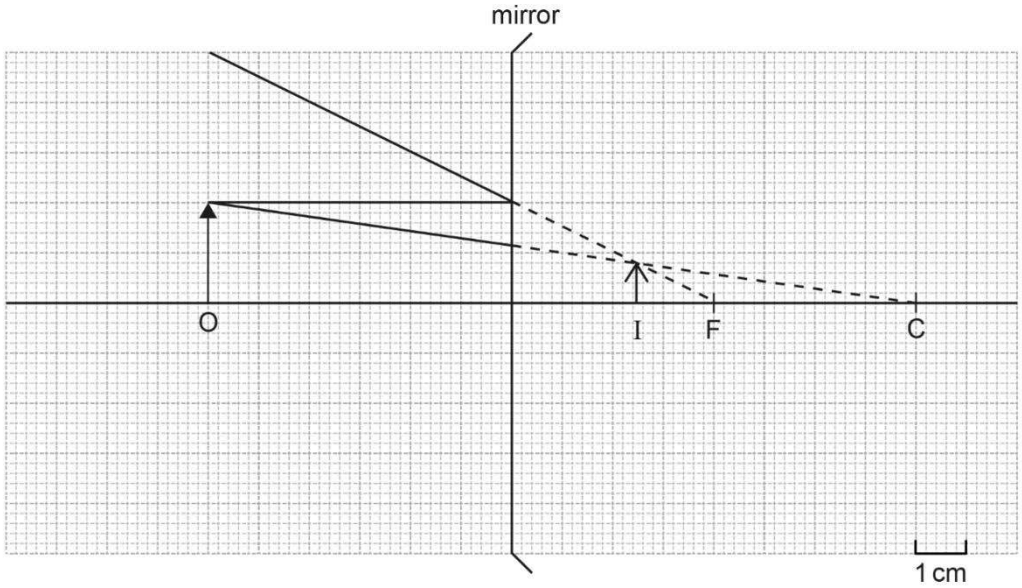
Question			Answers	Notes	Total
6	b	i	events at same perpendicular distance from x' axis of rocket are simultaneous ***OR*** line joining X to Y is parallel to x' axis ✓ X and Y simultaneously then Z ✓  	*MP1 may be present on spacetime diagram.*	**2**

Question			Answers	Notes	Total
6	b	ii	constructs light cones to intersect worldline of observer ✓ X first followed by Y and Z simultaneously ✓ 	*Only Y and Z light cones need to be seen.*	**2**

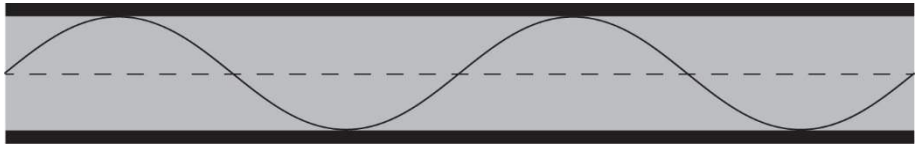
Option B — Engineering physics					
Question			**Answers**	**Notes**	**Total**
7	**a**		because *Mg* and *N* act through the axis ***OR*** only *F* has a non-zero lever arm «about the axis» ✓		**1**
	b	**i**	***ALTERNATIVE 1*** use of Newton's law for linear motion: $Mg\sin\theta - F = Ma$ ✓ use of Newton's law for rotational motion: $FR = I\alpha$ ✓ combining $Mg\sin\theta = Ma + \frac{I\alpha}{R}$ ✓ substitution of $I = \frac{1}{2}MR^2$ and $\alpha = \frac{a}{R}$ ✓ to get result ***ALTERNATIVE 2*** $Mgh = \frac{1}{2}Mv^2 + \frac{1}{4}Mv^2$ «from $\frac{1}{2}I\omega^2 = \frac{1}{2}\left(\frac{1}{2}MR^2\right)\frac{v^2}{R^2}$» ✓ $v^2 = \frac{4}{3}gh$ ✓ $v^2 = 2as = 2a\frac{h}{\sin\theta}$ ✓ manipulation to produce given answer ✓	*Accept correct use of torques about point of contact.*	**4**

Question			Answers	Notes	Total
7	b	ii	rearranging $s = \frac{1}{2}at^2$ to get $t = \sqrt{\frac{2s}{a}}$ ✓ substitution to get $t = \text{«}\sqrt{\frac{2\times 1.5}{\frac{2}{3}\times 9.81\times\frac{1}{2}}}\text{»} = 0.96$ s ✓		**2**
	c		<u>acceleration</u> of ice is $g\sin\theta$ whereas for the solid cylinder acceleration is two thirds of this «so speed of ice must always be greater at same point» ✓	*Allow answers in terms of energies, eg ice does not use energy to rotate and therefore will have a greater translational speed.*	**1**
	d		the hollow cylinder has a greater moment of inertia ✓ and hence a smaller acceleration ✓		**2**

Question			Answers	Notes	Total
8	a	i	1400 «K» ✓		1
	a	ii	$\frac{3}{2}P\Delta V = \frac{3}{2}\times 4\times 10^{5}\times 3\times 10^{-3}$ ✓ 1800 J ✓		2
	a	iii	$1800 + P\Delta V = 1800 + 4\times 10^{5}\times 3\times 10^{-3}$ ***OR*** use of $\Delta Q = \frac{5}{2}P\Delta V$ ✓ 3000 J ✓		2
	a	iv	curve starting at A ending on line CB ***AND*** between B and zero pressure ✓		1
	b	i	0 ✓		1
	b	ii	***ALTERNATIVE 1*** C has the same volume as B ***OR*** entropy is related to disorder ✓ higher temperature/pressure means greater disorder ✓ therefore entropy at C is greater «because entropy is related to disorder» ✓ ***ALTERNATIVE 2*** to change from B to C, $\Delta Q > 0$ ✓ so $\Delta S > 0$ ✓ ΔS related to disorder ✓		3

Option C — Imaging					
Question			**Answers**	**Notes**	**Total**
9.	**a**		 one correct ray drawn ✓ another correct ray ✓ image located at intersection of rays, behind the mirror ✓	*Label I is required.*	**3**
	b		≈ 0.4 ✓		**1**
	c		image is in better focus/sharper ***OR*** parabolic do not suffer from spherical aberration ✓ parabolic mirrors reflect parallel rays through one point ✓ whereas spherical mirrors reflect parallel rays through different points ✓	*Award 3rd mark even if implied in the answer.*	**3**

Question			Answers	Notes	Total
10	a		$F_o + f_e = 84$ so $f_e = 84 - 82 = 2$ cm ✓ « $M = \frac{f_o}{f_e} = \frac{82}{2} =$ » 41 ✓		2
	b		a sign convention is a way to distinguish between real and virtual objects ***or*** images ***or*** converging and diverging lenses ✓		1
	c	i	image will be virtual $v = -25$ cm ✓ $\frac{1}{u} = \frac{1}{82} + \frac{1}{25}$ ✓ «=19 cm ***or*** 0.19 m»	*Award **[1 max]** if $v = +25$ cm used to give $u = -36$ cm.*	2
	c	ii	image will be real $v = 84 - 19 = 65$ cm ✓ « $\frac{1}{u} = \frac{1}{2} - \frac{1}{65}$ » so $u = 2.1$ cm ✓		2
	c	iii	$M_e =$ « $\frac{D}{f_e} + 1 = \frac{25}{82} + 1 =$ » 1.3 ***AND*** $m_o =$ « $\frac{v}{f_o} - 1 = \frac{65}{2} - 1 =$ » 31 ***or*** 32 ✓ so $M =$ « $M_e m_o = 1.3 \times 31 =$ » 40 ***or*** 41 ✓	*Far point adjustment gives $M = 9.3$ (accept answers from interval 9.3 to 9.6), award **[1 max]** for full working.*	2

Question			Answers	Notes	Total
11	a		curved, symmetrical path ✓ 	*Refraction on entry not required and ignored in diagram for simplicity.*	1
	b		waveguide dispersion means that rays not parallel to the central axis take longer to transmit ✓ in a graded-index fibre rays away from the central axis travel at a higher speed ***OR*** rays are «refracted» closer to the central axis ***OR*** effective diameter of the fibre is reduced ✓ because refractive index is greater in the centre ***OR*** refractive index is less at the edge ✓		3

Option D — Astrophysics					
Question			**Answers**	**Notes**	**Total**
12	**a**		made of dust and/or gas ✓ formed from supernova ✓ can form new stars ✓ some radiate light from enclosed stars ✓ some absorb light from distant stars ✓		**1 max**
	b		$d = \frac{1}{8.32 \times 10^{-3}}$ ***OR*** $120\,\text{pc}$ ✓ $120 \times 3.26 \times 9.46 \times 10^{15} = 3.70 \times 10^{18}\,\text{m}$ ✓	*Answer must be in metres, watch for POT.*	**2**
	c		distances are so big/large ***OR*** to avoid using large powers of 10 ***OR*** they are based on convenient definitions ✓		**1**

13	**a**		$T = \frac{2.9 \times 10^{-3}}{740 \times 10^{-9}}$ ✓ 3900 K ✓	*Answer must be to at least 2SF.*	**2**
	b		$L = 5.67 \times 10^{-8} \times 4\pi \times \left(3.1 \times 10^{10}\right)^2 \times 4000^4$ ✓ $= 1.8 \times 10^{29}\,\text{W}$ ✓	*Accept use of 3900^4 to give 1.6×10^{29} W .*	**2**
	c		absorption lines in spectra ✓ are specific to particular elements ✓	*Accept "emission lines in spectra".*	**2**
	d		helium ✓		**1**

Question			Answers	Notes	Total
13	e		helium flash ✓ expansion of outer shell ***OR*** surface temperature increase ✓ planetary nebula phase ✓ only the core remains ✓ if below 1.4 M_S/Chandrasekhar limit then white dwarf ✓		**3 max**

14	a	i	$z = \frac{\Delta\lambda}{\lambda_o}$ where $\Delta\lambda$ is the redshift of a wavelength and λ_o is the wavelength measured at rest on Earth ***OR*** it is a measure of cosmological redshift ✓	*Do not allow just "redshift".*	**1**
	a	ii	«$z = \frac{R}{R_o} - 1$, $\frac{R_o}{R} = \frac{1}{z+1}$» so $\frac{R_o}{R} = «\frac{1}{1.16}» = 0.86$ ✓	*Do not accept answer 1.16.*	**1**
	a	iii	$v = zc = 0.16 \times 3 \times 10^8 = 4.8 \times 10^4 \text{km s}^{-1}$ ✓ $d = \frac{v}{H_0} = \frac{4.8 \times 10^4}{68} = 706 \text{Mpc}$ ***OR*** $2.2 \times 10^{25} \text{m}$ ✓		**2**
	b		as the universe expanded it cooled/wavelength increased ✓ the temperature dropped to the present approximate 3 K ***OR*** wavelength stretched to the present approximate 1 mm ✓	*Value is required for MP2.*	**2**