Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2018

Physics

Standard level

Paper 3

24 pages

Section A

Question			Answers	Notes	Total
1.	a		distance fallen $= 654 - 12 = 642$ «mm» ✓ absolute uncertainty $= 2 + 0.1$ «mm» $\approx 2 \times 10^{-3}$ «m» ***or*** $= 2.1 \times 10^{-3}$ «m» ***or*** 2.0×10^{-3} «m» ✓	*Accept answers in mm or m*	**2**
1.	b		«$a = \frac{2s}{t^2} = \frac{2 \times 0.642}{0.363^2}$» $= 9.744$ «m s^{-2}» ✓ fractional uncertainty in distance $= \frac{2}{642}$ ***AND*** fractional uncertainty in time $= \frac{0.002}{0.363}$ ✓ total fractional uncertainty $= \frac{\Delta s}{s} + 2\frac{\Delta t}{t}$ «$= 0.00311 + 2 \times 0.00551$» ✓ total absolute uncertainty $= 0.1$ ***or*** 0.14 ***AND*** same number of decimal places in value and uncertainty, *ie*: 9.7 ± 0.1 ***or*** 9.74 ± 0.14 ✓	*Accept working in % for MP2 and MP3* *Final uncertainty must be the absolute uncertainty*	**4**

Question			Answers	Notes	Total
2.	**a**		combines the two equations to obtain result **«**for example $\frac{1}{I} = K^2(C+x)^2 = \frac{4\pi}{P}(C+x)^2$**»** ✓ ***OR*** reverse engineered solution – substitute $K = 2\sqrt{\frac{\pi}{P}}$ into $\frac{1}{I} = K^2(C+x)^2$ to get $I = \frac{P}{4\pi(C+x)^2}$ ✓	*There are many ways to answer the question, look for a combination of two equations to obtain the third one*	**1**
2.	**b**	**i**	extrapolating line to cross x-axis / use of x-intercept ***OR*** Use $C = \frac{y\text{-intercept}}{\text{gradient}}$ ***OR*** use of gradient and one point, correctly substituted in one of the formulae ✓ accept answers between 3.0 and 4.5 **«**cm**»** ✓	*Award **[1 max]** for negative answers*	**2**

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**b**	**ii**	***ALTERNATIVE 1*** Evidence of finding gradient using two points <u>on the line</u> at least 10 cm apart ✓ Gradient found in range: 115–135 ***or*** 1.15–1.35 ✓ Using $P = \frac{4\pi}{K^2}$ to get value between 6.9×10^{-4} and 9.5×10^{-4} **«**W**»** and POT correct ✓ Correct unit, W **and** answer to 1, 2 or 3 significant figures ✓ ***ALTERNATIVE 2*** Finds $I\left(\frac{1}{y^2}\right)$ from use of one point (x and y) on the line with $x > 6\text{cm}$ and C from (b)(i) to use in $I = \frac{P}{4\pi(C+x)^2}$ or $\frac{1}{\sqrt{I}} = Kx + KC$ ✓ Correct re-arrangement to get P between 6.9×10^{-4} and 9.5×10^{-4} **«**W**»** and POT correct ✓ Correct unit, W **and** answer to 1, 2 or 3 significant figures ✓	*Award **[3 max]** for an answer between 6.9W and 9.5W (POT penalized in 3rd marking point)* *Alternative 2 is worth **[3 max]***	**4**

(continued…)

(Question 2 continued)

Question			Answers	Notes	Total
2.	**c**		this graph will be a curve / not be a straight line ✓ more difficult to determine value of *K* ***OR*** more difficult to determine value of *C* ***OR*** suitable mathematical argument ✓	*OWTTE*	**2**

Section B

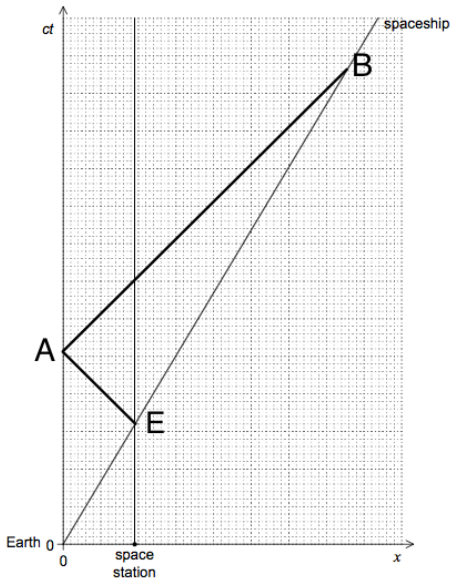
Option A — Relativity

Question			Answers	Notes	Total
3.	**a**	**i**	1.25*c* ✓		**1**
3.	**a**	**ii**	***ALTERNATIVE 1*** $u' = \frac{(0.50 + 0.75)}{1 + 0.5 \times 0.75} c$ ✓ 0.91*c* ✓ ***ALTERNATIVE 2*** $u' = \frac{-0.50 - 0.75}{1 - (-0.5 \times 0.75)} c$ ✓ –0.91*c* ✓		**2**
3.	**b**		nothing can travel faster than the speed of light (therefore (a)(ii) is the valid answer) ✓	*OWTTE*	**1**

Question			Answers	Notes	Total
4.	a		0.60*c* ***OR*** 1.8×10^{8} **«**$\mathrm{m\,s^{-1}}$**»** ✓		**1**
4.	b		***ALTERNATIVE 1*** time interval in the Earth frame $=90\times\gamma=112.5$ minutes ✓ **«**in Earth frame it takes 112.5 minutes for ship to reach station**»** so distance $=112.5\times60\times0.60c$ ✓ 1.2×10^{12} **«**m**»** ✓ ***ALTERNATIVE 2*** Distance travelled according in the spaceship frame $=90\times60\times0.6c$ ✓ $=9.72\times10^{11}$ **«**m**»** ✓ Distance in the Earth frame **«**$=9.72\times10^{11}\times1.25$**»** $=1.2\times10^{12}$ **«**m**»** ✓		**3**

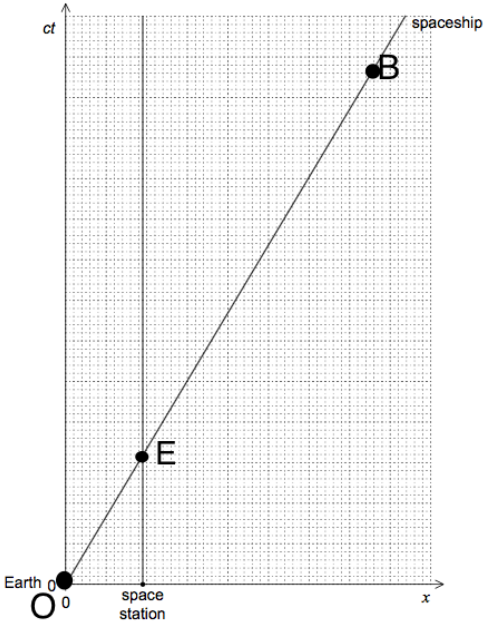
(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**c**		signal will take **«**$112.5 \times 0.60 =$**»** 67.5 **«**minutes**»** to reach Earth **«**as it travels at *c***»** **OR** signal will take **«**$\frac{1.2 \times 10^{12}}{3 \times 10^{8}} =$**»** 4000 **«***s***»** ✓ total time **«**$= 67.5 + 112.5$**»** $= 180$ minutes ***or*** 3.00 h or 3:00am✓		**2**
4.	**d**	**i**	line from event E to A, upward and to left with A on *ct* axis (approx correct) ✓ line from event A to B, upward and to right with B on *ct'* axis (approx correct) ✓ both lines drawn with ruler at 45 (judge by eye) ✓	*eg*:  	**3**

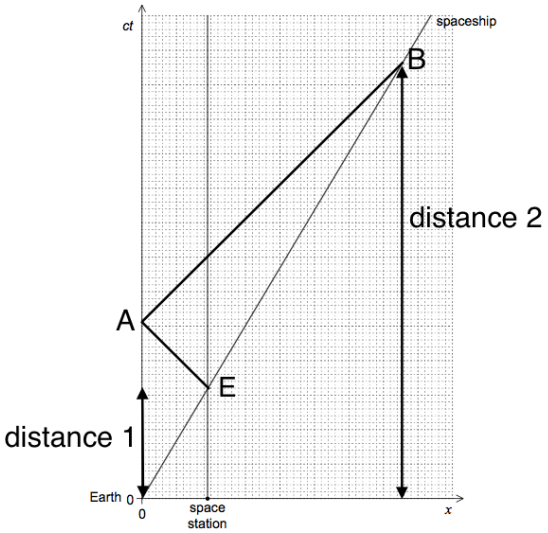
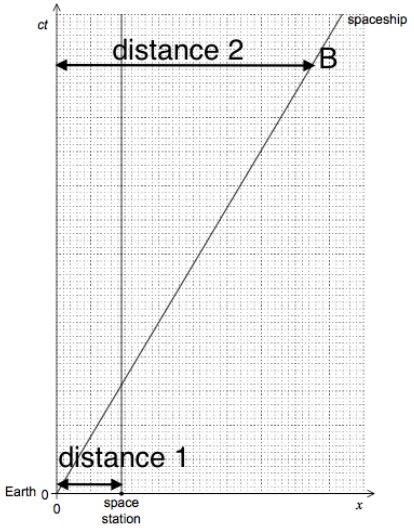
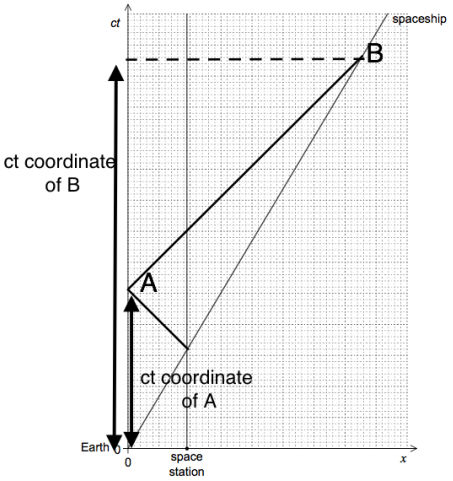
(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**d**	**ii**	***ALTERNATIVE 1*** **«**In spaceship frame**»** Finds the ratio $\frac{OB}{OE}$ (or by similar triangles on x or ct axes), value is approximately 4 ✓ hence time elapsed $\approx 4 \times 90\text{mins} \approx 6\text{h}$ **«**so clock time is $\approx 6{:}00$**»** ✓	***Alternative 1:***  *Allow similar triangles using x-axis or ct-axis, such as* $\frac{\text{distance 2}}{\text{distance 1}}$ *from diagrams below*	**2**

(continued…)

(Question 4 continued)

Question			Answers	Notes	Total
4.	**d**	**ii**	***ALTERNATIVE 2*** **«**In Earth frame**»** Finds the ratio $\frac{ct \text{ coordinate of B}}{ct \text{ coordinate of A}}$, value is approximately 2.5 ✓ hence time elapsed $\approx \frac{2.5 \times 3\text{h}}{1.25} \approx 6\text{h}$ **«**so clock time is $\approx$6:00**»** ✓	  ***ALTERNATIVE 2:*** 	

Question			Answers	Notes	Total
5.	**a**		quantity that is the same/constant in all inertial frames ✓		**1**
5.	**b**	**i**	spacetime interval $= 27^2 - 15^2 = 504$ **«**m^2**»** ✓		**1**
5.	**b**	**ii**	***ALTERNATIVE 1*** Evidence of $x' = 0$ ✓ t' **«**$= \frac{\sqrt{504}}{c}$**»** $= 7.5 \times 10^{-8}$ **«**s**»** ✓ ***ALTERNATIVE 2*** $\gamma = 1.2$ ✓ t' **«**$= \frac{9 \times 10^{-8}}{1.2}$**»** $= 7.5 \times 10^{-8}$ **«**s**»** ✓		**2**
5.	**c**		observer B measures the proper time and this is the shortest time measured ***OR*** time dilation occurs **«**for B's journey**»** according to A ***OR*** observer B is stationary relative to the particle, observer A is not ✓		**1**

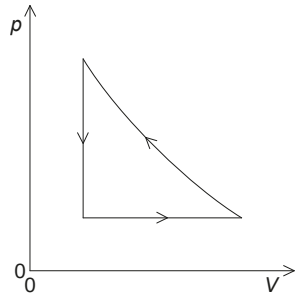
Option B — Engineering physics

Question			Answers	Notes	Total
6.	**a**	**i**	an object's resistance to change in rotational motion ***OR*** equivalent of mass in rotational equations ✓	*OWTTE*	**1**
6.	**a**	**ii**	$\Delta\text{KE} + \Delta\text{rotational KE} = \Delta\text{GPE}$ ***OR*** $\frac{1}{2}mv^2 + \frac{1}{2}I\frac{v^2}{r^2} = mgh$ ✓ $\frac{1}{2}\times 0.250\times v^2 + \frac{1}{2}\times 1.3\times 10^{-4}\times\frac{v^2}{1.44\times 10^{-4}} = 0.250\times 9.81\times 0.36$ ✓ $v = 1.2$ **«**m s^{-1}**»** ✓		**3**
6.	**a**	**iii**	ω **«**$= \frac{1.2}{0.012}$**»** $= 100$ **«**rad s^{-1}**»** ✓		**1**
6.	**b**	**i**	force in direction of motion ✓ so linear speed increases ✓		**2**
6.	**b**	**ii**	force gives rise to anticlockwise/opposing torque on wheel ✓ so angular speed decreases ✓	*OWTTE*	**2**

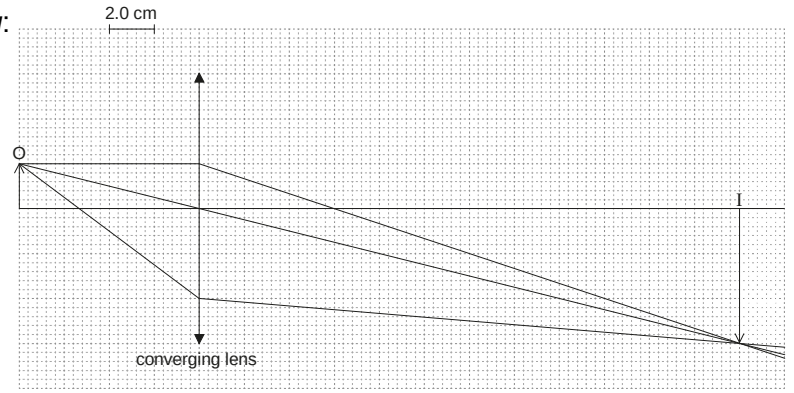
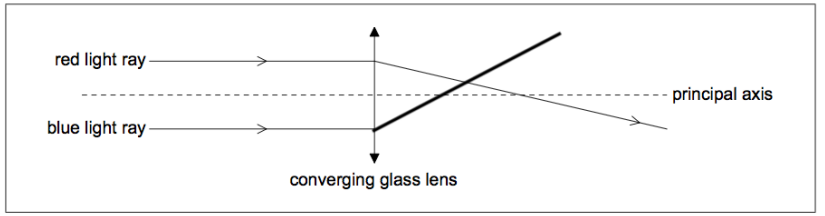
Question			Answers	Notes	Total
7.	a		***ALTERNATIVE 1*** «Using $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ » $V_2 = \frac{47.1 \times (273 + 19)}{(273 - 12)}$ ✓ $V_2 = 52.7$ «m^3» ✓ ***ALTERNATIVE 2*** «Using $PV = nRT$ » $V = \frac{243 \times 8.31 \times (273 + 19)}{11.2 \times 10^3}$ ✓ $V = 52.6$ «m^3» ✓		**2**
7.	b		W «$= P\Delta V$» $= 11.2 \times 10^3 \times (52.7 - 47.1)$ ✓ $W = 62.7 \times 10^3$ «J» ✓	*Accept 66.1×10^3 J if 53 used* *Accept 61.6×10^3 J if 52.6 used*	**2**
7.	c		ΔU «$= \frac{3}{2} nR\Delta T$» $= 1.5 \times 243 \times 8.31 \times (19 - (-12)) = 9.39 \times 10^4$ ✓ Q «$= \Delta U + W$» $= 9.39 \times 10^4 + 6.27 \times 10^4$ ✓ $Q = 1.57 \times 10^5$ «J» ✓	*Accept 1.60×10^5 if 66.1×10^3 J used* *Accept 1.55×10^5 if 61.6×10^3 J used*	**3**

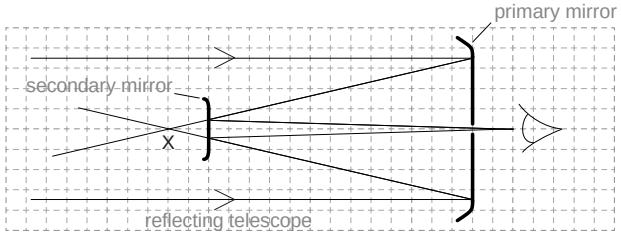
(continued…)

(Question 7 continued)

Question			Answers	Notes	Total
7.	**d**	**i**	concave curve from RHS of present line to point above LHS of present line ✓ vertical line from previous curve to the beginning ✓		**2**
7.	**d**	**ii**	energy is removed from the gas and so entropy decreases ***OR*** temperature decreases **«**at constant volume (less disorder)**»** so entropy decreases ✓	*OWTTE*	**1**
7.	**e**		different paradigms/ways of thinking/modelling/views ✓ allows testing in different ways ✓ laws can be applied different situations ✓	*OWTTE*	**1 max**

Option C — Imaging

Question			Answers	Notes	Total
8.	**a**	**i**	constructs ray parallel to principal axis and then to image position ***OR*** $u = 8\,\text{cm}$ and $v = 24\,\text{cm}$ and lens formula ✓ 6 «cm» ✓	*eg*:  *Allow answers in the range of 5.6 to 6.4 cm*	**2**
8.	**a**	**ii**	$m =$ «–»3.0 ✓		**1**
8.	**b**		completes diagram with blue focal point closer to lens ✓ blue light/rays refracted/deviated more ***OR*** speed of blue light is less than speed of red light ✓ ***OR*** different colors/wavelengths have different focal points/converge at different points ✓	*First marking point can be explained in words or seen on diagram*  	**2**

Question			Answers	Notes	Total
9.	**a**		where the extensions of the reflected rays from the primary mirror would meet, with construction lines ✓	*eg*: 	**1**
9.	**b**		greater magnification ✓		**1**
9.	**c**		Newtonian mount has plane/not curved **«**secondary**»** mirror ✓ **«**secondary**»** mirror at angle/45° to axis ✓ eyepiece at side/at 90° to axis ✓ mount shown is Cassegrain ✓	*OWTTE* *Accept these marking points in diagram form*	**2 max**
9.	**d**		waves collected above mirror/dish ✓ waves collected at the focus of the mirror/dish ✓ waves detected by radio receiver/antenna ✓ waves converted to electrical signals ✓		**1 max**

Question			Answers	Notes	Total
10.	**a**		$\sin c = \frac{1.4444}{1.4475}$ ***or*** $\sin c = 0.9978$ ✓ critical angle $= 86.2$**«°»** ✓ with cladding only rays travelling nearly parallel to fibre axis are transmitted ***OR*** pulse broadening/dispersion will be reduced ✓	*OWTTE*	**3**
10.	**b**	**i**	attenuation $=$ **«**$10 \log \frac{I}{I_0}$**»** $= 10 \log \frac{2.0 \times 10^{-6}}{400 \times 10^{-6}}$ ✓ attenuation $=$ **«–»**23 **«**dB**»** ✓	*Accept* $10 \log \frac{400}{2.0}$ *for first marking point*	**2**
10.	**b**	**ii**	$185 \times 0.200 = 37$ loss over length of cable ✓ **«**$\frac{37 - 23}{12} = 1.17$**»** so two amplifiers are sufficient ✓		**2**
10.	**b**	**iii**	mention of material dispersion ✓ mention that rays become separated in time ***OR*** mention that ray A travels slower/arrives later than ray B ✓		**2**

(continued…)

(Question 10 continued)

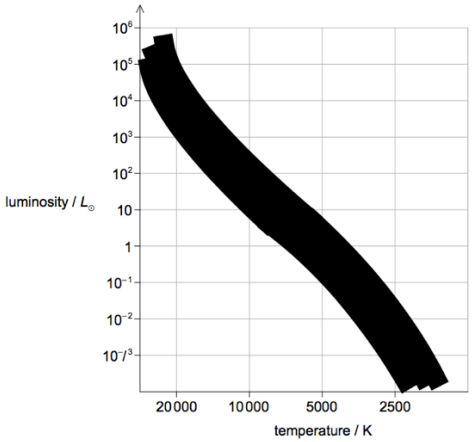
Question			Answers	Notes	Total
10.	**c**		high bandwidth/data transfer rates ✓ low distortion/Low noise/Faithful reproduction ✓ high security ✓ fast «fibre» broadband/internet ✓ high quality optical audio ✓ medical endoscopy ✓	*Allow any other verifiable sensible advantage*	**1 max**

Option D — Astrophysics

Question			Answers	Notes	Total
11.	**a**		photon/fusion/radiation force/pressure balances gravitational force/pressure ✓ gives both directions correctly (outwards radiation, inwards gravity) ✓	*OWTTE*	**2**
11.	**b**		**«**$L \propto M^{3.5}$ for main sequence**»** luminosity of $P = 2.5$ **«**luminosity of the Sun**»** ✓		**1**
11.	**c**	**i**	$L_{Gacrux} = 5.67\times10^{-8}\times4\pi\times(58.5\times10^{9})^2\times3600^4$ ✓ $L_{Gacrux} = 4.1\times10^{29}$ **«**W**»** ✓ $\frac{L_{Gacrux}}{L_{\odot}}$ **«**$= \frac{4.1\times10^{29}}{3.85\times10^{26}}$**»** $= 1.1\times10^{3}$ ✓		**3**
11.	**c**	**ii**	if the star is too far then the parallax angle is too small to be measured ***OR*** stellar parallax is limited to closer stars ✓	*OWTTE*	**1**

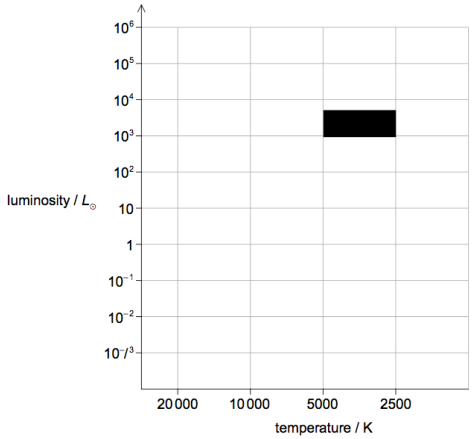
(continued…)

(Question 11 continued)

Question			Answers	Notes	Total
11.	**d**	**i**	line or area roughly inside shape shown – judge by eye ✓	*Accept straight line or straight area at roughly 45°* 	**1**
11.	**d**	**ii**	P between $1 L_\odot$ and $10^1 L_\odot$ on main sequence drawn ✓		**1**

(continued…)

(Question 11 continued)

Question			Answers	Notes	Total
11.	**d**	**iii**	at $10^3 L_\odot$, further to right than 5000 K and to the left of 2500 K (see shaded region)✓		**1**

(continued…)

(Question 11 continued)

Question			Answers	Notes	Total
11.	**e**		***ALTERNATIVE 1*** Main sequence to red giant ✓ planetary nebula with mass reduction/loss ***OR*** planetary nebula with mention of remnant mass ✓ white dwarf ✓ ***ALTERNATIVE 2*** Main sequence to red supergiant region ✓ Supernova with mass reduction/loss ***OR*** Supernova with mention of remnant mass ✓ neutron star ***OR*** Black hole ✓	*OWTTE for both alternatives*	**3**

Question			Answers	Notes	Total
12.	**a**		use of gradient or any coordinate pair to find H_0 «$= \frac{v}{d}$» or $\frac{1}{H_0}$ «$= \frac{d}{v}$» ✓ convert Mpc to m and km to m «for example $\frac{82 \times 10^3}{10^6 \times 3.26 \times 9.46 \times 10^{15}}$» ✓ age of universe «$= \frac{1}{H_0}$» $= 3.8 \times 10^{17}$ «s» ✓	*Allow final answers between* 3.7×10^{17} *and* 3.9×10^{17} «*s*» *or* 4×10^{17} «*s*»	**3**
12.	**b**		non-accelerated/uniform rate of expansion ***OR*** H_0 constant over time ✓	*OWTTE*	**1**
12.	**c**		z «$= \frac{v}{c}$» $= \frac{4.6 \times 10^4 \times 10^3}{3.00 \times 10^8} = 0.15$ ✓ $\frac{R}{R_0} =$ «$z + 1$» $= 1.15$ ✓ $\frac{R_0}{R} =$ «$\frac{1}{1.15} =$» 0.87 ***OR*** 87 % of the present size ✓		**3**