Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2018

Physics

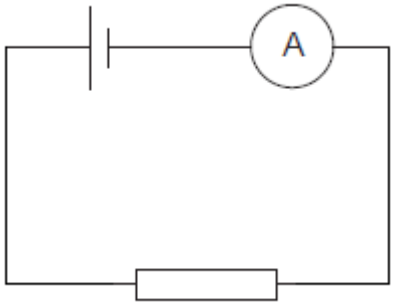
Higher level

Paper 3

23 pages

Section A

Question			Answers	Notes	Total
1.	a		smooth line, not kinked, passing through <u>all</u> the error bars ✓		1
1.	b	i	0.84 ± 0.03 **«s»** ✓	*Accept any value from the range: 0.81 to 0.87.* *Accept uncertainty 0.03* ***OR*** *0.025.*	1
1.	b	ii	$K = \sqrt{0.005} \times 0.84 = 0.059$ ✓ **«** $\frac{\Delta K}{K} = \frac{\Delta P}{P}$ **»** $\Delta K = \frac{0.03}{0.84} \times 0.0594 = 0.002$ ✓ **«** $K = (0.059 \pm 0.002)$ **»** uncertainty given to 1sf ✓	*Allow ECF* ***[3 max]*** *if 10T is used.* *Award* ***[3]*** *for BCA.*	3
1.	b	iii	$sT^{\frac{1}{2}}$ ✓	*Accept* $s\sqrt{T}$ *or in words.*	1
1.	c		straight ***AND*** ascending line ✓ through origin ✓		2
1.	d		$K = \sqrt{\text{slope}}$ ✓		1

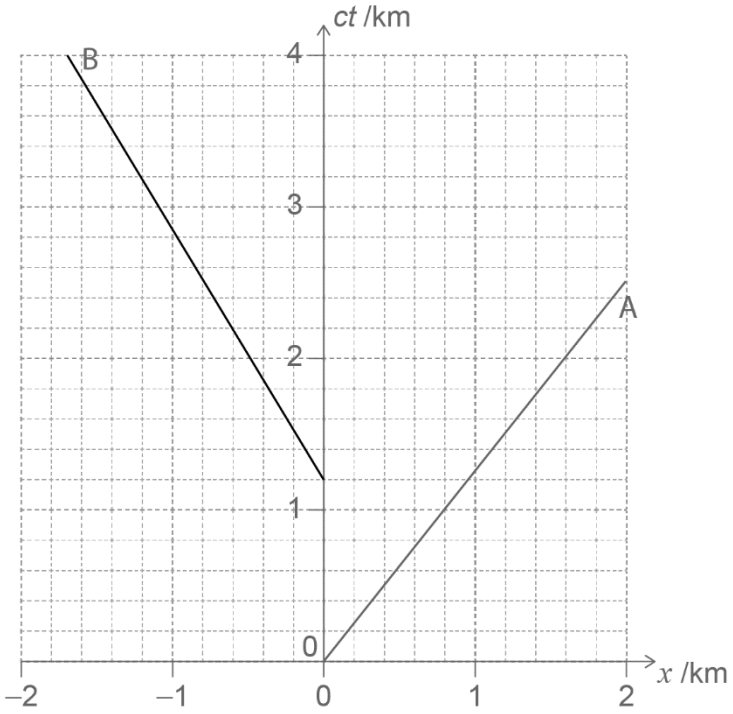
2.	**a**		 cell, ammeter and resistor in series ✓		**1**
2.	**b**		resistance of resistor would increase / be greater than $10\,\Omega$ ✓ $R + r$ **«**from $\varepsilon = I(R + r)$**»** would be overestimated / lower current ✓ therefore calculated r would be larger than real ✓	*Award MP3 only if at least one previous mark has been awarded.*	**3**
2.	**c**		variable resistor would allow for multiple readings to be made ✓ gradient of V-I graph could be found **«**to give r **»** ✓	*Award **[1 max]** for taking average of multiple.*	**2**

Section B

Option A — Relativity

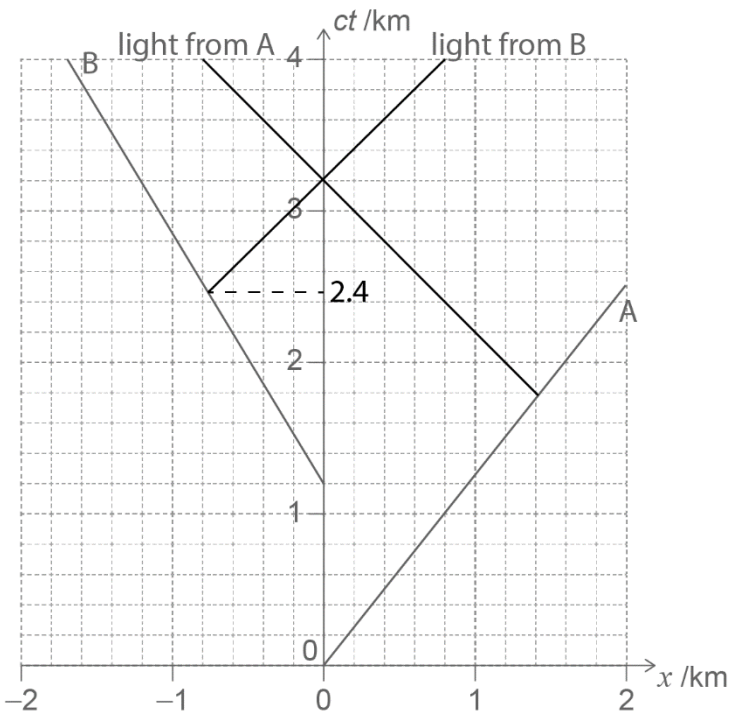
3.	**a**		magnetic field ✓		**1**
3.	**b**	**i**	**«**according to Y**»** the positive charges are moving **«**to the right**»** ✓ *d* decreases ✓	*For MP1, movement of positive charges must be mentioned explicitly.*	**2**
3.	**b**	**ii**	positive charges are moving, so there is a magnetic field ✓ the density of positive charges is higher than that of negative charges, so there is an electric field ✓	*The reason must be given for each point to be awarded.*	**2**

4.	**a**	**i**	« $\frac{10^4}{0.995 \times 3 \times 10^8} =$ » 34 « μs » ✓	*Do not accept $10^4/c$ = 33 μs .*	**1**
4.	**a**	**ii**	time is much longer than 10 times the average life time «so only a small proportion would not decay» ✓		**1**
4.	**b**	**i**	$\gamma = 10$ ✓ $\Delta t_0 =$ « $\frac{\Delta t}{\gamma} = \frac{34}{10} =$ » 3.4 « μs » ✓		**2**
4.	**b**	**ii**	the value found in (b)(i) is of similar magnitude to average life time ✓ significant number of muons are observed on the ground ✓ «therefore this supports the special theory»		**2**

5.	**a**		straight line with negative gradient with vertical intercept at $ct = 1.2$ **«km»** ✓ through (–0.6, 2.2) *ie* gradient = –1.67 ✓  	*Tolerance: Allow gradient from interval –2.0 to –1.4, (at ct = 2.2, x from interval 0.5 to 0.7).* *If line has positive gradient from interval 1.4 to 2.0 and intercepts at ct = 1.2 km then allow **[1 max]**.*	**2**
5.	**b**		line for the flash of light from A correctly drawn ✓ line for the flash of light of B correctly drawn ✓ correct reading taken for time of intersection of flash of light and path of B, $ct = 2.4$ **«km»** ✓	*Accept values in the range: 2.2 to 2.6.*	**3**

(continued…)

(Question 5 continued)

5.	**b**				
5.	**c**		the two events take place in the same point in space at the same time ✓ so all observers will observe the two events to be simultaneous / so zero difference ✓	*Award the second MP only if the first MP is awarded.*	**2**
5.	**d**		$u' = \frac{-0.6 - 0.8}{1-(-0.6)\times 0.8}$ ✓ $= \text{«–»}0.95$ **«*c*»** ✓		**2**

6.	**a**	**i**	**«** – **»** 29.8 **«**MeVc^{-1}**»** ✓		**1**
6.	**a**	**ii**	$E_\pi = \sqrt{p_\mu^2 c^2 + m_\mu^2 c^4} + p_\nu c$ ***OR*** $E_\mu = 109.8$ **«**MeV**»** ✓ $E_\pi =$ **«** $\sqrt{29.8^2 + 105.7^2} + 29.8 =$ **»** 139.6 **«**MeV**»** ✓	*Final value to at least 3 sig figs required for mark.*	**2**
6.	**b**		139.6MeVc^{-2} ✓	*Units required.* *Accept 140 MeVc^{-2}.*	**1**

7.	**a**		$\Delta f \propto f$ ✓ therefore the change is **«**–**»**$3\Delta f$ ✓		**2**
7.	**b**		$g =$ **«** $c^2 \frac{\Delta f}{f \Delta h} =$ **»** $(3 \times 10^8)^2 \frac{170}{5.0 \times 10^{14} \times 10\,000}$ ✓ $g = 3.1$ **«** ms^{-2} **»** ✓	*If POT mistake, award **[0]**.* *Award **[2]** for BCA.*	**2**
7.	**c**		the mass of the planet warps spacetime around itself ✓ the light will follow the shortest path in spacetime **«**which is curved**»** ✓		**2**

Option B — Engineering physics

8.	**a**		Γ «$= Fr = 50 \times 2$» $= 100$ «Nm» ✓ α «$= \frac{\Gamma}{I} = \frac{100}{450}$» $= 0.22$ «rad s^{-2}» ✓	*Final value to at least 2 sig figs,* ***OR*** *clear working with substitution required for mark.*	**2**
8.	**b**	**i**	«$\omega_t^2 - \omega_0^2 = 2\alpha\Delta\theta$» «$\omega_t^2 - 0 = 2 \times 0.22 \times 2\pi$» $\omega_t = 1.7$ «rad s^{-1}» ✓	*Accept BCA, values in the range: 1.57 to 1.70.*	**1**
8.	**b**	**ii**	«$L = I\omega = 450 \times 1.66$» $= 750$ «$\text{kgm}^2\text{rad s}^{-1}$» ✓	*Accept BCA, values in the range: 710 to 780.*	**1**
8.	**c**		«$I = 450 + mr^2$» I «$= 450 + 30 \times 2^2$» $= 570$ «kgm^2» ✓ «$L = 570 \times \omega = 747$» $\omega = 1.3$ «rad s^{-1}» ✓	*Watch for ECF from (a) and (b).* *Accept BCA, values in the range: 1.25 to 1.35.*	**2**

(continued…)

(Question 8 continued)

8.	**d**	**i**	moment of inertia will decrease ✓ angular momentum will be constant **«**as the system is isolated**»** ✓ **«**so the angular speed will increase**»**		**2**
8.	**d**	**ii**	$\omega_t = 1.66$ from bi ***AND*** $W = \Delta E_k$ ✓ $W = \frac{1}{2} \times 450 \times 1.66^2 - \frac{1}{2} \times 570 \times 1.31^2 = 131$ **«**J**»** ✓	*ECF from 8(b)(i).* *Accept BCA, value depends on the answers in previous questions.*	**2**

9.	**a**		**«** $p_1 V_1^{\frac{5}{3}} = p_2 V_2^{\frac{5}{3}}$ **»** $1.1 \times 10^5 \times 5^{\frac{5}{3}} = p_2 \times 2^{\frac{5}{3}}$ ✓ p_2 **«** $= \frac{1.1 \times 10^5 \times 5^{\frac{5}{3}}}{2.5^{\frac{5}{3}}}$ **»** $= 5.066 \times 10^5$ **«**Pa**»** ✓	*Volume may be in litres or m^3.* *Value to at least 2 sig figs, **OR** clear working with substitution required for mark.*	**2**

(continued…)

(Question 9 continued)

9.	**b**	**i**	**«** $W = p\Delta V$ **»** **«** $= 5.07\times10^{5}\times(5\times10^{-3}-2\times10^{-3})$ **»** $= 1.52\times10^{3}$ **«J»** ✓	*Award **[0]** if POT mistake.*	**1**
9.	**b**	**ii**	$\Delta U = \frac{3}{2}p\Delta V = \frac{3}{2}5.07\times10^{5}\times3\times10^{-3} = 2.28\times10^{3}$ **«J»** ✓	*Accept alternative solution via T_C.*	**1**
9.	**b**	**iii**	Q**«**$= (1.5+2.28)\times10^{3}=$**»**$3.80\times10^{3}$ **«J»** ✓	*Watch for ECF from (b)(i) and (b)(ii).*	**1**
9.	**c**	**i**	for isothermal process, PV = constant / ideal gas laws mentioned ✓ since $V_C > V_B$, P_C must be smaller than P_B ✓		**2**
9.	**c**	**ii**	the area enclosed in the graph would be smaller ✓ <u>so</u> the net work done would decrease ✓	*Award MP2 only if MP1 is awarded.*	**2**
9.	**d**		to reduce energy loss; increase engine performance; improve mpg *etc* ✓	*Allow any sensible answer.*	**1**

10.	**a**		in laminar flow, the velocity of the fluid is constant **«**at any point in the fluid**» «**whereas it is not constant for turbulent flow**» ✓**	*Accept any similarly correct answers.*	**1**
10.	**b**		$P_S = P_T$ **«**as both are exposed to atmospheric pressure**» ✓** then $V_T = 0$ **«**if the surface area of the reservoir is large**» ✓** **«** $\frac{1}{2}\rho v_S^2 + \rho g z_S = \rho g z_T$ **»** $\frac{1}{2}v_S^2 = g(z_T - z_S) = gH$ **✓** and so $v_S = \sqrt{2gH}$	*MP1 and MP2 may be implied by the correct substitution showing line 3 in the mark scheme.* *Do not accept simple use of* $v = \sqrt{2as}$ *.*	**3**
10.	**c**	**i**	$R = \frac{59.4 \times 0.6 \times 1 \times 10^3}{1.31 \times 10^{-3}} = 2.72 \times 10^7$ **✓**	*Accept use of radius 0.3 m giving value 1.36 x* 10^7*.*	**1**
10.	**c**	**ii**	as $R > 1000$ it is not reasonable to assume laminar flow **✓**		**1**

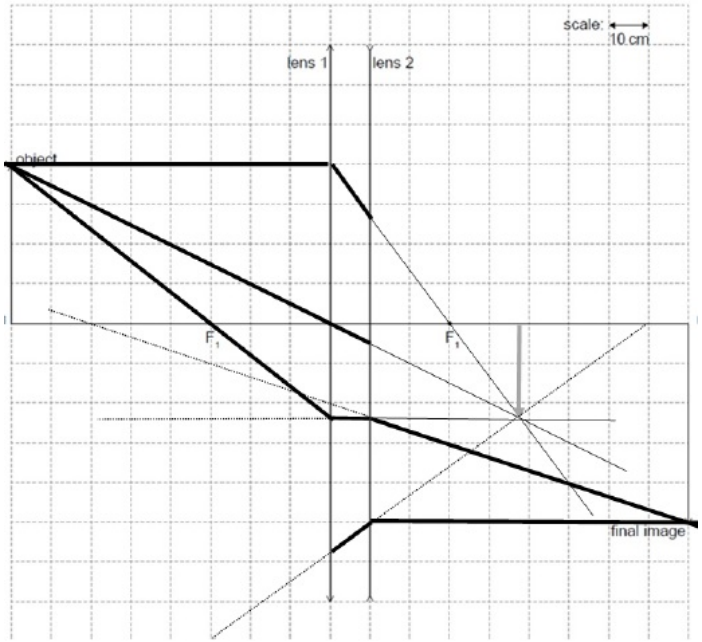
11.	**a**		damped oscillation / *OWTTE***✓**		**1**
11.	**b**	**i**	E **«** $= \frac{1}{2} \times 30 \times \pi^2 \times 0.8^2$ **»** $= 95$ **«J» ✓**	*Allow initial amplitude between 0.77 to 0.80, giving range between: 88 to 95 J.*	**1**
11.	**b**	**ii**	$\Delta E = 95 - \frac{1}{2} \times 30 \times \pi^2 \times 0.72^2 = 18$ **«J» ✓** $Q =$ **«** $2\pi \frac{95}{18} =$ **»** 33 **✓**	*Accept values between 0.70 and 0.73, giving a range of* ΔE *between 22 and 9, giving Q between 27 and 61.* *Watch for ECF from (b)(i).*	**2**

Option C — Imaging

12.	**a**	**i**	image is real **«**as projected on a screen**»** ✓		**1**
12.	**a**	**ii**	**«** $-\frac{18}{u}=-0.40$ **»** $u=45$ ✓ $\frac{1}{45}+\frac{1}{18}=\frac{1}{f}$ ***OR*** $f=13$ **«**cm**»** ✓ $P=\frac{1}{f}=$ **«**$\frac{1}{13}$**»** $=0.078$ **«**cm^{-1}**»** ✓	*Accept answer 7.7**«D».***	**3**
12.	**a**	**iii**	refractive index depends on wavelength ✓ light of different wavelengths have different focal points / refract differently ✓ there will be coloured fringes around the image ***/*** image will be blurred ✓		**3**
12.	**b**		any 2 correct rays to find image from lens 1 ✓ ray to locate F_2 ✓ Focal length = **«–»**70**«**cm**»** ✓	*Accept values in the range: 65cm to 75cm.* *Accept correct MP3 from accepted range also if working is incorrect or unclear, award **[1]**.*	**3**

(continued…)

(Question 12 continued)

12.	**b**				

13.	**a**		« $\sin c = \frac{1.34}{1.56}$ » $c = 59.2$«°» ✓	*Accept values in the range: 59.0 to 59.5.* *Accept answer 1.0 rad.*	**1**
13.	**b**		optic fibres are not susceptible to earthing problems ✓ optic fibres are very thin and so do not require the physical space of electrical cables ✓ optic fibres offer greater security as the lines can not be tapped ✓ optic fibres are not affected by external electric/magnetic fields/interference ✓ optic fibres have lower attenuation than electrical conductors / require less energy✓ the bandwidth of an optic fibre is large and so it can carry many communications at once/in a shorter time interval /faster data transfer ✓		**2 max**
13.	**c**	**i**	a signal that is wider and lower, not necessarily rectangular, but not a larger area ✓		**1**
13.	**c**	**ii**	attenuation $= -1.24 \times 3.4$ « $= -4.216$ dB» ✓ $-4.216 = 10\log\frac{I}{15}$ ✓ $I = 5.68$ «mW» ✓	*Need negative attenuation for MP1, may be shown in MP2.* *For MP3 answer must be less than 15mW (even with ECF) to earn mark.* *Allow **[3]** for BCA.*	**3**

(continued…)

(Question 13 continued)

13.	**c**	**iii**	refractive index near the edge of the core is less than at the centre ✓ speed of rays which are reflected from the cladding are greater than the speed of rays which travel along the centre of the core ✓ the time difference for the rays that reflect from the cladding layer compared to those that travel along the centre of the core is less ***OR*** the signal will remain more compact/be less spread out **/**dispersion is lower✓ bit rate of the system may be greater ✓		**3 max**

14.	**a**		crystal vibration /piezo-electric effect ✓ caused by an alternating potential difference is applied across a crystal ✓		**2**
14.	**b**		***ADVANTAGES*** the wavelength must be less than the size of the object being imaged to avoid diffraction effects ✓ the frequency must be high to ensure several full wavelengths in the pulse ✓ ***DISADVANTAGES*** the depth of the organ being imaged must be considered (no more than 200 wavelengths) ✓ attenuation increases at higher frequencies ✓	***[1]*** *for advantages,* ***[1]*** *for disadvantages.*	**2 max**
14.	**c**		X-rays are an ionizing radiation and so might cause harm to the developing fetus. ***OR*** there are no known harmful effects when using ultrasound ✓	*Ignore "moving images by ultrasound".*	**1**

(continued…)

(Question 14 continued)

14.	**d**	**i**	$\rho = \frac{1.99 \times 10^6}{1.73 \times 10^3} = 1.15 \times 10^3$ **«** kgm^{-3} **»** ✓		**1**
14.	**d**	**ii**	$F = \frac{(1.99 \times 10^6 - 4.3 \times 10^2)^2}{(1.99 \times 10^6 + 4.3 \times 10^2)^2} = 1.0$ ✓ $F = \frac{(1.48 \times 10^6 - 1.99 \times 10^6)^2}{(1.48 \times 10^6 + 1.99 \times 10^6)^2} = 0.02$ ✓ almost 100 % of the ultrasound will be reflected from the air-skin surface ***OR*** almost none is transmitted ✓ whereas only 2 % will be reflected from the gel-skin surface and so a much greater proportion is <u>transmitted</u> ✓	*Need to explain that more is transmitted through gel-skin surface for MP4.*	**4**

Option D — Astrophysics

15.	**a**	**i**	a galaxy is much larger in size than a solar system ✓ a galaxy contains more than one star system / solar system ✓ a galaxy is more luminous ✓	*Any other valid statement.*	**1 max**
15.	**a**	**ii**	a comet is a small icy body whereas a planet is mostly made of rock or gas ✓ a comet is often accompanied by a tail/coma whereas a planet is not ✓ comets (generally) have larger orbits than planets ✓ a planet must have cleared other objects out of the way in its orbital neighbourhood ✓		**1 max**

16.	**a**	**i**	the wavelengths of the dips correspond to the wavelength in the emission spectrum ✓ the absorption lines in the spectrum of star X suggest it contains predominantly hydrogen ***OR*** main sequence stars are rich in hydrogen ✓		**2**
16.	**a**	**ii**	peak wavelength: 290 ± 10 **«**nm**»** ✓ $T = \frac{2.9 \times 10^{-3}}{290 \times 10^{-9}} =$ **«**$10\,000 \pm 400$ K**»** ✓	*Substitution in equation must be seen.* *Allow ECF from MP1.*	**2**

(continued…)

(Question 16 continued)

16.	**b**	**i**	$35 \pm 5L_s$ ✓		**1**
16.	**b**	**ii**	$\frac{L_x}{L_s} = \frac{R_x^2 \times T_x^4}{R_s^2 \times T_s^4}$ ***OR*** $R_X = \sqrt{\frac{L_X T_s^4}{L_s T_X^4}} \times R_s$ ✓ $R_X = \sqrt{\frac{35 \times 6000^4}{10000^4}} \times R_s$ (mark for correct substitution) ✓ $R_X = 2.1R_s$ ✓	*Allow ECF from (b)(i).* *Accept values in the range: 2.0 to 2.3R_s.* *Allow T_S in the range: 5500 K to 6500 K.*	**3**
16.	**b**	**iii**	$M_X = (35)^{\frac{1}{3.5}} M_s$ ✓ $M_X = 2.8M_s$ ✓	*Allow ECF from (b)(i).* *Do not accept $M_X = (35)^{\frac{1}{3.5}}$ for first marking point.* *Accept values in the range: 2.6 to 2.9M_s.*	**2**
16.	**c**		the star «core» collapses until the «inward and outward» forces / pressures are balanced ✓ the outward force / pressure is due to electron degeneracy pressure «not radiation pressure» ✓		**2**

17.	**a**		experiments and collecting data are extremely costly ✓ data from many projects around the world can be collated ✓	*OWTTE*	**1 max**
17.	**b**		$v = «zc = 0.19 \times 3 \times 10^8 =» 5.7 \times 10^7$ «ms^{-1}» ✓ $d = «\frac{v}{H_0} = \frac{5.7 \times 10^4}{70}» = 810$ Mpc ***OR*** 8.1×10^8 pc ✓	*Correct units must be present for MP2 to be awarded.* *Award **[2]** for BCA.*	**2**
17.	**c**		***ALTERNATIVE 1*** $\frac{R_{\text{now}}}{R_{\text{then}}} = 1 + z = 1.19$ ✓ so (assuming constant expansion rate) $\frac{t_{\text{now}}}{t} = 1.19$ ✓ $t = \frac{14}{1.19} = 11.7$ By $= 12$ «By (billion years)» ✓ ***ALTERNATIVE 2*** light has travelled a distance: $(810 \times 10^6 \times 3.26 =) 2.6 \times 10^9$ ly ✓ so light was emitted: 2.6 billion years ago ✓ so the universe was 11.4 billion years old ✓	*MP1 can be awarded if MP2 clearly seen.* *Accept 2.5×10^{25} m for MP1.* *MP1 can be awarded if MP2 clearly seen.*	**3**

18.	**a**		a white dwarf accretes mass **«**from a binary partner**»** ✓ when the mass becomes more than the Chandrasekhar limit $(1.4M_s)$ **«**then a supernova explosion takes place**»** ✓		**2**
18.	**b**	**i**	$d = \sqrt{\frac{L}{4\pi b}} = \sqrt{\frac{5\times10^5\times3.8\times10^{26}}{4\pi\times1.6\times10^{-6}}}$ ✓ $d = 3.07\times10^{18}$ **«**m**»** ✓	*At least 3 sig fig required for MP2.*	**2**
18.	**b**	**ii**	type Ia supernova can be used as standard candles ✓ there is no dust absorbing light between Earth and supernova ✓ their supernova is a typical type Ia ✓		**1 max**

19.	**a**		$\frac{mv^2}{r} = \frac{GMm}{r^2}$ and correct rearranging ✓		**1**
19.	**b**		linear /rising until R_0 ✓ then **«**almost**»** constant ✓		**2**
19.	**c**		for *v* to stay constant for *r* greater than R_0, *M* has to be proportional to *r* ✓ but this contradicts the information from the *M*-*r* graph ✓ ***OR*** if *M* is constant for *r* greater than R_0, then we would expect $v \propto r^{\frac{-1}{2}}$ ✓ but this contradicts the information from the *v*-*r* graph ✓		**2 max**