Name of the Student:_____
Max. Marks : 19 Marks **Time : 19 Minutes**

Mark Schemes

Q1.

Question Number	Answer		Mark
	(Observed frequency is less, so) source is receding (from Earth)	(1)	
	Use of $\frac{\Delta f}{f} = \frac{v}{c}$ Or $z = \frac{\Delta f}{f}$	(1)	
	$v = 1.5 \times 10^6\ \text{m s}^{-1}$ Or $z = 5.0 \times 10^{-3}$	(1)	3
	(min 2 sf answer required)		
	Example of calculation:		
	$\Delta f = (4.547 \times 10^{14} - 4.570 \times 10^{14})\ \text{Hz} = (-)2.3 \times 10^{12}\ \text{Hz}$		
	$v = \frac{c\,\Delta f}{f} = \frac{3.0 \times 10^8\ \text{m s}^{-1} \times 2.3 \times 10^{12}\ \text{Hz}}{4.57 \times 10^{14}\ \text{Hz}} = 1.51 \times 10^6\ \text{m s}^{-1}$		
	Total for question		**3**

Q2.

Question Number	Acceptable answers		Additional guidance	Mark
	• The frequency/wavelength (of a line in the spectrum) emitted by the star must be measured	(1)		
	• Determine the difference between this frequency/wavelength and that emitted in the lab	(1)	MP2 – accept in terms of difference between measured frequency/wavelength with average frequency/wavelength	
	• (The Doppler equation is used to) determine the speed of the star (relative to the Earth) $v/c = \Delta f/f_0$ or $v/c = \Delta\lambda/\lambda_0$	(1)		
	• Clear indication (stated in words or via a formula) that v is positive/approaching when the frequency has increased and negative/receding when it has decreased **Or** corresponding statement about wavelength	(1)		4

Q3.

Question Number	Acceptable answers	Additional guidance	Mark
	• The wavelength change is bigger the further away the galaxies are **(1)** • The further away galaxies are the faster they are moving, so all distant galaxies are moving away from each other (and the universe is expanding) **(1)** • There is a large amount of scatter in Hubble's original data set. **(1)** • The original data set covers a very small range of distances [only the closest galaxies considered] **(1)** • Hence, on the basis of the original data, the conclusion drawn by Hubble was quite speculative **(1)**		**5**

Q4.

Question number	Acceptable answers	Additional guidance	Mark
(i)	• use of $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • use of $F = Gm_1m_2/r^2$ **(1)** • Expresses forces as a ratio **(1)** **OR** calculates the individual forces $F_e = 8.1 \times 10^{-8}$ N $F_g =$ • 3.6×10^{-47} N **(1)** • Ratio = 2×10^{39} or 5×10^{-40} and identifies gravitational force as insignificant **(1)**		**4**
(ii)	• use of $F = mv^2/r$ and $F = Q_1Q_2/4\pi\varepsilon_0 r^2$ **(1)** • to derive $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ **(1)** • velocity = 2.2×10^6 m s^{-1} **(1)**	Example of calculation: $v = \sqrt{\frac{Q_1Q_2}{4\pi\epsilon_0 rm}}$ $v = \sqrt{\frac{1.6\times10^{-19}\text{ C}\times1.6\times10^{-19}\text{ C}}{4\pi\times8.85^{-12}\text{ Fm}^{-1}\times5.3\times10^{-11}\text{m}\times9.1\times10^{-31}\text{ kg}}}$ $v = 2.185 \times 10^6$ m s^{-1}	**3**