Mark scheme for Support Worksheet – Topic E, Worksheet 3

1 **a** For the $1\,M_e$ mass star the stages are red giant, planetary nebula and white dwarf. [1]

b For the $1\,M_e$ mass star the stages are red supergiant, supernova and most likely a neutron star. [1]

2 Since $L \propto M^{3.5}$ we have that $L = L_e\, 3^{3.5} = 46.8 L_e \approx 47 L_e$ [1]

3 This is the highest mass a white dwarf can have (and equals about $1.4\,M_e$). [1]

4 This is the highest mass a neutron star can have (and equals about $3\,M_e$). [1]

5 A neutron star that rotates about its axis with a magnetic field that has a different direction from that of the axis of rotation. [1]

6 Because pulsars radiate radio waves and not visible light. [1]

7 Distant galaxies move away from each other with a speed proportional to their separation. [1]

8 Because galaxies that are near each other attract each other gravitationally and may move towards each other. [1]

9 $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow v = \frac{\Delta\lambda}{\lambda}c$; hence $v = \frac{680-656}{656} \times 3\times10^{8} = 1.1\times10^{7}\ \text{m s}^{-1}$ [2]

10 $\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \Rightarrow v = \frac{\Delta\lambda}{\lambda}c$; hence

$v = \frac{670-656}{656} \times 3\times10^{8} = 6.4\times10^{6}\ \text{m s}^{-1} = 6.4\times10^{3}\ \text{km s}^{-1}$; therefore

$d = \frac{v}{H} = \frac{6.4\times10^{3}}{73} = 87.67 \approx 88\ \text{Mpc}$ [3]

11 $\frac{1}{H} = \frac{1}{73\ \text{km s}^{-1}\,\text{Mpc}^{-1}} = \frac{1}{73}\frac{10^{6}\times3.26\times9.46\times10^{15}}{10^{3}\times365\times24\times3600} = 1.34\times10^{10}\ \text{yr}$, i.e. about 13 billion years. [1]

12 Assume that galaxies move away from each other at the present speed of $v = Hd$ where d is their present separation; then $v = \frac{d}{T}$ where T is the age of the universe; combining gives $T = \frac{1}{H}$. [3]

