Mark scheme for Extension Worksheet – Option E, Worksheet 2

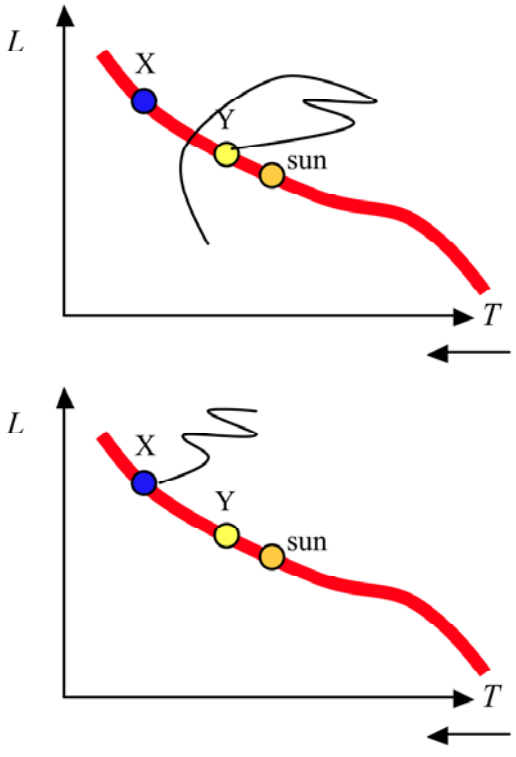
1 The release of gravitational potential energy as the cloud shrinks in size. [1]

2 **a** The available energy is Mc^2 and the luminosity is the rate of production of energy so on the average $L = \frac{Mc^2}{T}$ where T is the lifetime of the star; from which follows $T = \frac{Mc^2}{L} \propto \frac{M}{L}$ [2]

b So $T \propto \frac{M}{L} \propto \frac{M}{M^{3.5}} \propto M^{-2.5}$; and hence $\frac{T}{T_e} = \left(\frac{M}{M_e}\right)^{-2.5} = (12)^{-2.5} = 2.0 \times 10^{-3}$ [2]

3 **a** The stars are all main sequence stars so the mass–luminosity relation applies; since star X has the greatest luminosity it must have the largest mass of the three. [2]

b See diagrams.



[2]

4 **a** The $2M_e$ mass star will most likely end up as a white dwarf; whereas the $10M_e$ mass star will end up as a neutron star. [2]

b The $2M_e$ will evolve to become a red giant and then explode as a planetary nebula; whereas the $10M_e$ star will evolve to become a super red giant and explode as supernova. [2]

c The nuclear reactions in the low-mass star will, at most, involve the fusing of helium after leaving the main sequence to produce carbon; whereas in the high-mass star, a sequence of fusion reactions involving progressively heavier elements take place; helium and carbon can fuse to form oxygen, oxygen and helium can fuse to form neon etc. [3]

5 In each case the opposing force to gravity is:

a for main sequence stars the force created due to the radiation pressure produced by the nuclear reactions at the core. [1]

b for white dwarf stars it is provided by the pressure due to electrons. [1]

c for neutron stars it is provided by the pressure due to neutrons. [1]

6 Because their luminosity is extremely small. [1]

7 It overestimates the age of the universe; because the estimate is based on the present rate of expansion. [2]

8 The temperature in the very early universe was very high and so the average kinetic energy of particles at that time was also very high; and so they could not be forced into bound states/structures. [2]