1 Centaurus A is the nearest example of an active galactic nucleus. Many astronomers believe a supermassive black hole at the centre of such a galaxy produces a quasar as it consumes the material of its nearby stars.

(a) Explain what is meant by the event horizon of a black hole.

_____

_____

_____

(1)

(b) (i) The mass of the black hole is 60 million times the mass of the Sun. Calculate the radius of its event horizon.

answer = _____m

(2)

(ii) Calculate the average density of the matter within its event horizon.

answer = _____kg m^{-3}

(2)

(Total 5 marks)

2 (a) Betelgeuse is a red supergiant star with a mass approximately ten times greater than that of the Sun. Eventually it is quite likely that Betelgeuse will become a *supernova*, leaving a *neutron star* or perhaps a *black hole*.

State a significant property of a

(i) supernova,

_____

_____

(ii) neutron star,

_____

_____

(iii) black hole.

_____

_____

(3)

(b) Calculate the Schwarzchild radius for a black hole whose mass is ten times greater than that of the Sun.

_____

_____

(2)

(Total 5 marks)

3 NGC 3842 is a galaxy which contains one of the biggest black holes ever discovered.

(a) State what is meant by a black hole.

_____

_____

_____

(1)

(b) The mass of the black hole in NGC 3842 is believed to be 1.0×10^{10} times greater than that of the Sun.

Calculate the radius of its event horizon.

radius = _____ m

(2)

(c) NGC 3842 is 3.3×10^{8} light years from the Earth, and is receding at a velocity of 6.3×10^{6} m s^{-1}.

Estimate, using these data, an age in seconds for the Universe.

age of Universe = _____ s

(3)

(Total 6 marks)

4 Antares is a red supergiant star in the constellation of Scorpio. It has a mass about 18 times that of the Sun.
Eventually the star will become a supernova, leaving behind a core that could form a neutron star or a black hole.

(a) State what is meant by a supernova.

_____

_____

(1)

(b) State the defining properties of a neutron star.

_____

_____

_____

(2)

(c) To become a black hole it is likely that the core would have to have a mass at least twice that of the Sun.

Calculate the Schwarzschild radius of a black hole with a mass twice that of the Sun.

radius = _____ m

(2)

(d) Some scientists are concerned about the consequences for the Earth of a supernova occurring in a nearby part of the galaxy.

Explain the cause of this concern.

_____

_____

_____

_____

(2)

(Total 7 marks)

5 The Chandra X-ray Observatory was launched into orbit in 1999. It is used to observe hot and turbulent regions of space.

(a) Explain why X-ray telescopes need to be in orbit.

_____

_____

(1)

(b) In 2000, the Chandra telescope was used to observe a *black hole* in Ursa Major.

(i) Explain what is meant by a black hole.

_____

_____

(1)

(ii) The black hole is believed to have a mass 7 times that of the Sun. Calculate the radius of its event horizon.

mass of the Sun = 2.0×10^{30} kg

radius = _____ m

(2)

(c) Chandra makes use of a charge coupled device (CCD) to detect the X-ray photons. Describe the processes involved in the detection of photons by a CCD.

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

6 The Antennae Galaxies are a pair of colliding galaxies in the constellation Corvus.

(a) Measurements of the *red shift* of radio signals from the galaxies suggest they are approximately 25 Mpc from the Earth.

(i) Explain what is meant by red shift.

_____

_____

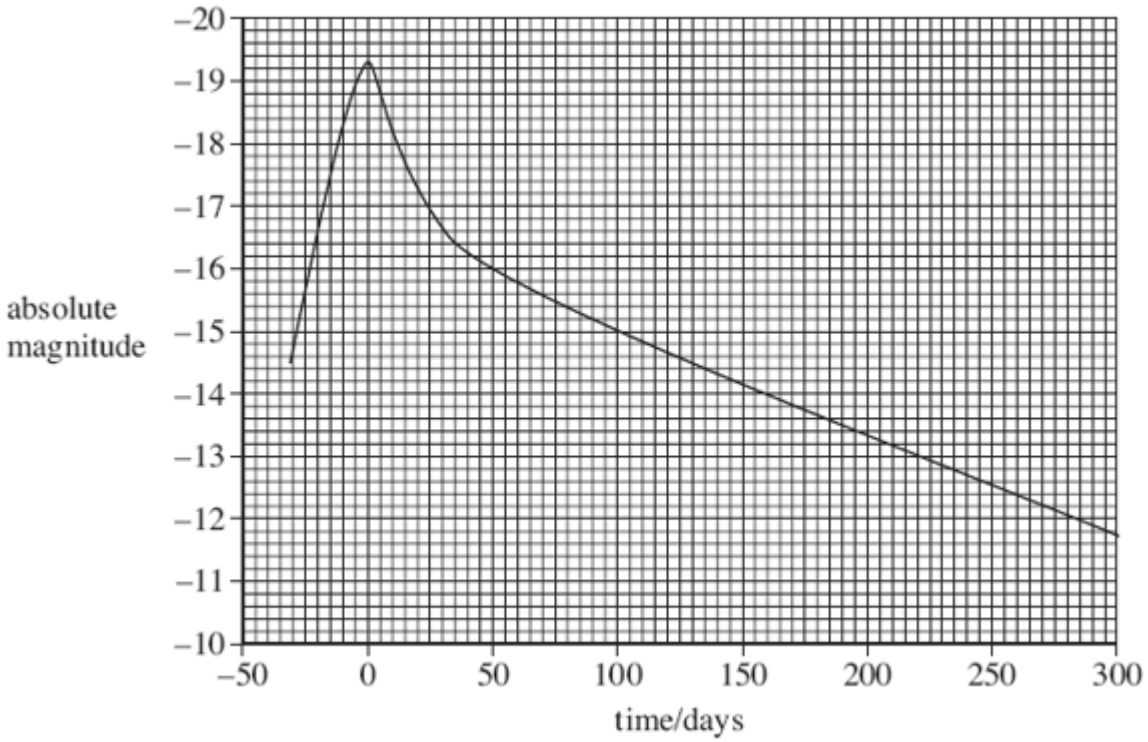
(1))

(ii) Calculate the recessive velocity of the Antennae Galaxies.

answer = _____km s^{-1}

(2)

(b) SN 2008sr was a type 1a supernova detected in the Antennae Galaxies. The figure below is the light curve of a type 1a supernova.



(i) With reference to the figure above, explain why type 1a supernovae can be used as standard candles to determine distances.

_____

_____

_____

_____

_____

(2)

(ii) The peak value for the apparent magnitude of this supernova was 12.9. Using this measurement and information from the figure above, calculate the distance to the Antennae Galaxies in Mpc.

answer = _____Mpc

(2)

(c) Why is it important for astronomers to have several independent methods of determining the distance to galaxies?

_____

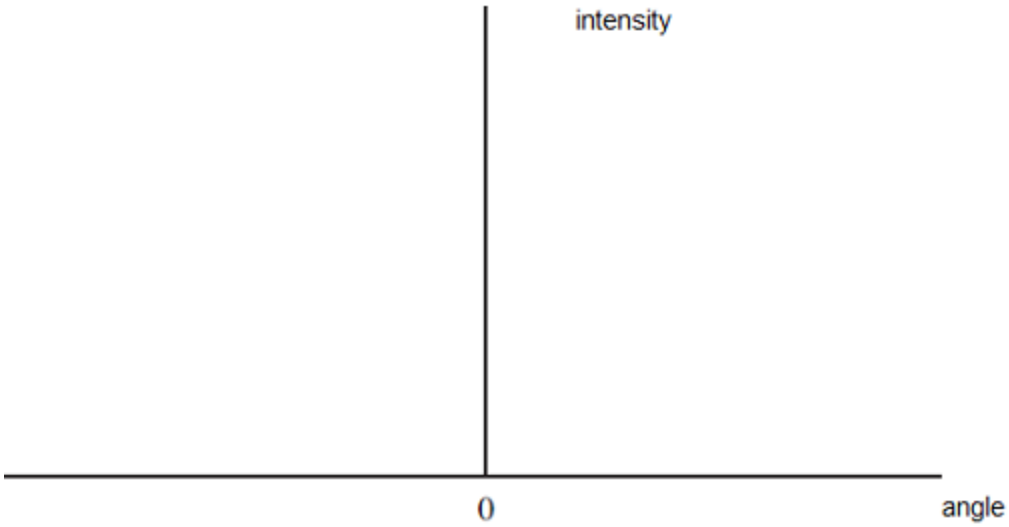
_____

(1)

(Total 8 marks)

7 There is a supermassive black hole at the centre of the Milky Way galaxy. It is difficult to resolve images of the region around this black hole directly.

(a) (i) Sketch, on the axes, the variation in intensity of the diffraction pattern produced when light from a point object passes through a circular aperture.



(2)

(ii) The *Rayleigh criterion* is used to determine the smallest angular separation between two point objects which can be resolved by a telescope. With reference to the diffraction patterns formed, explain what is meant by the Rayleigh criterion. You may draw a diagram to aid your explanation.

_____

_____

_____

_____

(2)

(b) The supermassive black hole at the centre of the Milky Way galaxy has a mass equal to 4.1 million solar masses.
Calculate the Schwarzschild radius, R_s, for this black hole.
Give your answer to an appropriate number of significant figures.

R_s _____ m

(3)

(c) Astronomers investigating the supermassive black hole at the centre of the Milky Way galaxy detect radio waves at a frequency of 230 GHz. By correlating the information from several radio telescopes, they can obtain images with the same resolution as a single radio telescope with a diameter of 5000 km.

(i) Calculate the minimum angular separation which could be resolved by a radio telescope of diameter 5000 km detecting waves of frequency 230 GHz.

angular separation _____ rad

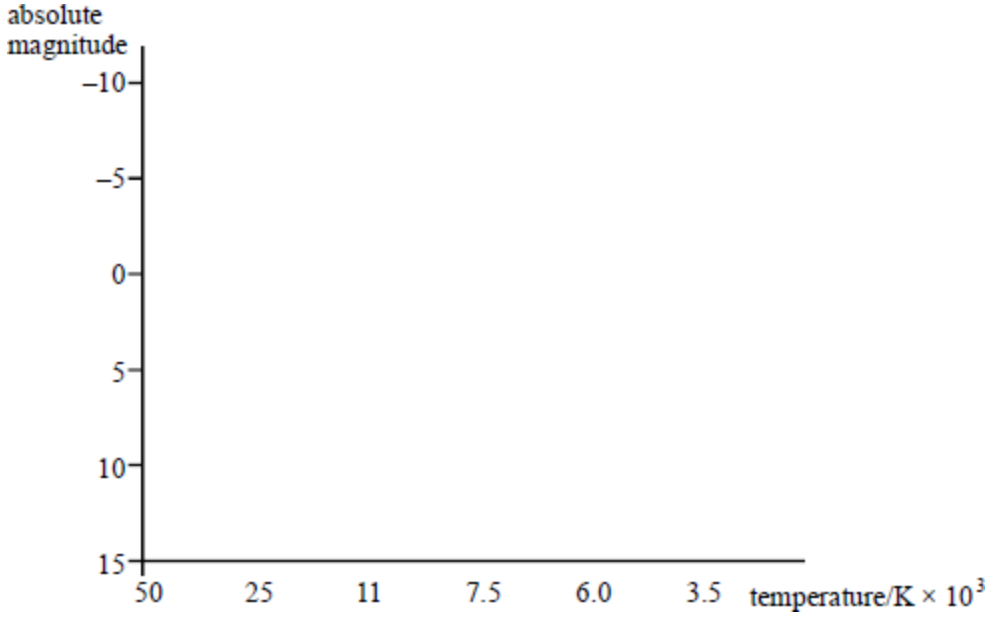
(2)

(ii) The centre of the Milky Way galaxy is 25 000 light years from the Earth.

Show that the limit of the resolution of the telescope is approximately five times the angle subtended by the Schwarzschild radius of the black hole at this distance.

(2)
(Total 11 marks)

8 (a) Sketch a Hertzsprung-Russell diagram using the axes below. Label the approximate positions of main sequence stars, Red Giant stars, White Dwarf stars and the Sun.



(3)

(b) The evolution of a star from the main sequence depends on its mass. A certain star in the main sequence, in a position close to the Sun, evolves into a Red Giant.

(i) Compare the brightness of this star when it is a Red Giant to when it was in the main sequence.

_____

(ii) Given that the hydrogen in this star undergoes fusion, suggest a sequence of events which causes this star to evolve into a Red Giant.

_____

_____

_____

_____

_____

_____

(4)

(c) Nova Muscae is believed to be a black hole with a mass approximately three times that of the Sun.

(i) What property of this star causes it to be a black hole? Explain why it is so named.

_____

_____

(ii) State what is meant by the term *event horizon* and calculate the radius of the event horizon for this star, using data from the Data booklet.

_____

_____

_____

(5)

(Total 12 marks)