**Q1.** NGC 3842 is a galaxy which contains one of the biggest black holes ever discovered.

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

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**(1)**

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

Calculate the radius of its event horizon.

radius = ..... m

**(2)**

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

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

age of Universe = ..... s

**(3)**

**(Total 6 marks)**

**Q2.** 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.

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**(1)**

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

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.....

**(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.

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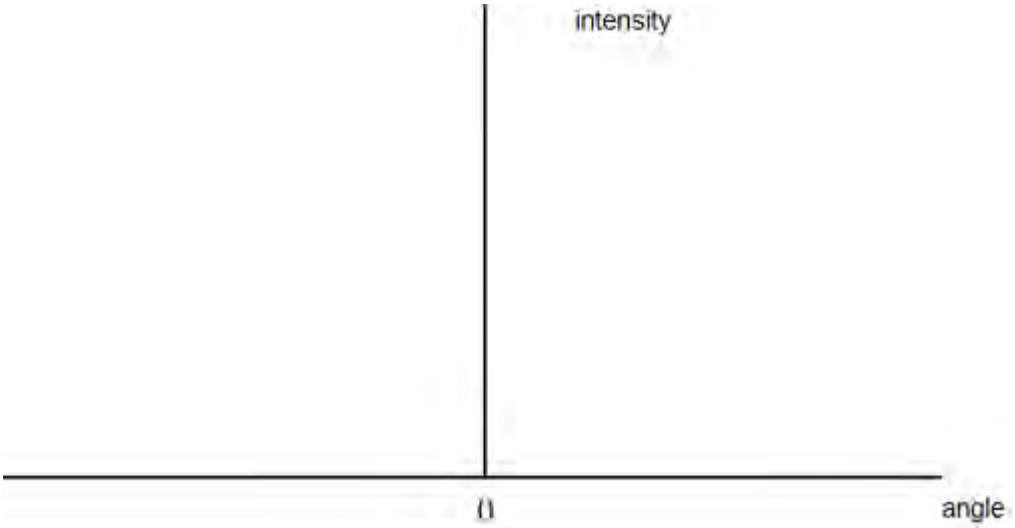
**(2)**
**(Total 7 marks)**

**Q3.** 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.

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**(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)**

**Q4.** 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.

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.....

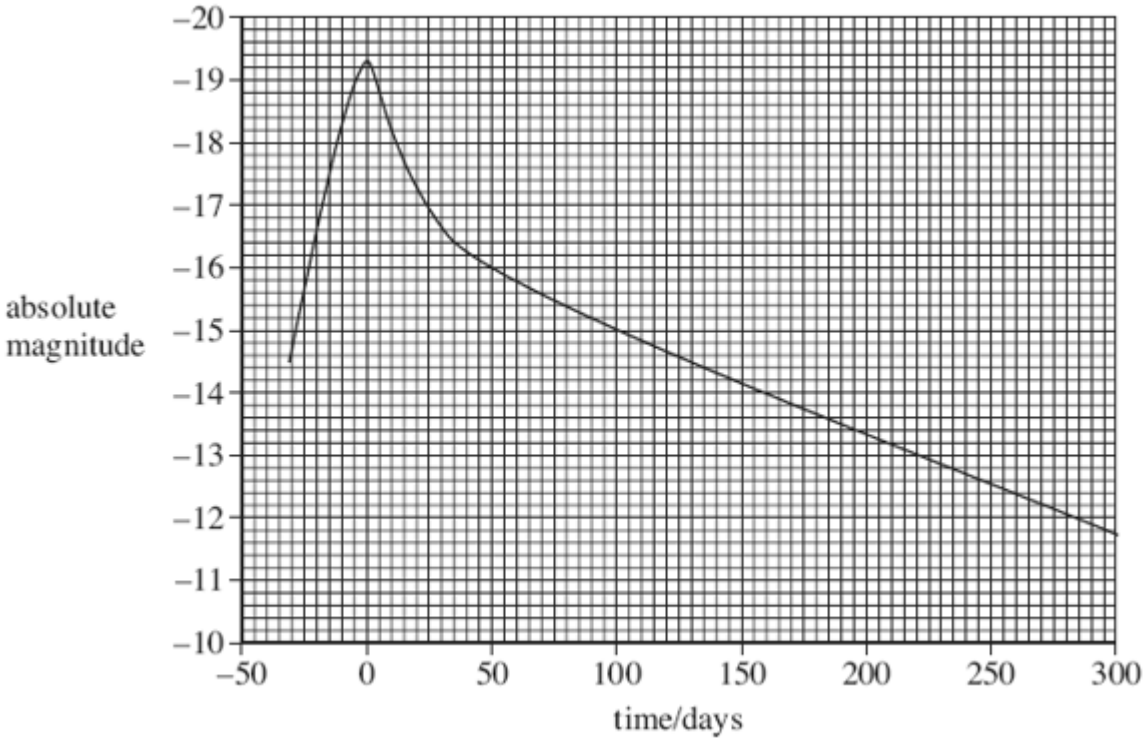
**(1))**

(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.

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**(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?

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**(1)**

**(Total 8 marks)**