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 1.0×10^{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)

Q2.(a) State what is meant by the Hubble constant.

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(1)

(b) The recessional velocity of a galaxy 8.0×10^8 ly from Earth is measured to be 1.8×10^4 km s^{-1}.

Show that this suggests a value for the Hubble constant of 73 km s^{-1} Mpc^{-1}.

(2)

(c) (i) Using the value for the Hubble constant given in part (b), estimate the age of the Universe.
Give your answer in years.

age of the Universe ..... years

(3)

(ii) State **one** assumption that must be made to justify the estimate made in part (i).

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(1)

(Total 7 marks)

Q3.(a) The table summarises some of the properties of two stars in the constellation of Ursa Minor.

name	apparent magnitude	radius of star / radius of the Sun	spectral class
Polaris	2.0	50	F
Kocab	2.0	50	K

(i) Using these data, describe and explain **one** similarity and **one** difference in the appearance of the two stars as seen with the unaided eye by an observer on the Earth.

similarity.....

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difference.....

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(2)

(ii) Deduce which of the two stars is further from the Earth.

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(3)

(b) Ursa Minor also contains the galaxy NGC 6251. Measurements indicate that the light from the galaxy has a red shift, *z*, of 0.025 and that the galaxy is 340 million light years from Earth.

(i) Use these data to calculate a value for the Hubble constant.

value ..... k ms^{-1} Mpc^{-1}

(3)

(ii) Use your answer to part (b)(i) to estimate a value for the age of the Universe. State an appropriate unit for your answer.

age ..... unit .....

(3)
(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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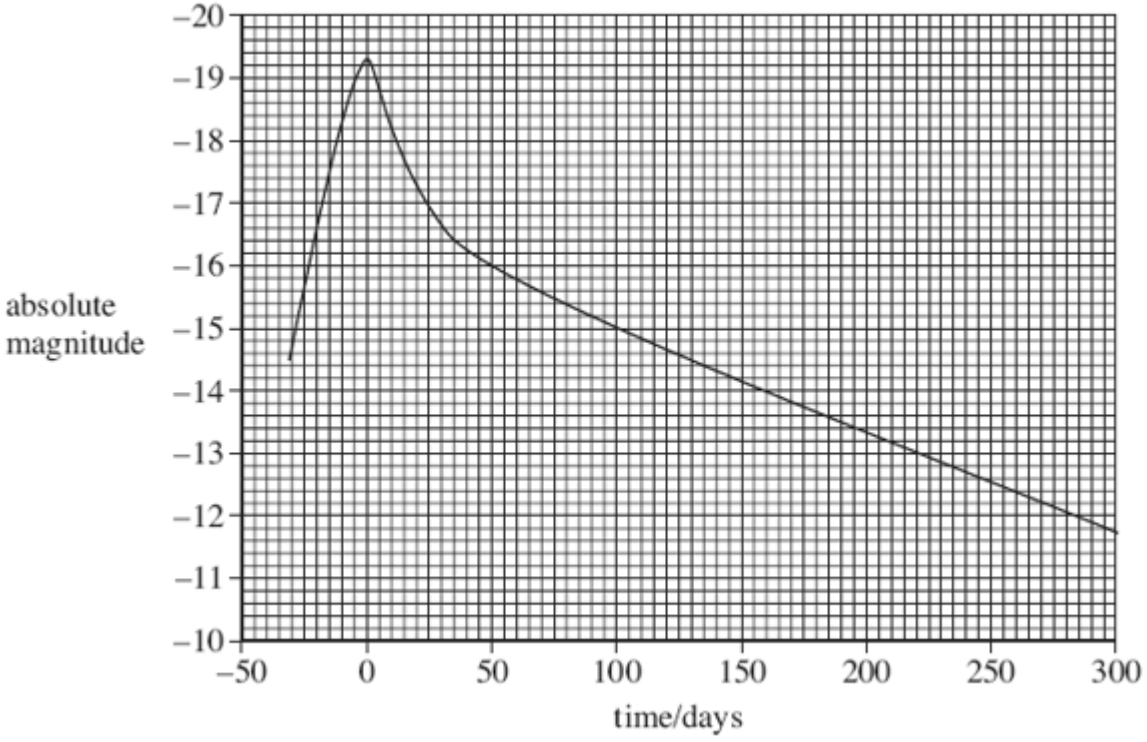
(1))

(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)

Q5. The red shift of a galaxy's spectrum can be used to determine its velocity, relative to the Earth.

(a) The wavelength of the hydrogen alpha line in the spectrum of the galaxy NGC 1357 is 660.86 nm. The wavelength of the same line from a laboratory based source is 656.28 nm. Calculate the velocity of galaxy NGC 1357.

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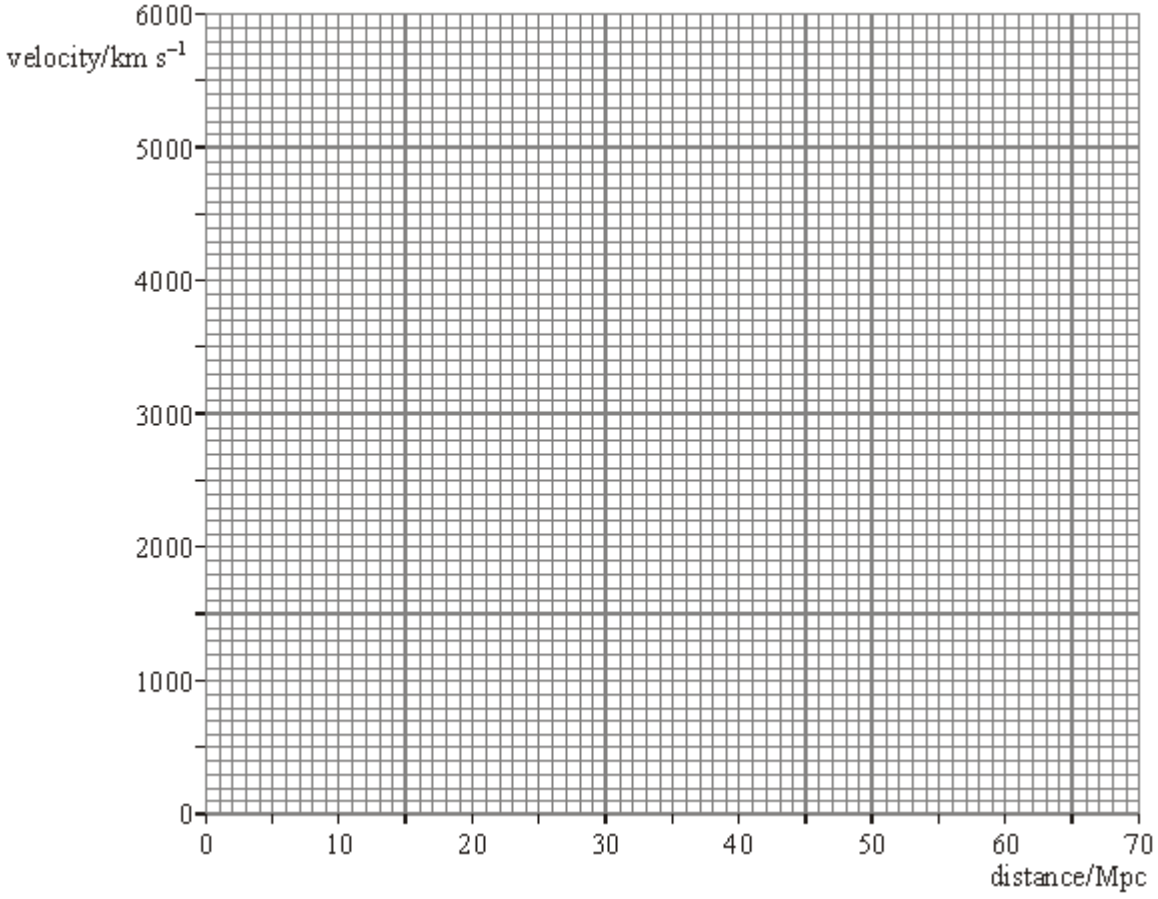
(2)

(b) Use the value obtained in part (a) to complete the table. Plot a graph of the data in the table below and use the graph to determine a value for the Hubble constant.

galaxy	velocity/km s^{-1}	distance/Mpc
NGC 1357		28
NGC 1832	2000	31
NGC 5548	5270	67
NGC 7469	4470	65



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(3)
(Total 5 marks)

Q6. (a) The Sombrero Galaxy is 50 million light years away from the Earth.

(i) Calculate the distance to this galaxy in parsecs.

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(ii) Use Hubble's Law to show that this galaxy is receding at 1000 km s^{-1}.

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(iii) One of the lines in the Hydrogen spectrum has a wavelength of 656.3 nm when measured in a laboratory on Earth. Calculate the wavelength of the same line in the observed spectrum of the Sombrero Galaxy.

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(4)

(b) Show how Hubble's Law can be used to estimate the age of the Universe. State the assumption made.

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(3)
(Total 7 marks)