Questions on Universe

1. The Doppler shift may be used in the study of distant galaxies. Explain what is meant by a Doppler shift and how it is used to deduce the motion of distant galaxies. You may be awarded a mark for the clarity of your answer.

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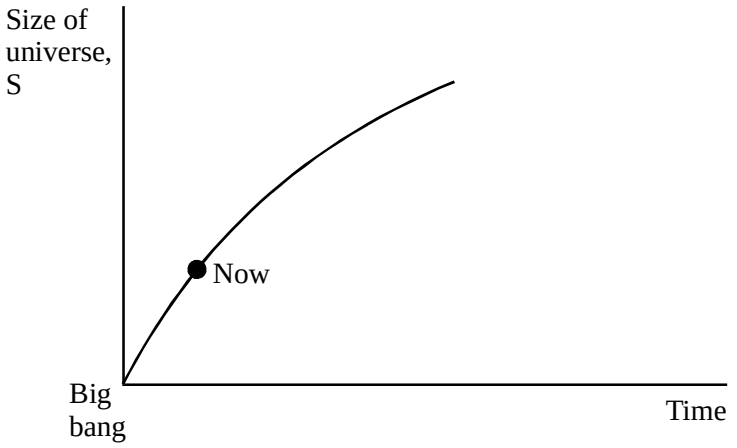
(5)

The graph shows the variation of the size *S* of an open universe against time *t*.



On the same axes, sketch a second graph showing how *S* varies with *t* for a closed universe.

(1)

It can be shown that the Universe is closed if its density exceeds a critical value ρ.
This is determined from the Hubble constant *H* using

$$\rho = kH^2$$

where *k* is a known constant.

Outline the experimental difficulties in determining ρ accurately.

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(3)
(Total 9 marks)

2. Calcium has a line spectrum, which includes the spectral line at a wavelength of 393 nm.

Calculate the frequency of this line.

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Frequency = ...

To which region of the electromagnetic spectrum does this line belong?

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(3)

What is a line spectrum?

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(1)

In cosmology, this calcium line may be used to determine the speed of recession of a distant galaxy.

A galactic cluster in Ursa Major has a recessional velocity of 1.43×10^7 m s^{-1}.
Calculate the wavelength of this calcium line as observed from Earth.

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Wavelength = ...

(3)

Given that this galactic cluster is 1.0×10^9 light years distant, calculate a value for the Hubble constant in s^{-1}.

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Hubble constant = ... s^{-1}

(4)

Another galactic cluster is 4.0×10^9 light years away from us. Suggest a value for the recessional velocity of this cluster.

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Velocity = ...

(1)

(Total 12 marks)

3. The hydrogen lines in the spectra of almost all galaxies show a red shift. Explain the meaning of a red shift.

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(2)

Explain how this red shift is thought to occur, and what the measurements of galactic red shifts suggest about the Universe.

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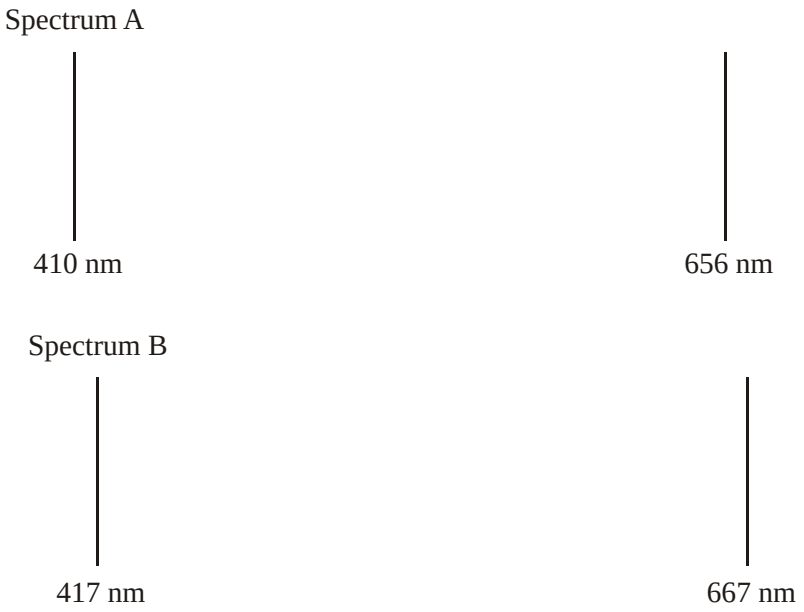
(3)

4. Spectrum A shows two emission lines of hydrogen obtained in a laboratory; spectrum B shows the same lines as obtained from light from a distant galaxy. Use these spectra to determine the **velocity** of this galaxy. (The diagrams are not to scale.)



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Velocity = ...

(4)

Using a value for the Hubble constant of 1.8×10^{-18} s^{-1}, estimate the distance of this galaxy from Earth.

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Distance = ...

(2)

(Total 6 marks)

5. (a) What is meant by the Doppler effect (electromagnetic Doppler effect) when applied to light?

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(2)

(b) Edwin Hubble reached a number of conclusions as a result of observations and measurements of red-shift. State two of these conclusions.

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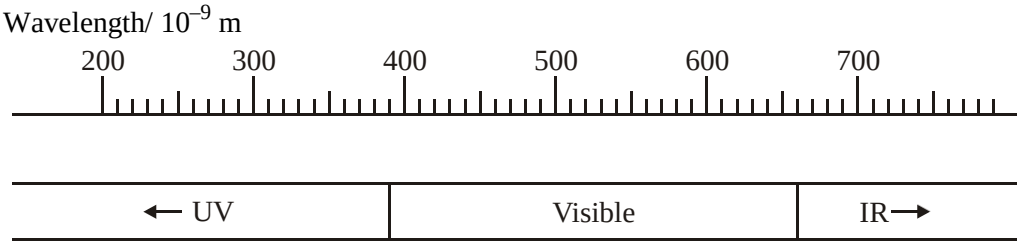
(2)

(c) The diagram gives values of wavelength for part of the electromagnetic spectrum.



A very hot distant galaxy emits violet light just at the edge of the visible spectrum. Estimate the maximum velocity the galaxy could have so that visible light could still be detected as it moves away from the Earth.

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(4)

(d) The fate of the Universe is dependent on the average mass-energy density of the Universe. What is meant by the critical density of the Universe?

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(2)

(Total 10 marks)

6. Hubble's law can be represented by the formula $v = Hd$.

(a) State the unit of the Hubble constant H.

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(1)

(b) Show how the age of the Universe can be estimated by using the above formula. State an assumption that has to be made.

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Assumption: .....

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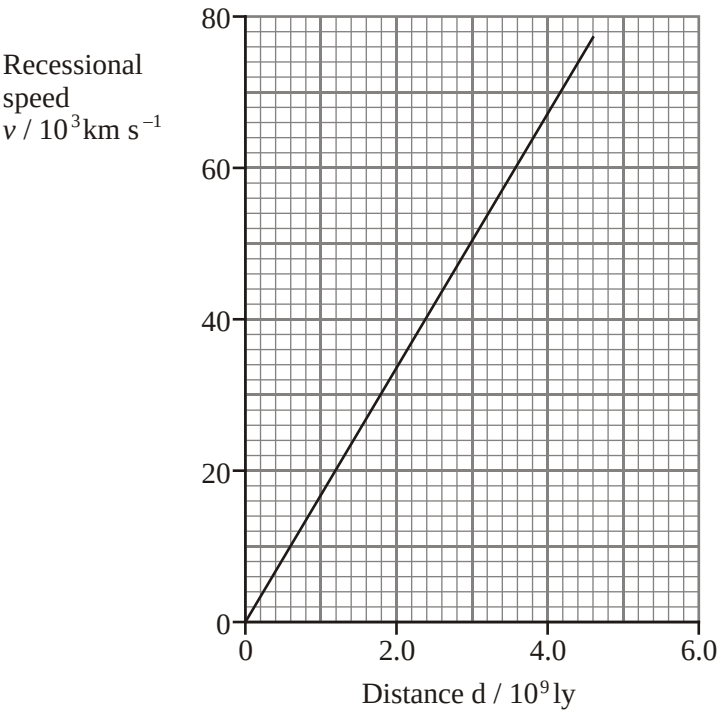
(4)
(Total 5 marks)

7. (a) Edwin Hubble examined the relationship between the recessional speed of galaxies, *v*, and their distance, *d*, from Earth. The graph shows the best-fit line for his results.



(i) Use the graph to determine a value for the Hubble constant, *H*, in s^{-1}. Show your working.

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Hubble constant = ...s^{-1}

(4)

(ii) What is the main source of uncertainty in the value of *H*?

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(1)

(b) Explain how the Hubble constant provides us with an estimate for the age of the Universe, *t*.

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(2)

(c) Ionised calcium has a line spectrum which includes a spectral line of wavelength 393 nm. The observed wavelength of this calcium line in the radiation from a distant galaxy is 469 nm. Calculate the galaxy's recessional speed.

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Recessional speed = ...

(3)

(d) Briefly explain how the value of the average mass-energy density of the Universe will determine whether the Universe is open or closed.

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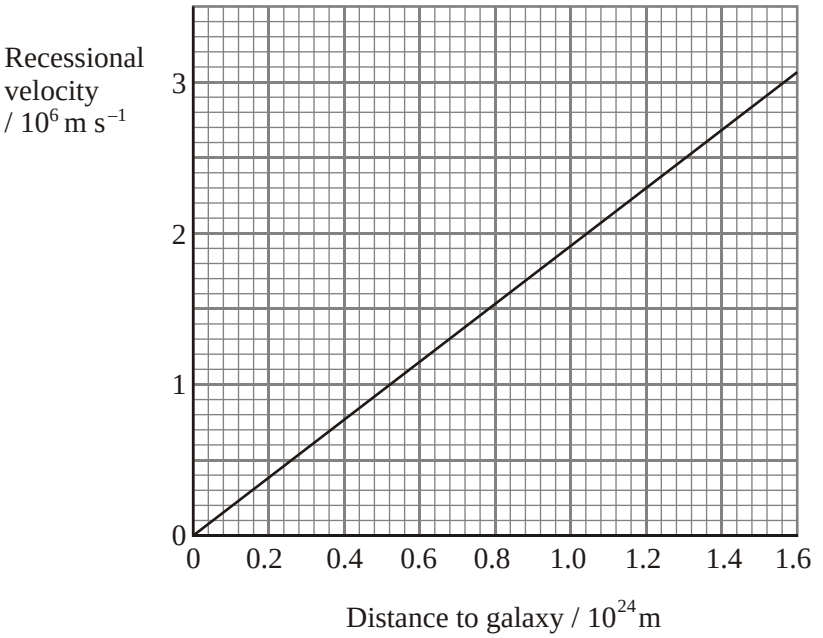
(2)

(Total 12 marks)

8. (a) The graph shows the best-fit line obtained when recessional velocity is plotted against distance from Earth for a large number of galaxies.



Use this graph to calculate a value for the Hubble constant.

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Hubble constant = ...

(2)

A spectral line measured using a laboratory source has a wavelength of 372.7 nm. The same line, measured in light from a distant galaxy, has an apparent wavelength of 410.0 nm. Estimate the distance of this galaxy from Earth.

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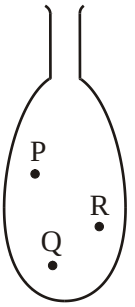
Distance = ...

(4)

(b) The diagram shows a deflated balloon. It has three dots on its surface, labelled P, Q and R. In the space next to the diagram, draw the balloon as it would appear when fully inflated. Mark the new positions of the three dots.



(2)

Explain how the inflation of the balloon can be used to model the expansion of the Universe. You may be awarded a mark for the clarity of your answer.

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(4)
(Total 12 marks)

9. Discuss the ultimate fate of the Universe. Your answer should include reference to dark matter and the reason why the fate of the Universe is uncertain.

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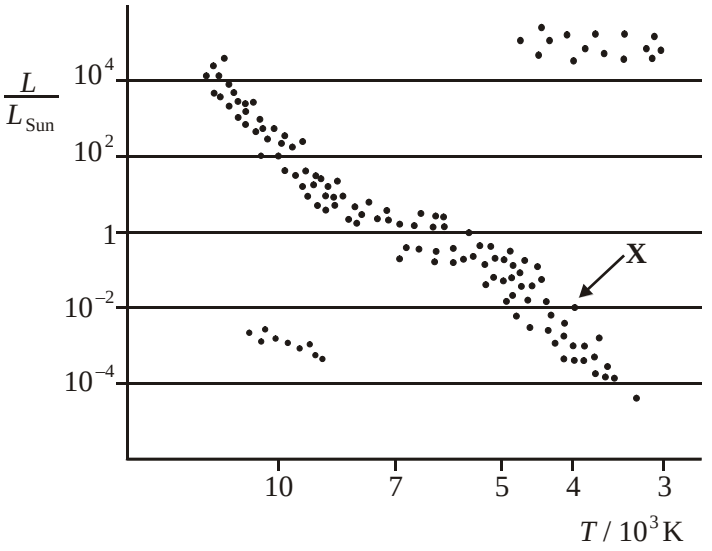
(Total 6 marks)

10. In the Hertzsprung-Russell (HR) diagram below, the dots represent stars.



What does *T*, on the horizontal axis, represent?

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(1)

Circle the dot on the diagram which represents our Sun.

(1)

Calculate the flux reaching the Earth from the star marked **X** on the HR diagram.

Distance from **X** to the Earth = 500 parsec
1 parsec = 3.09×10^{16} m
$L_{sun} = 3.9 \times 10^{26}$ W

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(3)

What force holds our Sun together?

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(1)

Explain how the nuclear processes within the Sun are able to release energy.

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(3)

At the end of the Sun's life, when energy can no longer be released in this manner, theory predicts that the Sun will become a larger star, of about the same mass, called a red giant.

(i) How will this change affect the Sun's gravitational pull on an outer planet? Explain your reasoning.

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(ii) On the HR diagram above, draw an arrow to represent the change in position of the Sun.

(3)

(Total 12 marks)