Q1. Describe, in as much detail as you can:

- the evidence that the size of the observable Universe is changing;
- the evidence that, billions of years ago, all the matter in the Universe was tightly packed together in the same place.

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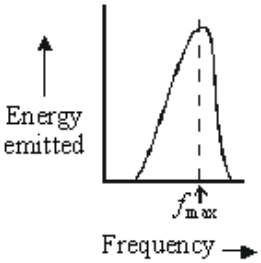
(Total 5 marks)

Q2. Read the following information about cosmic microwave background radiation.

Then use it to answer the questions below.

A Microwave "noise" reaches Earth with almost the same intensity from every direction. It is called cosmic microwave background radiation.	**B** All bodies with a temperature above zero kelvin (–273°C) emit electromagnetic radiation.	**C** Measurements made by the COBE satellite showed that there are very slight "ripples" in the cosmic microwave background radiation.
D Bodies which emit radiation do so across a range of frequencies, as shown on the graph.  	**E** Radiation in the microwave region of the electromagnetic spectrum reaches Earth from many stars and galaxies.	**F** In 1965, the astronomers Penzias and Wilson stopped trying to eliminate "noise" from their microwave detectors and studied it instead.
G The frequency at which a body radiates most energy (f_{max}) is directly proportional to the kelvin temperature.	**H** Cosmic microwave background radiation has an energy profile matching a temperature of 3 kelvin (–270°C).	**I** Because of the expansion of the Universe, the temperature of radiation from the time of the big bang will now be only a few kelvin.
J The early universe could not have been completely uniform otherwise galaxies would never have formed.		

(You may find it helpful to begin by deciding which items of information belong to which question.)

(a) Explain, as fully as you can, why the frequency profile of electromagnetic radiation is an indication of temperature.

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(3)

(b) Describe, in as much detail as you can, what cosmic microwave background radiation is and how it was discovered.

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(3)

(c) Explain, as fully as you can, how cosmic microwave background radiation fits in with the idea that the Universe, as it now is, began with a big bang.

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(4)

(d) Some people think that Penzias and Wilson's discovery of cosmic microwave background radiation was just lucky. Others disagree.

What do you think? Give reasons for your answer.

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(2)
(Total 12 marks)

Q3. Explain, in as much detail as you can, the scientific evidence for the “big bang” theory of the origin of the Universe.

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(Total 5 marks)

Q4. What does the Big Bang theory state? In your answer you may include evidence for the theory.

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(Total 4 marks)

Q5. Astronomers use red shift in two ways.
They calculate the distance to each galaxy from Earth.
They also calculate the speed at which galaxies are moving away from Earth.

The table shows some results. Distance is given in zettametres, Zm. One zettametre is 10^{21} metres.

Galaxy	Distance from Earth to galaxy in Zm	Speed at which galaxy is moving away from us in Zm per billion years	Time the galaxy has been moving away from us in billions of years (Calculated by distance ÷ speed)
Abell 963	25 000	1950	12.8
Abell 1302	14 000	1100	
Abell 1314	4 100	320	12.8
Abell 1978	18 000	1400	12.9
Abell 2255	10 000	770	13.0

(a) Complete the data for Abell 1302.

(1)

(b) Describe the relationship between the distance to a galaxy and the speed at which the galaxy is moving away from us.

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(1)

(c) Explain how the data for time provides evidence for the theory that the origin of the Universe was a huge explosion (‘big bang’).

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(2)
(Total 4 marks)

Q6. ‘Red shift’ is one of the pieces of evidence which led scientists to propose the ‘big bang’ theory.

(a) Describe the big bang theory.

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(2)

(b) *To gain full marks for this question you should write your ideas in good English. Put them into a sensible order and use the correct scientific words.*

Explain how red shift provides evidence for the big bang theory.

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(3)

(Total 5 marks)

Q7. Studies of light from distant galaxies have provided evidence for the theory that the Universe started from one place and is expanding. Explain how.

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(Total 3 marks)

Q8. Astronomers believe that the Universe is expanding.

(i) How might the Universe have started?

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(1)

(ii) State and explain briefly, **one** piece of scientific evidence which may be used to support this belief.

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(2)

(Total 3 marks)

Q9. Explain how observations at the red end of the spectrum of light from galaxies have led to one theory about the origin of the Universe.

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(Total 6 marks)

Q10. The Big Bang theory attempts to explain the origin of the Universe.

(i) What is the Universe?

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(1)

(i) What are the main ideas of the Big Bang theory?

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(2)

(iii) What is thought to be happening to the size of the Universe?

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(1)
(Total 4 marks)

Q11. The Big Bang theory attempts to explain the origin of the Universe.

(i) What is the Big Bang theory?

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(1)

(ii) What can be predicted from the Big Bang theory about the size of the Universe?

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(1)
(Total 2 marks)

Q12. (a) The light spectrum from a distant galaxy shows a red shift.

What is meant by *red shift* and what does it tell us about distant galaxies?

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(2)

(b) What name is given to the theory that the Universe started with a massive explosion?

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(1)
(Total 3 marks)

Q13. (a) A student listens to the sound waves produced by a car siren. When the car is stationary, the student hears a constant frequency sound.

Describe how the wavelength and frequency of the sound waves heard by the student change when the car is driven away from the student.

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(2)

(b) Satellites fitted with various telescopes orbit the Earth. These telescopes detect different types of electromagnetic radiation.

Why are telescopes that detect different types of electromagnetic waves used to observe the Universe?

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(1)

(c) In 2005 a space telescope detected a star that exploded 13 billion years ago. The light from the star shows the biggest *red-shift* ever measured.

(i) What is *red-shift*?

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(1)

(ii) What does the measurement of its red-shift tell scientists about this star?

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(1)

(d) Red-shift provides evidence for the ‘big bang’ theory.

(i) Describe the ‘big bang’ theory.

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(2)

(ii) Suggest what scientists should do if new evidence were found that did not support the 'big bang' theory.

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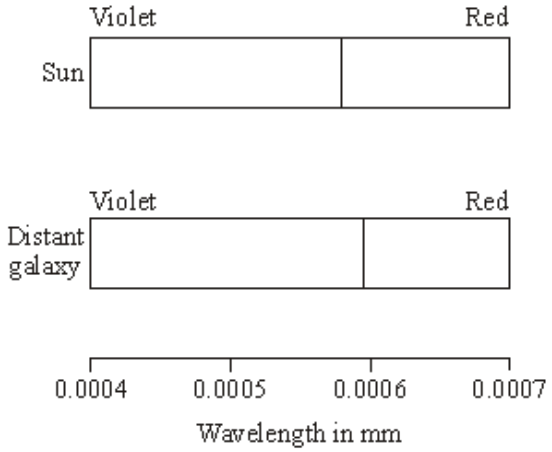
(1)

(Total 8 marks)

Q14. The visible part of the electromagnetic spectrum from a star includes a dark line. This line is at a specific wavelength. The diagram shows the position of the dark line in the spectrum from the Sun and in the spectrum from a distant galaxy.



(a) Explain how the spectrum 'shift' of the dark line supports the theory that the Universe began from a very small point.

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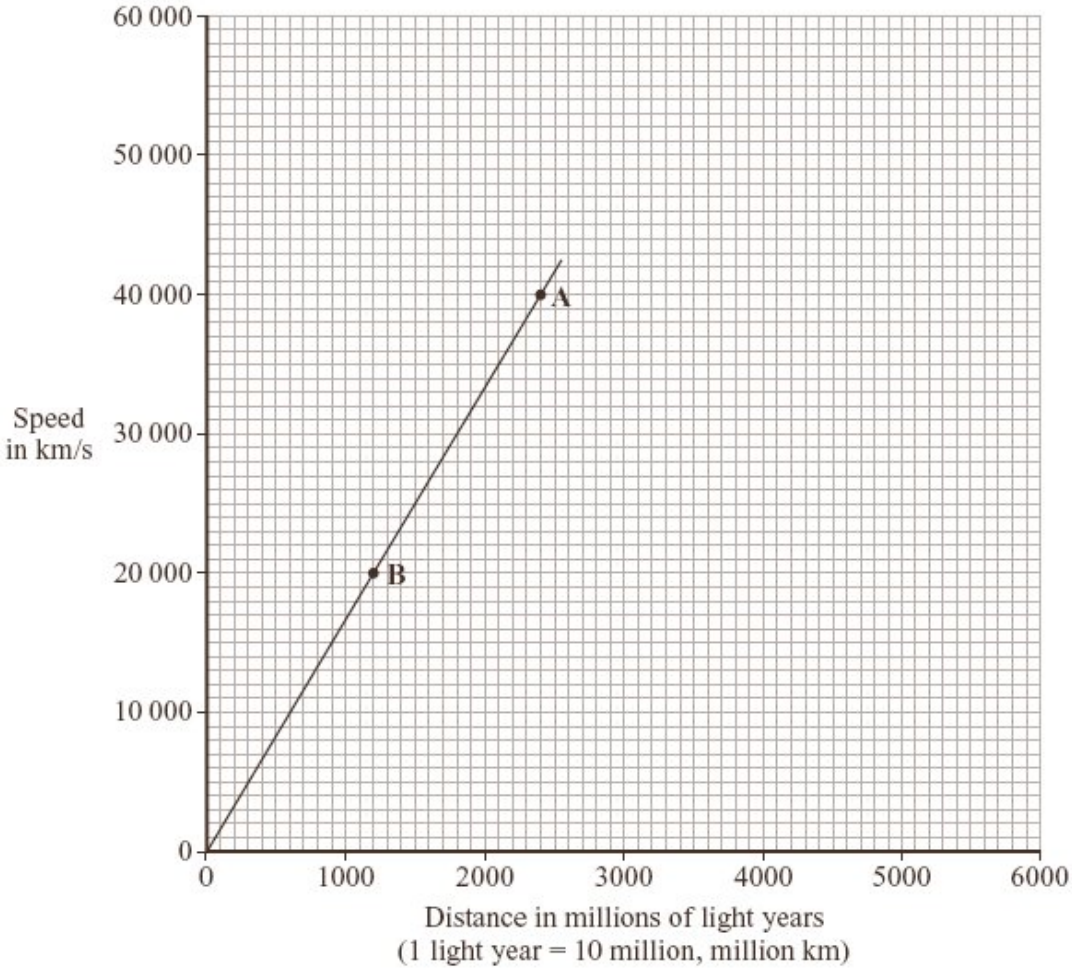
(3)

(b) From data collected, a graph can be drawn that links the speed of a galaxy with the distance of the galaxy from the Earth.



(i) How does the visible light spectrum from galaxy **A** look different from the visible light spectrum from galaxy **B**?

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(1)

(ii) A third galaxy, **C**, seems to be travelling away from the Earth at about 60 000 km/s.

Estimate how far galaxy **C** might be from the Earth, showing how you use the graph to do this.

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Distance between galaxy **C** and the Earth = …… million light years

(2)

(Total 6 marks)

Q15. The ‘steady state’ theory was once a popular alternative to the ‘big bang’ theory.

The ‘steady state’ theory suggested that the universe, although expanding, had no origin and it has always existed. As the universe expands, a small amount of matter is created to keep the universe looking exactly the same all of the time.

(a) When considering the origin of the universe, what is the difference between the ‘big bang’ theory and the ‘steady state’ theory?

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(2)

(b) The light from distant galaxies shows a *red-shift*.

(i) What is *red-shift*?

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(1)

(ii) Why does red-shift provide evidence to support both the ‘big-bang’ theory and the ‘steady state’ theory?

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(2)

(c) The ‘steady state’ theory was important in encouraging new research into the universe.

Suggest a reason why scientists were keen to carry out new research.

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(1)

(d) Scientists can answer many questions about the universe, but not the question:

'Why was the universe created?'

Suggest a reason why this question cannot be answered by scientists.

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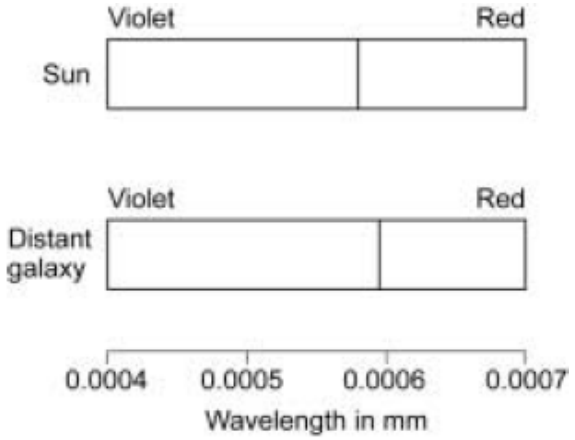
(1)

(Total 7 marks)

Q16. The visible part of the electromagnetic spectrum from a star includes a dark line. This line is at a specific wavelength.

The diagram shows the position of the dark line in the spectrum from the Sun and in the spectrum from a distant galaxy.



(a) Explain how the spectrum 'shift' of the dark line supports the theory that the Universe began from a very small initial point.

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(3)

(b) Name **one** other piece of evidence that supports the theory that the Universe began from a very small initial point.

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(1)
(Total 4 marks)

Q17. (a) In 1929, the astronomer Edwin Hubble observed that the light from galaxies that are moving away from the Earth showed a *red-shift*.

What is *red-shift* ?

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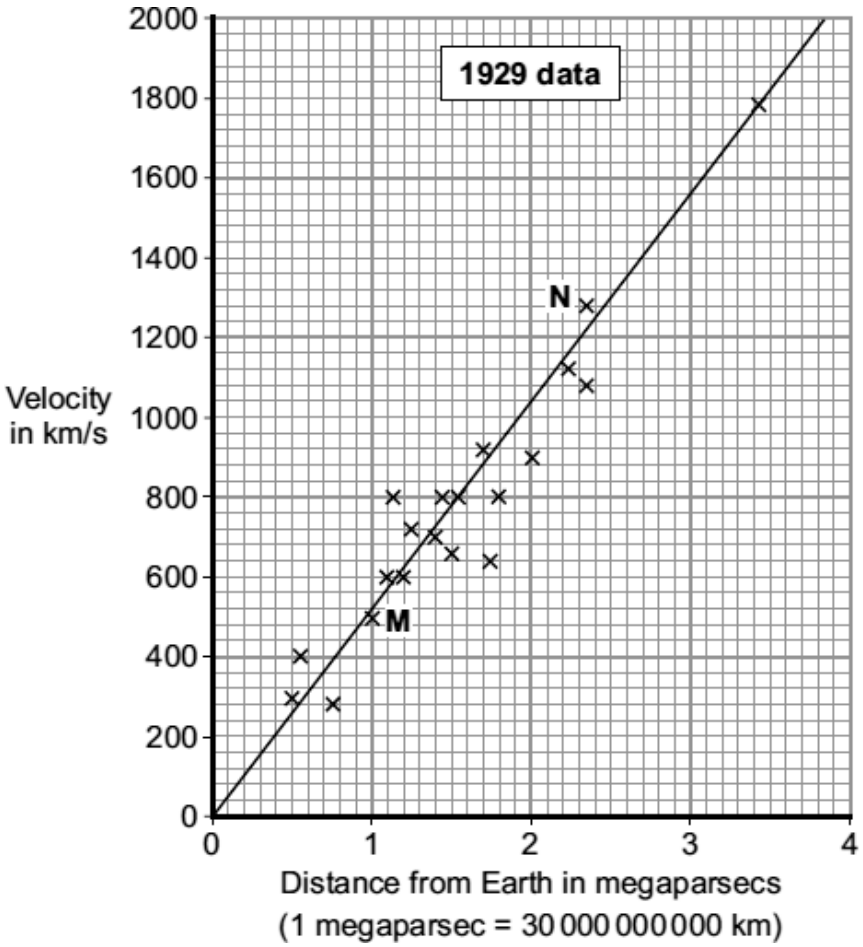
(1)

(b) By measuring the *red-shift*, Hubble was able to calculate the speed at which the galaxies are moving away from the Earth. He was also able to calculate the distance of these galaxies from the Earth.

The graph shows some of the data calculated by Hubble.



(i) The data from two galaxies, **M** and **N**, has been included in the graph. The light from galaxy **M** has a smaller *red-shift* than the light from galaxy **N**.

What does the difference in *red-shift* tell scientists about the two galaxies, **M** and **N**?

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(2)

(ii) The gradient of the line drawn on the graph gives a number known as the Hubble constant. The Hubble constant can be used to estimate when the universe began.

Use the graph to calculate the value of the Hubble constant.

Show clearly how you obtained your answer.

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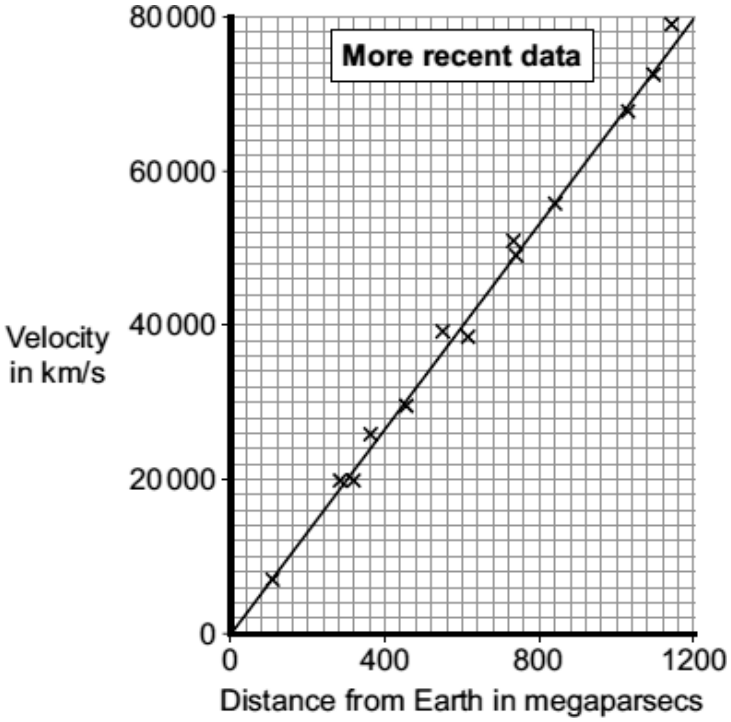
Hubble constant = ... km/s per megaparsec

(2)

(iii) More recently, data has been obtained from more distant galaxies.



The results from the more recent data give a totally different value for the Hubble constant to the one calculated from the 1929 data.

Which set of data, the 1929 or the more recent, is most likely to give the value closest to the true value for the Hubble constant?

Draw a ring around your answer.

1929 **more recent**

Give a reason for your answer.

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(1)

(c) The Andromeda galaxy is not moving away from the Earth. It is actually moving towards the Earth. This means that the light from Andromeda shows a blue-shift.

How do the wavelength and frequency of the light from Andromeda seem to have changed when viewed from the Earth?

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(2)

(Total 8 marks)

Q18. The 'Big Bang' theory is one theory of the origin of the Universe.

(a) (i) Explain what is meant by the 'Big Bang' theory.

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(2)

(ii) The light arriving from distant galaxies provides scientists with evidence to support the 'Big Bang' theory.

Explain how.

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(2)

(b) At a meeting held in 2005, a group of scientists claimed that new data had been collected that showed the 'Big Bang' theory to be wrong. Other scientists said that there was no reason to doubt the 'Big Bang' theory.

What should scientists do when a theory does **not** appear to be supported by new data?

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(2)

(c) Scientists can answer many questions about the Universe, but not the question:

Why was the Universe created?

Suggest a reason why this question **cannot** be answered by scientists.

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(1)

(Total 7 marks)

Q19. Optical telescopes may be used to observe galaxies. Some optical telescopes are on the Earth and some are on satellites in space.

(a) How is the image produced by an optical telescope on a satellite in space better than the image produced by an optical telescope on the Earth?

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Give a reason for your answer.

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(2)

(b) Scientists have observed that the wavelengths of the light from galaxies moving away from the Earth are longer than expected. This observation is called red-shift.

(i) What does the size of the red-shift tell the scientists about the distance a galaxy is from the Earth?

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(1)

(ii) Complete the following passage.

Red-shift provides evidence to support the 'big bang' theory. The 'big bang' theory is one of the ways of explaining the ..... of the Universe.

(1)

(Total 4 marks)

Q20. (a) The ‘Big Bang’ theory uses red-shift as evidence to explain the beginning of the Universe.

How does the red-shift from distant galaxies provide evidence for the beginning of the Universe?

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(3)

(b) Cosmic microwave background radiation (CMBR) is a type of electromagnetic radiation. CMBR fills the Universe. It was first discovered in 1965 by two astronomers called Penzias and Wilson.

(i) What do scientists believe is the origin of CMBR?

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(1)

(ii) Why was the discovery of CMBR so important to the scientists believing the ‘Big Bang’ theory to be correct?

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(1)

(iii) How is the wavelength of CMBR likely to change, if at all, over the next billion years?

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Give a reason for your answer.

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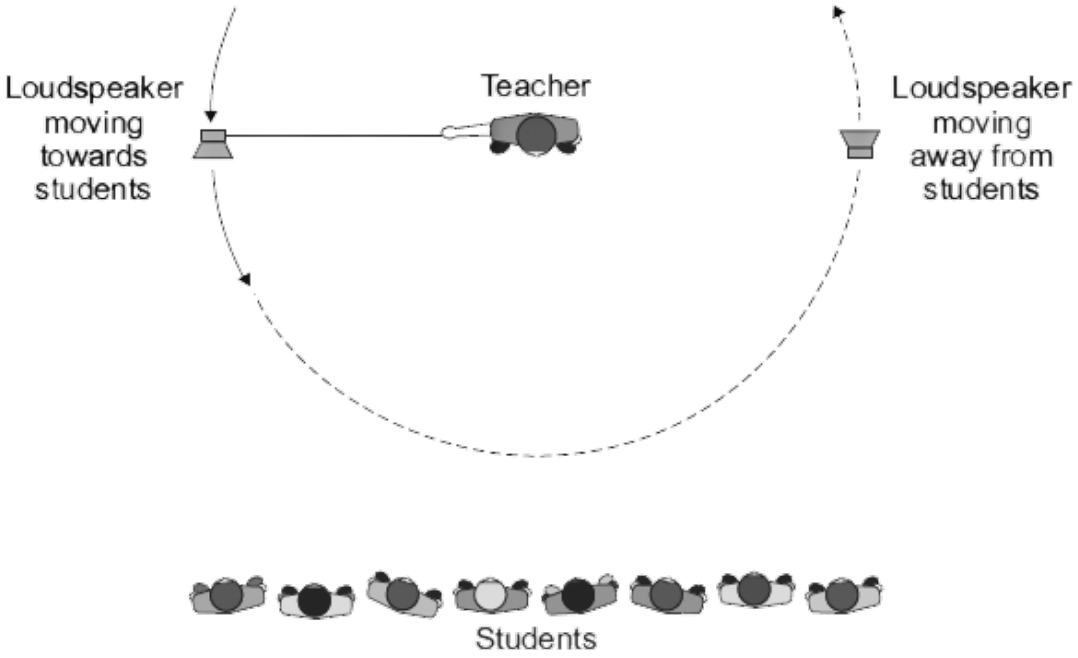
(2)

(Total 7 marks)

Q21. The diagram shows a teacher using a loudspeaker to demonstrate the Doppler effect. The loudspeaker, which produces a note of constant frequency, is swung around in a circle.



(a) What is the Doppler effect?

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(2)

(b) This demonstration of the Doppler effect can be used as a model for the *red-shift* observed in the light spectra from distant galaxies.

What is red-shift and what does the size of the red-shift tell us about distant galaxies?

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(3)
(Total 5 marks)

Q22. Galaxies emit all types of electromagnetic wave.

(a) (i) Which type of electromagnetic wave has the shortest wavelength?

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(1)

(ii) State **one** difference between an ultraviolet wave and a visible light wave.

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(1)

(b) Electromagnetic waves travel through space at a speed of 3.0×10^8 m/s.

The radio waves emitted from a distant galaxy have a wavelength of 25 metres.

Calculate the frequency of the radio waves emitted from the galaxy and give the unit.

Use the correct equation from the Physics Equations Sheet.

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Frequency = ...

(3)

(c) Scientists use a radio telescope to measure the wavelength of the radio waves emitted from the galaxy in part (b) as the waves reach the Earth. The scientists measure the wavelength as 25.2 metres. The effect causing this observed increase in wavelength is called red-shift.

(i) The waves emitted from most galaxies show red-shift.

What does red-shift tell scientists about the direction most galaxies are moving?

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(1)

(ii) The size of the red-shift is **not** the same for all galaxies.

What information can scientists find out about a galaxy when they measure the size of the red-shift the galaxy produces?

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(2)

(iii) What does the observation of red-shift suggest is happening to the Universe?

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(1)

(Total 9 marks)

Q23. (a) Observation of the spectra from distant galaxies provides evidence to support the 'Big Bang' theory.

(i) Complete the following sentence.

Many scientists think that the 'Big Bang' theory describes the .....

.....

(1)

(ii) Tick (✓) **one** box to complete the sentence.

The discovery of cosmic microwave background radiation was important because it ...

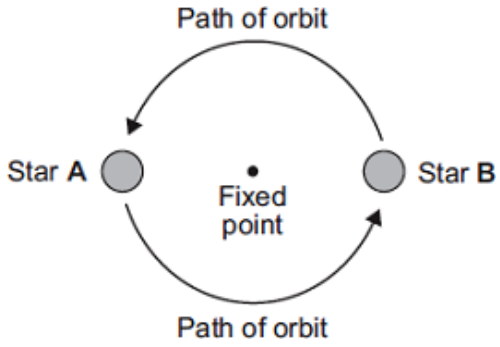
proved the 'Big Bang' theory to be correct. ☐

provided more evidence to support the 'Big Bang' theory. ☐

proved the Universe will continue to expand forever. ☐

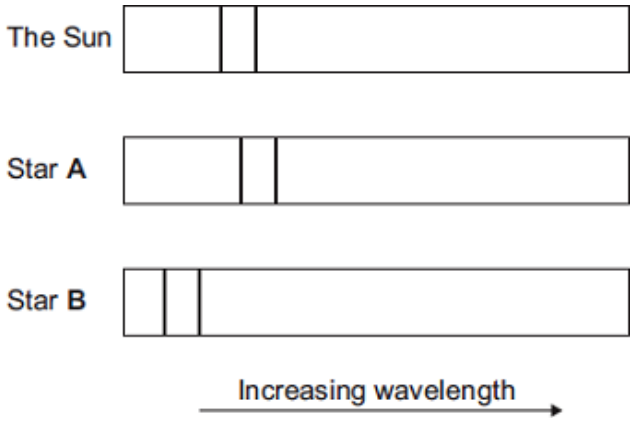
(1)

(b) Many stars are part of a binary star system. Binary star systems have two stars.



The visible spectrum from stars includes dark lines. These lines are at specific wavelengths.

The diagram shows the position of two dark lines in the spectrum from the Sun. It also shows the same lines in the spectra from two stars **A** and **B** in a binary star system at the same point in time.



(i) What name is given to the effect shown in the spectrum from star **A**?

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(1)

(ii) Scientists have concluded that the two stars in a binary star system orbit around a fixed point between the two stars.

A comparison of the spectra from the two stars in a binary star system provides evidence to support this conclusion.

Explain how.

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(3)
(Total 6 marks)