A Level · OCR · Physics

27 mins 3 questions

Structured Questions

Cosmology

Units for Astronomical Distances / Stellar Parallax / The Cosmological Principle / The Doppler Effect / Hubble's Law / An Expanding Universe / The Big Bang / The Age of the Universe / Evolution of the Universe / Dark Energy & Dark Matter

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Total Marks /27

1 (a) Proxima Centauri is the closest star to Earth.

Fig. 24.1 shows the apparent positions of this star against the background of very distant stars as seen from the Earth over a period of exactly 6 months.

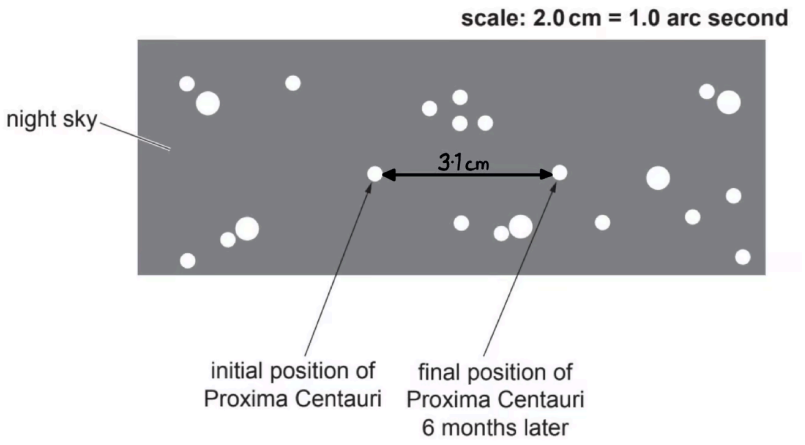

Fig. 24.1

The parallax angle for Proxima Centauri can be determined from Fig. 24.1 using the data provided.

i) Show that the parallax angle *p* for Proxima Centauri is about 0.8 arc second.

[1]

ii) Use your answer in **(i)** to calculate the distance *d* of Proxima Centauri from the Earth in light-years (ly).

1 pc = 3.26 ly

d = ... ly **[2]**

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(3 marks)

(b) The galaxies in the Universe may be assumed to be distributed uniformly through space. In this model, the separation between two neighbouring galaxies is 1.4×10^{23} m and each galaxy occupies a cube of space of volume 2.7×10^{69} m^3 as shown in Fig. 24.2.

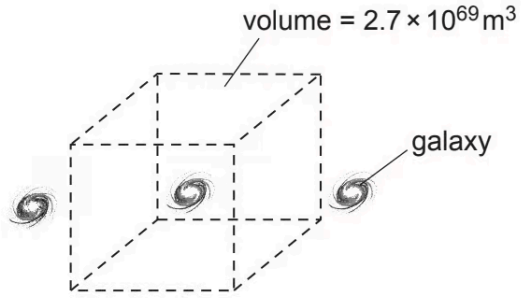

Fig. 24.2

There are on average 10^{11} stars in each galaxy and the mass of an average star is about 2.0×10^{30} kg.

i) Estimate the gravitational force between two neighbouring galaxies.

force = ... N **[2]**

ii) Show that the mean density of the Universe is about 7×10^{-29} kgm^{-3}.

[1]

iii) Suggest why the actual mean density of the Universe is different from the value calculated in **(ii)**.

[1]

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(4 marks)

2 (a) Describe the **Doppler effect.**

[1]

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(1 mark)

(b) Explain how ultrasound is used to measure the speed of blood flow in an artery.

[2]

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(2 marks)

(c) In cosmology, the Doppler effect can be observed with light from distant galaxies. The Doppler effect can also be observed with sound waves. Two students use sound waves to investigate the Doppler effect. In an open space, one student swings a loudspeaker at constant speed in a horizontal circle of radius 0.60 m. The other student stands a large distance away and holds a microphone. The microphone is connected to a data logger and computer. Fig. 6.1 shows the situation, viewed from above.

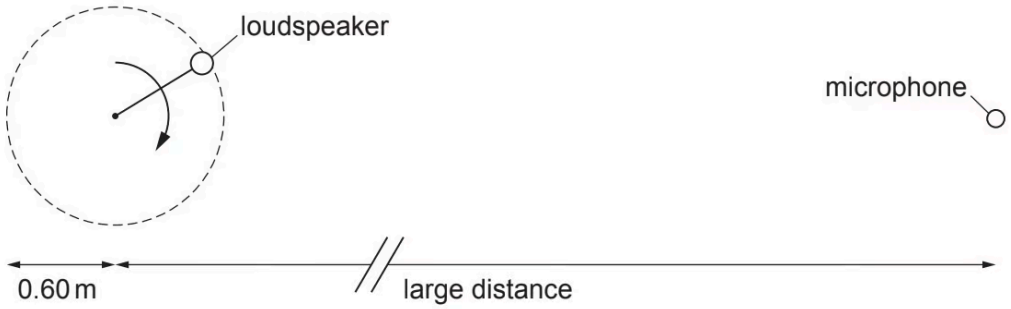

Fig. 6.1

The loudspeaker emits sound in all directions at a single frequency f_0 = 1700 Hz.

Fig. 6.2 shows the variation with time *t* of the frequency *f* received by the microphone.

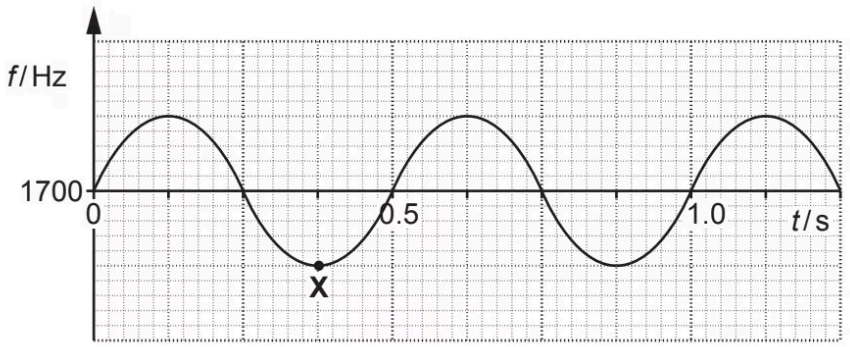

Fig. 6.2

i) Use Fig. 6.2 to show that the speed of the loudspeaker is 7.5 ms^{-1}.

[2]

ii) The speed of sound in this experiment is 330 ms^{-1}. Calculate the maximum change in frequency Δf of the sound detected by the microphone.

Δf = ... Hz **[2]**

iii) Hence complete the scale on the *y*-axis of Fig. 6.2. **[1]**

iv) Mark with an **X** on Fig. 6.1 the position of the loudspeaker which corresponds to the point **X** on Fig. 6.2. **[1]**

(6 marks)

(d) In their laboratory notes, one student writes about the **accuracy** of the measurements whereas the other writes about their **precision.**

Define these terms.

accuracy: .....

precision: .....

[2]

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(2 marks)

3 (a) According to the Cosmological principle, the Universe is isotropic, homogeneous and the laws of physics are universal. State what is meant by the term *homogeneous*.

[1]

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(1 mark)

(b) Astronomers often use absorption spectral lines to determine the relative velocity of distant galaxies. The wavelength of a specific absorption spectral line observed in the laboratory is 280 nm. The galaxy RXJ1242-11 is 200 Mpc away from the Earth and it has a massive black hole at its centre.

i) Calculate in nm the wavelength λ of the same spectral line from RXJ1242-11 when **observed** from the Earth. Assume the Hubble constant is 68 km s^{-1} Mpc^{-1}.

λ = ... nm **[3]**

ii) State one of the characteristics of a black hole.

[1]

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(4 marks)

(c) The Universe evolved from the Big Bang. Describe the evolution of the Universe up to the formation of the first nuclei.

[4]

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(4 marks)