12* This question is about spectroscopic measurements of stellar distances.

Describe how absorption spectra are formed and how they are useful in establishing the spectral class of a star.
Explain how determining the value for the absolute brightness and apparent brightness of a star can lead to a measurement of the distance to a star.

The following example may help in your explanation:

Star **X** is known to have three times the absolute brightness of star **Y** but both appear to be equally bright in the sky. The distance to star **Y** has been measured as 12 parsecs.

The photosphere of a star emits all wavelengths. The atmosphere of the star is somewhat cooler and so absorbs some of this e/m radiation. Only certain frequencies/wavelengths are absorbed - which ones is dependent on which elements we have in the atmosphere, as each element has its own unique energy levels. So certain values of f or λ are absorbed as electrons are excited between the energy levels. The resulting spectrum has dark lines in it which correspond to those excitations between levels. Therefore from these dark lines we can see what gases are in the star's atmosphere. We can put stars into groups depending on their absorption spectra. From these groups we can predict a good value of the star's absolute brightness. Star X has absolute brightness = 3 x Star Y which is at 12parsecs. Intensity falls off as an inverse square law with distance Apparent brightness the same So if the distance doubles the apparent brightness falls by a factor of 4

$$\text{apparent}_X \propto \frac{3ab}{S^2} = \text{apparent}_Y \propto \frac{ab}{12^2}$$

dist to x → S

$$= \frac{3}{S^2} = \frac{1}{12^2} \Rightarrow S = \sqrt{3 \times 12^2}$$

$$S = \underline{20.8 \text{ parsecs}}$$

[6]

END OF QUESTION PAPER

10 This question is about measuring stellar distances by parallax.

0.38 arc sec

$\frac{0.38}{60^2}$ °

The parallax of the star Sirius is 0.38 arc seconds.

One light year is the distance light travels in one year.

Calculate the distance to Sirius in light years.

$\tan\theta = \frac{o}{a} \Rightarrow a = \frac{o}{\tan\theta}$

Earth-Sun distance = 1 AU = 1.5×10^{11} m
1 year = 3.2×10^{7} seconds

$a = 8.14 \times 10^{16}$ m

1 light year $d = 3.2\times10^{7} \times 3\times10^{8}$
$= 9.6\times10^{15}$ m

$\therefore d = 8.5$

distance = 8.5 light year **[3]**

11 Explain why turbulence in the atmosphere limits the resolution of ground-based optical telescopes (lines 7–39).

~ different densities => different refractive indexes meaning light bend different amounts & a distorted image **[2]**

30 The relativistic factor $\gamma = \dfrac{1}{\sqrt{1-\dfrac{v^2}{c^2}}}$

Which statement about this factor is correct?

A At the speed of sound γ is close to zero.

B $\gamma \rightarrow 1$ as $v \rightarrow c$.

C γ predicts the time dilation factor so that moving clocks run slower as $v \rightarrow c$.

D γ^2 is the factor by which the total energy of a moving particle is greater than its rest energy.

Your answer $\boxed{C}$ **[1]**

SECTION C

Answer **all** the questions.

36 This question considers some of the evidence for a Hot Big Bang start to our expanding universe.

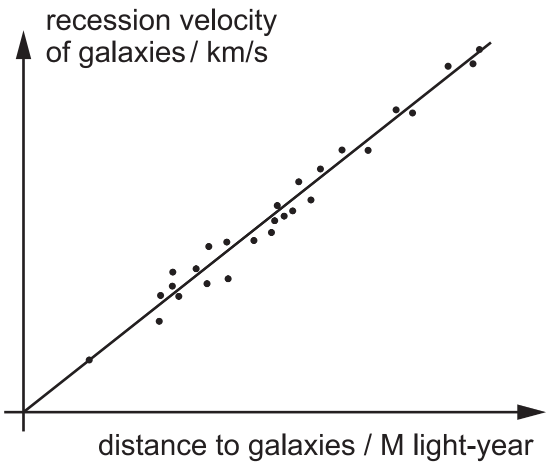

Fig. 36.1

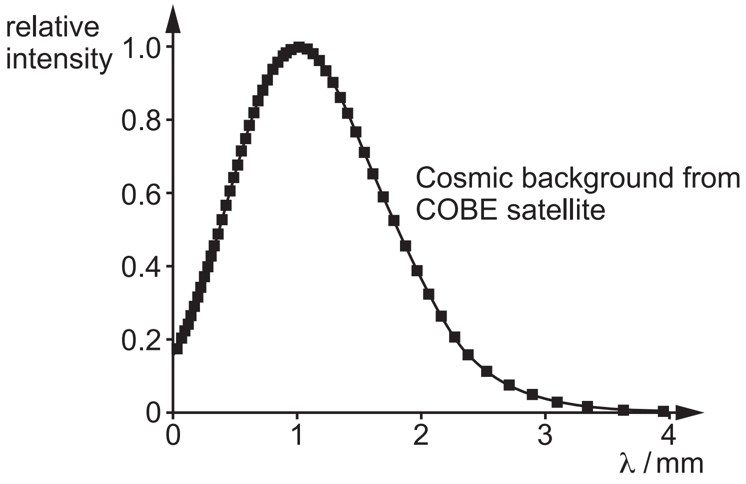

Fig. 36.2

(a) Explain how the graph(s) show evidence that the universe started from:

(i) a big bang expansion

d ∝ recession speed
further away moving faster.
Imagine rewinding time then the
galaxies collapse into a smaller space **[2]**

(ii) a hot state.

CB is in Mwave ∴ it has been
stretched as it seems radiation
should have had shorter λ & higher
energy – ie hotter **[2]**

(b) The intensity spectrum of thermal radiation depends on temperature T. Photons at the **peak** of intensity have energy $\varepsilon \approx 5kT$.

Use this approximation and data from **Fig. 36.2** to estimate the temperature of the cosmic microwave background radiation (CMBR).

$\lambda_{peak} = 1\,mm \Rightarrow f = 3 \times 10^{11}\ Hz$

$E = hf$ & $\varepsilon \approx 5kT$

$\therefore\ hf \approx 5kT \Rightarrow T = \frac{hf}{5k}$

$= 2.8\ K$

temperature = ... K **[4]**

35 An asteroid is tracked from the Earth by radar pulses.
A pulse places it at a distance of 44.444 light-minutes from Earth.
After 24 hours a second pulse places it 44.204 light-minutes from Earth.

(a) Use this data to calculate the average velocity of approach of the asteroid relative to Earth.

relative velocity = ... $m\,s^{-1}$ **[2]**

(b) The path of the asteroid is shown in **Fig. 36.1**. After 24 hours the angular shift in position of the asteroid relative to Earth is 1.8 mrad.

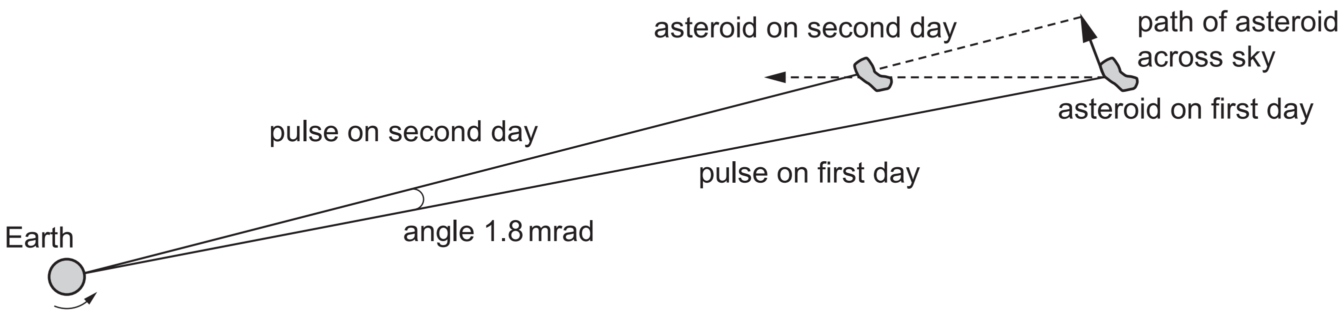

Fig. 36.1 (not to scale)

Estimate the velocity component of the asteroid perpendicular to its direction from Earth.
Make your method clear.

perpendicular velocity = ... $m\,s^{-1}$ **[3]**