OCR

A Level

A Level Physics

Astrophysics 2 (Answers)

Name:

M M E

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Total Marks: /30

1. Total for Question 1: 8

(a) Define, in words, the units AU and ly. [2]

Solution: AU: average distance from the earth to the sun.
ly: the distance travelled by light in a vacuum in one year.

(b) Show that 1 pc=3.1×10^{16} m. One astronomical unit is equivalent to 1.5×10^{11} m. [2]

Solution: 1 pc is the distance at which a radius of 1 AU subtends an angle of 1 arcsecond ($1/3600°$).
Therefore, by trigonometry: $\tan(1arcsecond) = \frac{AU}{pc} \rightarrow 1\ pc = \frac{1.5\times10^{11}}{\tan(\frac{1}{3600})} = 3.1 \times 10^{16}$ m

(c) Calculate the distance to a star whose parallax angle measures 0.30 arcseconds. Give your answer in AU, ly and pc. [3]

Solution: 3.33 pc = 10.9 ly = 689 kAU

(d) Why is the parallax method for determining astronomical distances limited to approximately 100 pc? [1]

Solution: For distances greater than 100 pc, the angle becomes too small to measure accurately.

2. The Doppler effect is something simple that you witness on a daily basis. Yet, it also holds the key to estimating galaxies' velocities and to obtaining an estimate for the age of the universe.

Total for Question 2: 10

(a) What are meant by the following?

i. The Doppler effect. [2]

Solution: The Doppler effect is the change in frequency/wavelength seen when a wave source moves relative to an observer: if the source moves away from (towards) the observer, the wavelength will increase (decrease).

ii. Red shift. [1]

Solution: The Doppler effect can be used to determine cosmological bodies' relative velocities. If A is receding from B, its absorption line spectra will be shifted to higher wavelengths i..e. closer to the red end of the spectrum. This is red shift.

The centre of a far-away, receding galaxy has an absorption spectra in which the hydrogen line has been Doppler shifted by 2.00 nm relative to laboratory measurements. Its apparent left edge, at a distance of 5 kpc from the centre, has only been shifted by 1.00 nm. In the laboratory, the absorption line for hydrogen occurs at a wavelength of 656.4 nm.

(b) Calculate the recessional velocity of the galaxy relative to the laboratory on Earth. [2]

Solution: 914 kms^{-1}

(c) Calculate the recessional velocity of the left edge. [2]

Solution: 457 kms^{-1}

(d) What angular velocity does the far-away galaxy have? [2]

Solution: 2.95×10^{-12} rad s^{-1}

(e) What Doppler shift would you expect the hydrogen line of the apparent right edge of the galaxy to have? [1]

Solution: 3.00 nm

3. The table below gives the velocities and distances for seven galaxies.

Total for Question 3: 12

Velocity / kms^{-1}	Distance / Mpc
6800	89
3000	45
4600	68
4000	58
3600	53
1100	20
6500	85

(a) State Hubble's law, both in words and mathematically. [2]

Solution: A galaxy's recessional velocity is proportional to its distance.
$v = H_0 d$

(b) Plot the data above on a graph of recessional velocity against distance and hence estimate the age of the universe. [5]

Solution: $\approx 4.3 \times 10^{17}$ s

Solution:

(c) State the cosmological principle. [2]

Solution: The laws of physics are universal and, when viewed on a large enough scale, the universe is homogeneous and isotropic.

(d) What is the primary piece of evidence that supports the theory of an expanding universe. [1]

Solution: Galactic red shift: almost all galaxies' light is red-shifted i.e. they are moving away from us in every direction.

(e) The notion that the universe is expanding is not sufficient to confirm the Big Bang Theory, which predicts a cosmic microwave background. In what two ways can the cosmic microwave background be explained? [2]

Solution:
1/ The young, hot universe was saturated with gamma photons. These have been red-shifted due to the expansion of space itself and are now in the microwave region of the EM spectrum.
2/ The universe was extremely dense and hot when it was young. Expansion has cooled it to a low temperature (2.7 K). If it is a black body, the universe would emit a peak wavelength of approximately 1 mm - microwaves.