Edexcel

A Level

A Level Physics

Astrophysics 2 (Answers)

Name:

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Total Marks: /30

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

Total for Question 1: 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

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

Total for Question 2: 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.

3. The future of the universe is not known. This question tackles some of the possible fates.

Total for Question 3: 8

(a) Sketch a graph of size against time showing the three possible fates of the universe. [4]

> **Solution:** Should show open, closed and flat scenarios:
> - open: size keeps increasing with time
> - flat: after some time, size remains constant
> - closed: after initial expansion, the universe contracts.

(b) What is thought to be the critical physical property in determining which course the universe takes? Justify your answer. [2]

> **Solution:** Density: if particles are sufficiently close together, gravitational attraction can initiate the 'big crunch'.

(c) The mass of all the stars in a galaxy is calculated using its luminosity. Usually, the estimated mass is only about 10% of that required to reconcile the rotational dynamics of the stars. Explain this observation and why it presents a barrier in determining the fate of the universe. [2]

Solution: The imbalance between the mass required to produce the rotational effects observed and that implied by the luminosity suggests a lot of 'missing mass'. This has been dubbed dark matter. We do not yet know how to quantify dark matter. Since density is related to mass, it is crucial to know how much dark matter exists and how it is distributed in space.