Cosmology Questions – OCR A Level Physics

Praneel Physics

1. Define the term 'cosmology'. **(P)**

Working and Answer:

The study of the origin, structure, evolution, and fate of the Universe.

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2. What is the Big Bang theory? **(P)**

Working and Answer:

The theory that the Universe began from an extremely dense and hot state
and has been expanding ever since.

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3. State the current estimated age of the Universe. **(P)**

Working and Answer:

Approximately 13.8 billion years.

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4. What is meant by critical density? **(P)**

Working and Answer:

The density of the Universe required for it to have a flat geometry and stop
expanding after infinite time.

5. Explain how the cosmic microwave background (CMB) provides evidence for the Big
Bang. **(PP)**

Working and Answer:

CMB is uniform blackbody radiation at 2.7 K, predicted as leftover heat from
an early, hot dense state.

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6. Describe the significance of the Hubble constant in cosmology. **(PP)**

Working and Answer:

It gives the rate at which the Universe is expanding; allows estimation of the Universe's age.

7. Explain the role of dark energy in the Universe. **(PP)**

Working and Answer:

Dark energy is thought to be responsible for the accelerated expansion of the Universe.

8. What is meant by an open, closed, and flat Universe? **(PP)**

Working and Answer:

Refers to the geometry and fate of the Universe, depending on its total
mass-energy density relative to the critical density.

9. Use Hubble's Law to estimate the age of the Universe if $H_0 = 2.2 \times 10^{-18}\,\text{s}^{-1}$. **(PPP)**

Working and Answer:

$$t = \frac{1}{H_0} = \frac{1}{2.2 \times 10^{-18}} \approx 4.55 \times 10^{17}\,\text{s} \approx 14.4\,\text{billion years}$$

10. A galaxy is observed moving away with a velocity of $1.5 \times 10^7 \, \text{ms}^{-1}$. If the Hubble constant is $70 \, \text{km/s/Mpc}$, estimate its distance. **(PPP)**

Working and Answer:

$$d = \frac{v}{H_0} = \frac{1.5 \times 10^7}{70 \times 10^3} \approx 214.3 \, \text{Mpc}$$

11. State the relationship between redshift and the scale factor. **(PPP)**

Working and Answer:

$$1 + z = \frac{\text{scale factor now}}{\text{scale factor then}}$$

12. A galaxy has a redshift of 2. Calculate the scale factor of the Universe when light was emitted. **(PPP)**

Working and Answer:

$$1 + z = \frac{1}{a} \Rightarrow a = \frac{1}{1+2} = \frac{1}{3}$$

13. Discuss how observations of distant supernovae suggest an accelerating Universe. **(PPPP)**

Working and Answer:

Their apparent brightness is less than expected, suggesting they are further away, implying the expansion rate has increased over time.

14. Outline how dark matter differs from ordinary matter and its cosmological significance. **(PPPP)**

Working and Answer:

Dark matter doesn't emit or absorb light, but its gravitational effects explain galactic rotation curves and structure formation.

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15. Describe how anisotropies in the CMB support models of structure formation. **(PPPP)**

Working and Answer:

Slight variations in CMB temperature indicate density fluctuations that grew into galaxies and clusters.

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16. Explain how both redshift and CMB provide evidence for the Big Bang. **(PPPP)**

Working and Answer:

Redshift shows expansion; CMB shows the Universe once was hot and dense—both are key predictions of the Big Bang.

17. Calculate the redshift z of a galaxy if a spectral line normally at 400 nm is observed at 520 nm. **(PPPPP)**

Working and Answer:

$$z = \frac{\lambda_{obs} - \lambda_{emit}}{\lambda_{emit}} = \frac{520 - 400}{400} = 0.3$$

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18. A galaxy is 500 Mpc away. Using $H_0 = 70\,\text{km/s/Mpc}$, estimate its recessional velocity. **(PPPPP)**

Working and Answer:

$$v = H_0 d = 70 \times 500 = 35\,000\,\text{km/s} = 3.5 \times 10^7\,\text{ms}^{-1}$$

19. Estimate the critical density of the Universe using $H_0 = 2.2 \times 10^{-18}\,\text{s}^{-1}$ and $G = 6.67 \times 10^{-11}\,\text{Nm}^2/\text{kg}^2$. **(PPPPP)**

Working and Answer:

$$\rho_c = \frac{3H_0^2}{8\pi G} = \frac{3(2.2 \times 10^{-18})^2}{8\pi \times 6.67 \times 10^{-11}} \approx 8.6 \times 10^{-27}\,\text{kg/m}^3$$

20. A star is observed with a redshift of $z = 1.5$. Estimate the recessional velocity assuming $v = cz$. **(PPPPP)**

Working and Answer:

$v = 3.0 \times 10^8 \times 1.5 = 4.5 \times 10^8 \, \text{ms}^{-1} \Rightarrow$ Relativistic correction may be needed.