

Q15 Still considering a *matter-dominated* Universe in which the density is *equal* to the critical density, which *two* of the following statements are correct? Pencil across *two* cells in row 15.

KEY for Q15

- A The spacetime is flat, and the space is flat. ☒
- B The spacetime is curved, and the space is flat. ☒
- C The scale factor R is constant. ☒
- D The scale factor R depends on time. ☒
- E The spacetime is curved, and the spatial curvature is positive. ☒
- F The spacetime is curved, and the spatial curvature is negative. ☒
- G Only one of the above responses is correct. ☒

Q16 Which one of the following statements is false? Pencil across *one* cell in row 16.

KEY for Q16

- A The current critical mass density of the Universe is approximately $1 \times 10^{-26} \text{ kg m}^{-3}$. ☒
- B A dynamical estimate of the total mass of our Galaxy, based on an orbital speed of about 220 km s^{-1} for stars in the neighbourhood of the Sun, leads to a value of about $10^{11} M_{\odot}$. ☒
- C The mass-to-light ratio of our Galaxy, based on dynamical mass estimates, is about 10. ☒
- D When galactic halos are taken into account, mass-to-light ratios for galaxies such as our own Milky Way may well be as big as 100. ☒
- E If we live in a universe with critical density, any matter not contained in galaxies (including their halos) is probably non-baryonic matter with a mass-to-light ratio of zero. ☒
- F Cold dark matter has been a key feature of recent attempts to explain galaxy formation. ☒

Q17 Which one of the following statements is false? Pencil across *one* cell in row 17.

KEY for Q17

- A To explain the closeness of the currently observed density of the Universe to the current critical density, those two quantities would have had to have agreed to one part in 10^{15} at the time of decoupling. ☒
- B The theory of inflation tries to explain why the Universe is so nearly critical, how the Universe came to be homogeneous and isotropic on large scales, and why magnetic monopoles are not observed. ☒

C In a (Friedmann-Robertson-Walker) universe dominated by the effects of vacuum quantum fluctuations, where there is a negative pressure of the same magnitude as the energy density, the scale factor $R(t)$ will increase exponentially with time. ☒

D One way of explaining the absence of exponential cosmic expansion, driven by the effects of vacuum quantum fluctuations, is to assume that the expansion effects are cancelled by effects due to a cosmological constant, to one part in 10^{110} or so. ☒

E According to the inflation theory, our Universe underwent a short period of exponential expansion at an early stage in its evolution. Most of the matter in the Universe came into being at the end of this inflationary expansion. ☒

Q18 Suppose that the present density of our Universe was known to be in the range from 1×10^{-27} to $8 \times 10^{-27} \text{ kg m}^{-3}$. Also suppose that it was possible to measure the freeze-out concentration (mass fraction) of each of the elements listed in the key to an accuracy of 1%. Which *one* of the measurements would provide the best estimate of the present density of the Universe? Pencil across *one* cell in row 18.

KEY for Q18

- A ^4He ☒
- B ^3He ☐
- C ^2H ☐
- D ^7Li ☐

Q19 Concerning our Universe, which *two* of the statements in the key are thought to be correct? Pencil across *two* cells in row 19.

KEY for Q19

- A The Universe was matter-dominated at the time of cosmological nucleosynthesis. ☒
- B Matter and radiation were decoupled at the time of cosmological nucleosynthesis. ☒
- C A significant fraction of the nuclei formed during the first 15 minutes after the big bang are still in existence today. ☒
- D If there were a large number of unobserved black holes in intergalactic space, the present density of the Universe could be greater than the critical density ρ^c . ☒
- E If the neutrino were found to have a non-zero mass, it would not affect the estimated mass-energy density of the Universe because neutrinos hardly ever react with matter. ☒

8TH G H²
3C

3C² H²
8TH G