

Q6 A volume of 'empty' space in an Einstein-de Sitter Universe, well away from galaxies, quasars, clusters of galaxies, etc., currently has a diameter of 30 kpc. What diameter will it scale to when the Universe is 1000 times older? Select the item from the key closest to your answer.

KEY for Q6 and Q7

- A 3 kpc E 30 Mpc
B 30 kpc F 300 Mpc
C 300 kpc G 3 000 Mpc
D 3 Mpc

Pencil across one cell in row 6.

Q7 Our galaxy has a diameter of approximately 30 kpc. If the Universe is accurately described by the Einstein-de Sitter model, what diameter will our galaxy scale to when the Universe is 1000 times older? Select the item from the key for Q6 and Q7 closest to your answer.

Pencil across one cell in row 7.

Q8 The Universe is estimated to be about 1.5×10^{10} years old. A quasar at $z = 1$ is observed. Using Figure 3.34 on p. 122 of Book 3, estimate the age of the Universe when the light now observed from the quasar was emitted, and express that as a fraction of the present age of the Universe. Select the item from the key nearest to your answer.

KEY for Q8

- A 0.005
B 0.05
C 0.5
D 1.0
E 2.0

Pencil across one cell in row 8.

Q9 Which three of the following are baryons? Select three items from the key.

KEY for Q9

- A Protons E Neutrons
B Photons F Neutrinos
C Positrons G Electrons
D Placyons H Alpha particles

Pencil across three cells in row 9.

Q10 Identify the two false statements about dark matter in the following list.

KEY for Q10

- A Obscuring material that causes darkness (e.g. dense clouds in the interstellar medium) is excluded from what cosmologists call dark matter.
B Dark matter is predominantly non-baryonic.
C Dark matter includes baryonic material that is not luminous - such as black holes and brown dwarfs.
D The baryonic material we know about forms only a small fraction of the material required by inflation.
E Slow moving, 'exotic', particles could be a form of cold dark matter.
F Cold dark matter is thought to be required to enable galaxies to form.
G Protons could be a significant component of dark matter, in which case it would be visible.
H Hot dark matter is so called because it is left over from the Big Bang.

Pencil across two cells in row 10.

Q11 and Q12 A straight line on a surface is the line that has the shortest distance between two points. These questions are concerned with the properties of an arbitrarily chosen pair of indefinitely extended straight lines. Each question assumes a different geometry for the Universe.

Q11 Suppose that the geometry of the Universe is that given by a value of the density parameter, $\Omega > 1$. How many times would the two straight lines intersect? Choose one item from the key for Q11 and Q12.

Pencil across one cell in row 11.

Q12 Suppose that the geometry of the Universe is that given by a value of the density parameter, $\Omega < 1$. How many times would the two straight lines intersect? Choose one item from the key for Q11 and Q12.

Pencil across one cell in row 12.

KEY for Q11 and Q12

- A 0
B 1
C Either 0 or 1
D 2
E Either 1 or 2
F Any of 0, 1 or 2

$$V = H_0 d$$

$$z = H_0 d \quad \therefore z = V \quad \left(\frac{t}{t_0} \right)^{2/3} = 1$$

$$t = 0.156 t_0$$

$$R(t) = (1000)^{2/3}$$

$$30 \text{ kpc}$$

$$z = \frac{R(t_0)}{R(t)} - 1 = \left(\frac{t_0}{t} \right)^{2/3} - 1$$

$$2 = \left(\frac{t_0}{t_1} \right)^{2/3} \quad t_0 = 2.8 \quad t_1 = 0.35$$

$$H_0 = 2.7 \times 3E8 = 88065$$