Q5 Suppose that, at some stage in the Universe's history, a spaceship moves in such a way that (in one direction) it records a maximum temperature for the cosmic background radiation of 6 K and (in another direction) a minimum temperature of $2\frac{2}{3}$ K.

What is the speed of the spaceship relative to the cosmic background? Select the item from the key that is closest to your answer. Pencil across *one* cell in row 5.

KEY for Q5

A $12c/13$
B $4c/5$
C $5c/9$
D $c/2$
E $5c/13$
F $c/8$

Q6 Which one of the following statements is false? Pencil across *one* cell in row 6.

KEY for Q6

A The cosmic microwave background radiation was discovered in 1965 by Penzias and Wilson of Bell Telephones while working on a satellite communications project.

B The COBE (Cosmic Background Explorer) satellite was launched in 1989. Its observations of the cosmic microwave background radiation are seriously contaminated in certain directions by microwave emission from the Milky Way.

C Because the intensity of the cosmic microwave background is well approximated by the Planck function $W(f,T) = Af^3/[\exp(Bf/T) - 1]$, the radiation's maximum intensity will occur at a frequency $f_{\max}$ that is very nearly proportional to its temperature.

D Although Penzias and Wilson only observed the cosmic microwave background radiation at a single frequency, by combining their measurements with the assumption that the radiation had a black-body spectrum, it was possible to associate the radiation with a temperature of 3 °C.

E In any large region of the Universe, there will be about 10^9 photons belonging to the cosmic background radiation for every proton and neutron.

F Observations by the COBE satellite, which sampled regions of angular separation about 10°, showed that the intensity of the cosmic background radiation is isotropic to about 1 part in 10^5, once allowance has been made for the overall motion of the satellite through the Universe.

Q7 to Q9 Each question consists of two statements, (i) and (ii). For each question, you should indicate whether you agree or disagree with statement (i) by selecting A *or* B from the key, and you should indicate whether you agree or disagree with statement (ii) by selecting C *or* D from the key. *If you agree with both statements*, you should indicate whether or not you consider that statements (i) and (ii) are closely related by selecting E *or* F. *If you disagree with either or both of the statements*, you should not choose either E or F. Your answer will consist of *two* or *three* items.

KEY for Q7 to Q9

A Statement (i) is true.
B Statement (i) is false.
C Statement (ii) is true.
D Statement (ii) is false.
E Statements (i) and (ii) are closely related.
F Statements (i) and (ii) are not closely related.

Q7 *Statement* (i) Matter and radiation were decoupled at the time of big bang nucleosynthesis.

Statement (ii) The Universe was matter-dominated at the time of nucleosynthesis. Pencil across *two or three* cells in row 7.

Q8 *Statement* (i) An open homogeneous universe has no bounds, so the total amount of matter is infinite.

Statement (ii) In an open universe, light paths between galaxies would be more strongly curved than in a closed universe. Pencil across *two or three* cells in row 8.

Q9 *Statement* (i) Deuterium production is thought to be negligible in stellar nuclear reactions.

Statement (ii) The present measured concentration of deuterium provides evidence in support of the big bang. Pencil across *two or three* cells in row 9.

Q10 to Q14 concern a *matter-dominated* universe in which the density is *equal to* the critical density. In each question, you are to select one item from the key to describe how a particular quantity behaves as R approaches infinity.

KEY for Q10 to Q14

A It tends to zero, becoming proportional to $1/R^{3/2}$.
B It tends to zero, becoming proportional to $1/R^2$.
C It tends to zero, becoming proportional to $1/R^3$.
D It tends to zero, becoming proportional to $1/R^4$.
E It becomes infinite.
F It retains a finite negative value.
G It approaches or remains at a finite positive value.
H It is always zero.

Q10 How does the energy density ρ behave as R approaches infinity? Pencil across *one* cell in row 10.

Q11 How does the spatial curvature parameter k behave as R approaches infinity? Pencil across *one* cell in row 11.

Q12 How does the Hubble parameter H behave as R approaches infinity? Pencil across *one* cell in row 12.

Q13 How does the deceleration parameter q behave as R approaches infinity? Pencil across *one* cell in row 13.

Q14 How does the critical density ρ^* behave as R approaches infinity? Pencil across *one* cell in row 14.