Chapter E4

Q1 According to the Olbers "paradox", the night sky should be bright and not dark at all. This is based on the observation that in an infinite universe (the question should have referred to infinite cosmologies) every line of sight ends up on a star and so the sky should be bright. The obvious way of the paradox is that "there are many stars but those far away are too dim" does not work because whereas the distant stars are indeed are dim, there are also very many of them. Therefore the distance stars contribute as much light as the closer ones. In the big bang model the problem is resolved in two main ways: stars do not live forever and there is a finite number of them.

Q2 (a) In $1\ \text{m}^3$ we have a mass of 10^{-26} kg and so $\frac{10^{-26}}{1.67\times10^{-27}}\approx 6$ atoms of hydrogen.

Q3 The three standard pieces of evidence in favor of the big bang are (1) the cosmic background radiation, (2) the expansion of the universe and (3) the helium abundance in the universe. Detailed discussions of these are on page 517 of the textbook.

Q4 (a) The significance of the CMBR is that it is black body radiation coming from all directions indicating that it does not have any specific source. It fills the universe and was once at the very high temperature that as ambient in the early universe. As the universe expanded and cooled down the radiation stretched out along with the universe i.e. its wavelength increased to its present value that corresponds to a temperature of about 2.7 K. So the existence of this radiation is a necessary feature of the big bang cosmology. (b) The universe is expected to be homogeneous and isotropic so the same observations would be made from any part of the universe, hence the same temperature would be obtained.

Q5 (a) The temperature would keep falling to absolute zero. (b) The temperature would increase as the collapse begins.

Q6 The big bang signifies the beginning of time and space. At the big bang the universe was a point and so the big bang happened everywhere in the universe.

Q7 The question is meaningless *within the big bang model* since **by definition** time started with the big bang. It is as meaningless as to ask for a place 1 km north of the north pole. However, recent developments within string theory suggest that the question may not be as meaningless as it appears. See the very interesting article "The time before time", by Gabriele Veneziano (one of the true greats of theoretical physics) in the May 2004 Scientific American.

Q8 The surface of a flat sheet of paper extending forever is an example of what is called an open universe, whereas the surface of a sphere (just the surface not the interior) is an example of a closed universe. The surface of a sphere is finite (it has finite area) but it has no boundary – you cannot walk on a sphere and come to a point where you see an edge. On the other hand, a finite flat piece of paper is an example of a finite space (finite area) that does have an edge, a boundary.

Q9 (a) In the standard (and now outdated) big bang cosmology, the critical density of the universe is the density of matter (and energy) that makes the universe expand forever at a decreasing rate, the rate halting to zero at infinity. (b) A closed universe is a universe with a density greater than the critical density, a universe that will re-collapse. A closed universe has a finite volume. (c) An open universe has a density that is smaller than the critical density and will expand forever at a rate that will never become zero even though the rate will slow down.

Q10 What is wrong with the statement is that it assumes the existence of empty space into which matter (galaxies) move into. The space in between galaxies is being stretched giving the illusion of the motion of galaxies away from each other.

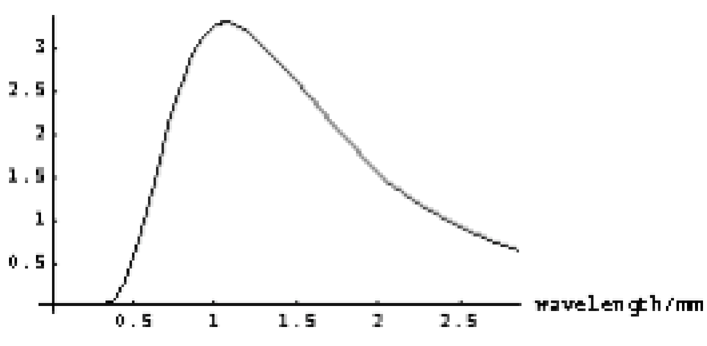
Q11 It allows us to determine (in the standard big bang model) whether the universe will follow one of the three possibilities of the model: expansion forever, expansion followed by re-collapse or expansion forever at a rate that approaches zero.

Q12 There is a lot of matter in the universe that does not radiate and so cannot be seen.

Q13 Matter in the universe that does not radiate or interacts with matter very weakly and so cannot be seen or easily detected. This is divided between WIMPS and MACHOS. WIMPS (massive weakly interacting particles) may include neutrinos and exotic particles predicted by models of particle physics e.g. supersymmetric particles. These have masses similar to those of atomic nuclei and interact via the weak force and gravity but not the electromagnetic force – and this makes them difficult to detect. MACHOS (massive astrophysical compact halo objects) is ordinary matter that may include brown, black and red dwarfs, and black holes. It is estimated that of all the matter in the universe, over 80% may be dark matter.

Q14 From Wien's law, $\lambda T = 2.90 \times 10^{-3} \Rightarrow T = \dfrac{2.90 \times 10^{-3}}{7 \times 10^{-7}} = 4100\ \text{K}$.

Q15 (a)



(b) After a long time the peak would move to the left and it would become lower.