CHAPTER 2

1   Carry out the calculation described in Note 4 (refer also to Note 2) to obtain an equilibrium average temperature for an Earth partially covered with clouds such that thirty per cent of the incoming solar radiation is reflected. If clouds are assumed to cover half the Earth and if the reflectivity of the clouds increases by one per cent what change will this make in the resulting equilibrium average temperature?

F is the black body radiation, s is the Boltzmann constant (5.67×10^{-8} J $m^{-2}K^{-4}s^{-1}$), and T is the temperature (in Kelvin).

30% of 288 is 86.4. Therefore if clouds are included in the simple radiation balance model, and assumed to reflect 30% of radiation back into space, the Earth receives 202 watts m^{-2}.

Using the black body equation, $F=sT^4$, the effective equilibrium temperature is:

$T = (201.6/(5.67x10^{-8})^{0.25}$

$T = 244.2K$

$T = -28.8\ °C$

for a 1% increase in reflectivity.

2   It is sometimes argued that the greenhouse effect of carbon dioxide is negligible because its absorption band in the infrared is so close to saturation that there is very little additional absorption of radiation emitted from the surface. What are the fallacies in this argument?

> *Even though the centres of the absorption bands are saturated there is enough additional absorption occurring in the wings of the band to make the difference we find. The total absorption for a given atmospheric path depends on the logarithm of the amount of CO2

> * It is also flawed because the argument treats the atmosphere as a single slab*

3   Use the information in Figure 2.5 to estimate approximately the surface temperature that would result if carbon dioxide were completely removed from the atmosphere. What is required is that the total energy radiated by the Earth plus atmosphere should remain the same, i.e. the area under the radiance curve in Figure 2.5 should be unaltered. On this basis construct a new curve with the carbon dioxide band absent.

If carbon dioxide were completely removed from the atmosphere, the surface temperature would be between 7 and -13°C, nearer the upper curve - we estimate about 0°C.

4   Using information from books or articles on climatology or meteorology describe why the presence of water vapour in the atmosphere is of such importance in determining the atmosphere's circulation.

*   * Water vapour supplies energy required for atmospheric circulation - latent heat is involved in the redistribution of energy associated with the processes of evaporation and recondensation.*

*   * Water vapour is strongly coupled to precipitation and soil moisture, affecting the patterns of circulation.*

When you are looking for information, look up interactions between water vapour, clouds, atmospheric motion, and radiation from both the Sun and the Earth.

5   Estimates of regional warming due to increased greenhouse gases are generally larger over land areas than over ocean areas. What might be the reasons for this?

   * The ocean has a higher heat capacity

   * For a given input of energy, the ocean will not increase temperature as much as land

   * The lag effect

6.   (For students with a background in physics) What is meant by Local Thermodynamic Equilibrium (LTE), a basic assumption underlying calculations of radiative transfer in the lower atmosphere appropriate to discussions of the greenhouse effect? Under what conditions does LTE apply?

Kirchhoff's law says that temperature is a function of emission, absorption and brightness (the latter given by Planck's law that describes spectral radiance), but temperature can only be defined strictly under thermodynamic equilibrium conditions. Real atmospheres are not in thermodynamic equilibrium - their effective brightness temperatures are different for infrared, visible and ultraviolet light, and scattering of light can also have an effect. However, for many purposes, a local thermodynamic equilibrium can be defined that is "good enough" to explain observations. In the lower atmosphere, the density of the atmosphere means that molecules interact enough for the blackbody rules to be applicable. Further explanation can be found in Houghton, J. 2002. The Physics of Atmospheres, Cambridge University Press, Chapters 1 and 14.