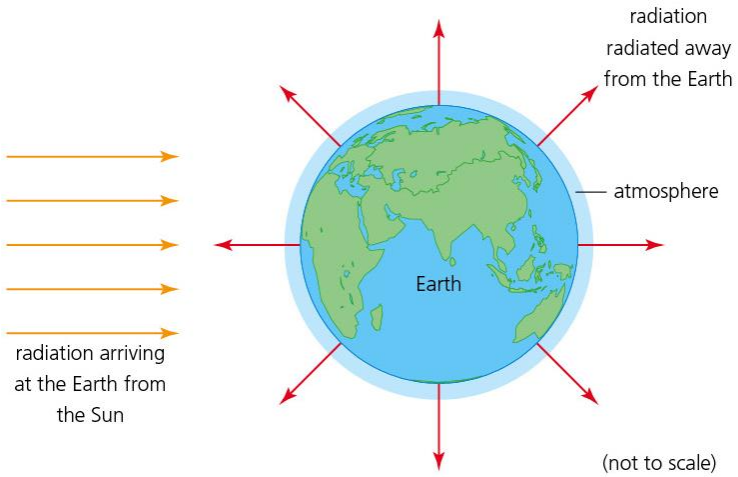
7 The Earth receives radiant energy from the Sum every second. If the Earth radiates or reflect energy back into space at the same rate, then it will be in thermal equilibrium and its average temperature will remain constant. If the Earth radiates or reflect less energy than it receives it will get hotter.



The greenhouse effect is the name that is given to the natural effect a planet's atmosphere has in increasing the temperature of the planet to a value higher than it would be without an atmosphere. The Earth has a beneficial greenhouse effect because it has an atmosphere. The Earth's atmosphere is a good transmitter of visible radiation and a good absorber of infrared radiation. The visible light that reaches the Earth's surface is absorbed and reradiated as infrared light, which in turn is absorbed (trapped) by the Earth's atmosphere.

If the Earth did not have an atmosphere it would be about 30°C cooler and without life. The Moon and the Earth are approximately the same distance from the Sun, but the surface of the Earth is hotter and therefore human life exists.

However, most scientists now believe that the greenhouse effect has become enhanced. This is attributed to human activities, primarily fossil fuel burning, As fossil fuels (coal, oil, and natural gas) are burned, large amounts of carbon dioxide, which is one of the most significant greenhouses gases, are released into the atmosphere. According to one estimate, doubling the carbon dioxide content in the atmosphere will cause temperatures to increase by 2°C. This is probably the most important cause of current global warming.

There is little doubt that global warming has led to consequences such as climate change and changes to the sea level. During December 2006, New York had one of its highest temperatures for a winter while Melbourne has snow in the hinterlands during summer. Global warming is causing global mean sea level to rise in two ways. Firstly, glaciers and ice sheets worldwide are melting and secondly, the volume of the ocean is expanding as the water warms.

(a) Solar radiation falling on the Earth's surface is absorbed by the Earth.

(i) This solar radiation has an average intensity of 5.0×10^{2} Wm^{-2} and falls on an area of 2.6×10^{14} m^{2} on the Earth.

Calculate the energy per second that is absorbed by the Earth due to this solar radiation.

energy per second = ... $J\ s^{-1}$ [2]

(ii) The Earth has acquired a mean equilibrium temperature due to the energy per second absorbed from the Sun being in balance with the power radiated from the Earth's surface into Space.

State the power that must be radiated from the Earth's surface so that it achieves a steady equilibrium temperature.

power = ... W [1]

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(iii) Assuming that the Earth radiates this power uniformly from all points on its surface and the radius of the Earth is 6400 km, show that the Earth radiates a power of 250 W per square metre of the Earth's surface

[2]

(b) Fig. 7.1 shows the variation with wavelength, λ, of the intensity of electromagnetic radiation emitted by a blackbody at a surface temperature of 2900 K.

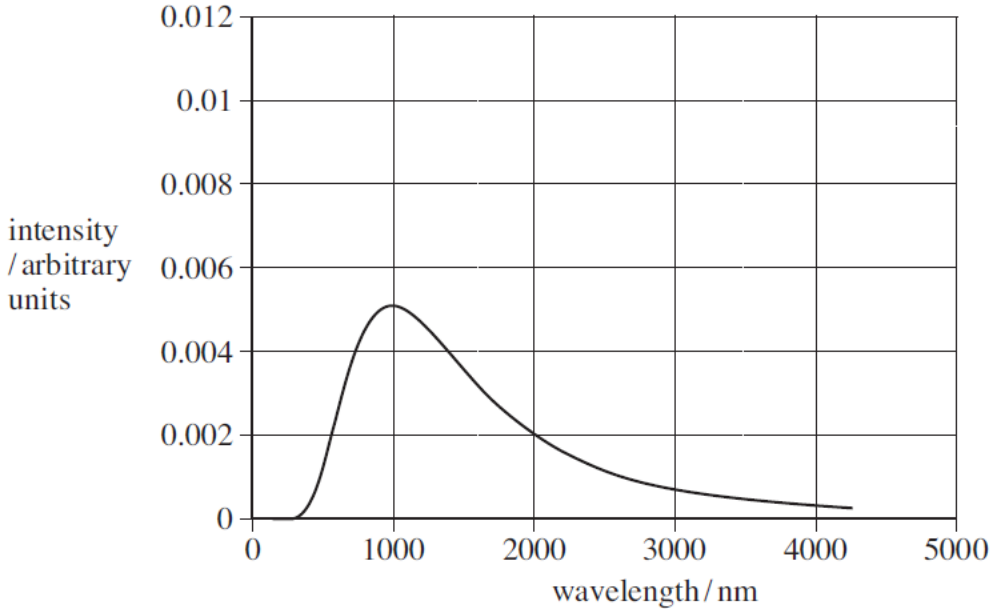

Fig. 7.1

At any surface temperature *T in kelvin*, there is a peak intensity corresponding to a wavelength λ_{max} of radiation. The wavelength λ_{max} is related to temperature *T* by the equation

$$\lambda_{max}\, T = k$$

where *k* is a constant. This equation is also known as Wien's Law.

(i) Mark, with an arrow labelled **M** on Fig. 7.1, the wavelength λ_{max} that correspond to the peak intensity of radiation from the blackbody. [1]

(ii) Use Fig. 7.1 to calculate the value of *k*.

k = ... nm K [2]

(iii) The surface of the Sun is at a temperature of 5800 K and that of the Earth is 290 K. They may both be considered to radiate energy as black bodies.

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Calculate the wavelengths, in nm, corresponding to the peak intensity for the radiation emitted by the Sun and the Earth.

wavelength for the Sun = ... nm

wavelength for the Earth = ... nm [2]

(iv) Draw on Fig. 7.1 the emission curve for the Sun. Label it **(iv).**

[1]

(c) Fig. 7.2 shows how the percentage of electromagnetic radiation, absorbed by carbon dioxide, varies with the wavelength of the radiation.

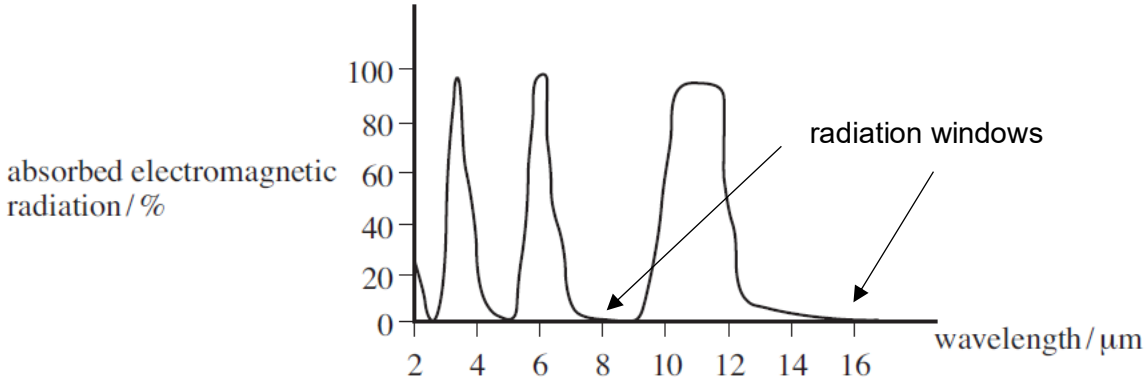

Fig. 8.2

(i) The graph indicates that carbon dioxide has radiation windows.
Suggest what is meant by the term *radiation windows* in this context.

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.....

..... [1]

(ii) State whether carbon dioxide has a radiation window for radiation of wavelength 11 μm.

.....

..... [1]

(d) Explain how Wien's law and knowledge of the radiation windows for carbon dioxide can be used to account for the greenhouse effect that contributes to global warming.

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..... [3]

(e) Large proportions of the Earth's ice will melt if the Earth's equilibrium temperature increases.

(i) Greenland has an ice sheet that covers a land area of 1.7×10^6 km^2. The mass of the ice in this sheet is 2.8×10^{18} kg.
Calculate the volume of water produced if all of this ice were to melt.
density of water = 1.0×10^3 kg m^{-3}

volume = ... m^3 [2]

(ii) Arctic pack ice mostly consists of frozen salt water that floats on the surface of the Arctic Ocean. Until recently, this ice remained frozen but now significant amounts of it melt during the summer.
State and explain any change in sea levels that may occur should all of this floating pack ice melt.

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..... [2]

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