8 Read the passage below and answer the questions that follow.

Observing the Sun from SOHO

The Solar and Heliographic Observatory (SOHO) shown in Fig. 8.1 is a spacecraft resulting from a highly successful collaboration between NASA and the European Space Agency (ESA). It was launched in December 1995 and was originally intended to be in operation for only two years. It proved to be such a successful mission that its lifetime has been extended several times. It is a relatively small spacecraft with a mass of 1900 kg but it is packed with instruments studying a wide range of the Sun's properties and emissions.

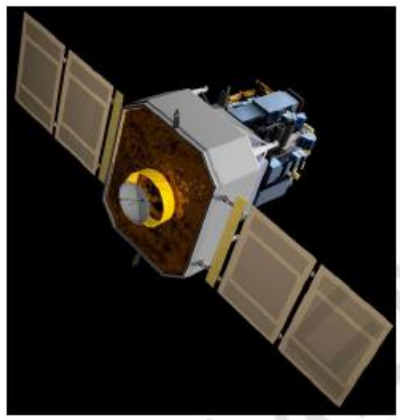

Fig. 8.1 SOHO spacecraft

SOHO is in a fixed orbit about the Sun located what is called the First Lagrangian Point (L1) in Fig. 8.2 and under the joint action of the Sun and the Earth always remains approximately on a straight line between the Earth and the Sun, about 1.5 Gm from the Earth. The orbital period of SOHO is the same as the Earth and it always faces the Sun, enabling data to be collected continuously.

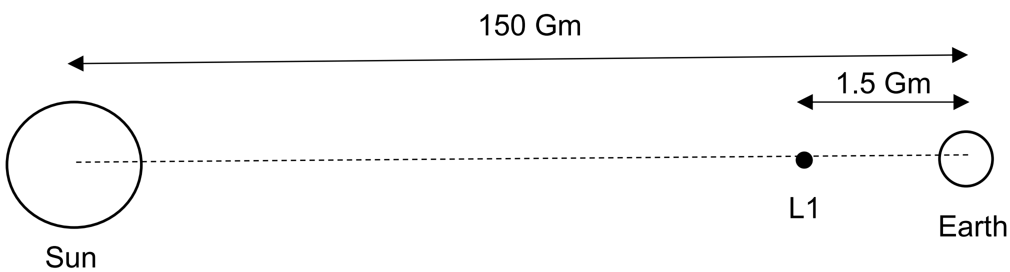

Fig. 8.2

The Sun is surrounded by a jacket of gases called an atmosphere. The 'corona' is the outermost part of the Sun's atmosphere. The Sun's corona has long fascinated astronomers. From the Earth the corona is visible only during an eclipse, as shown in Fig. 8.3, so one of

SOHO's instruments was designed to create a permanent artificial eclipse by blocking out the Sun's disc. This allowed the corona to be studied continuously.

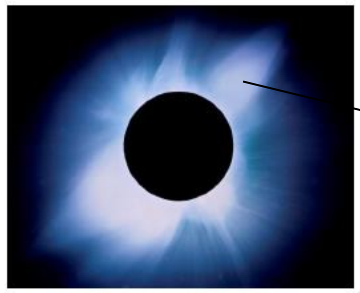

Fig. 8.3

It has been observed by SOHO that the Sun's corona is a strong emitter of "soft" X-rays (wavelengths ranging from 0.10 nm to 10 nm); these can only have been emitted from the corona whose temperature is far above 5800 K, which is the temperature of the bright surface of the Sun.

Other instruments on SOHO detect the particles emitted by the Sun in the solar wind. These particles, mostly electrons and protons, flow continually outwards from the Sun, but are often interrupted by large bursts of plasma called coronal mass ejections (CMEs) travelling at speeds between 20 km s^{-1} and 3200 km s^{-1}, with an average of 490 km s^{-1}. Any of these sudden outpourings of energetic charged particles, which head towards the Earth can cause serious negative effects on Earth, such as disabling electrical circuits and causing massive blackouts. One such catastrophic event was the massive blackout that occurred in Quebec, Canada, in March 1989.

(a) SOHO is mostly constructed from aluminium, instead of low-density carbon fibres often used for satellite construction. With reference to the physical properties of aluminium, state one advantage of using aluminium in the construction of SOHO.

....

....

.... [1]

(b) **(i)** Calculate the centripetal acceleration experienced by SOHO as it orbits the Sun at position L1.

acceleration = ... m s^{-2} [2]

(ii) Using Newton's law of gravitation, show that, for a circular orbit of an body about the Sun,

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

where T is the orbital period of the body,
M is the mass of the Sun, and
r is the distance between the centre of mass of the body and the planet.

[2]

(iii) By considering the gravitational forces exerted on SOHO by the Earth and Sun, explain how SOHO has the same orbital period as the Earth, although their orbital radii are different.
Given: Mass of Sun = 2.0×10^{30} kg
Mass of Earth = 6.0×10^{24} kg

....

....

.... [5]

(c) The Sun can be considered as a perfect black body emitting electromagnetic radiation.

A typical intensity distribution of the electromagnetic radiation emitted by a black body of thermodynamic temperature T is shown in Fig. 8.4.

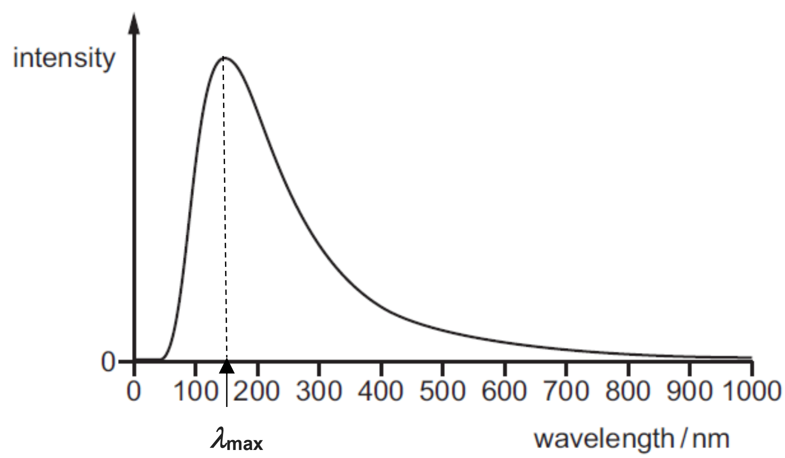

Fig. 8.4

At any thermodynamic temperature T, there is a peak intensity corresponding to a wavelength λ_{max} of radiation. Data for T and the corresponding values of λ_{max} are shown in Fig. 8.5.

T/K	λ_{max} / 10^{-7} m	$1/\lambda_{max}$ / 10^{7} m^{-1}
6000	4.83	0.207
5000	5.80	0.172
4000	7.24	0.137
3000	10.9	
2000	22.2	0.045

Fig. 8.5

It was observed that λ_{max} is related to temperature T by the equation

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

where k is a constant.

(i) Complete Fig. 8.5 by calculating the value of $1/\lambda_{max}$ for the temperature T = 3000 K. [1]

(ii) On Fig. 8.6, plot the point corresponding to T = 3000 K and draw the best fit for the points. [1]

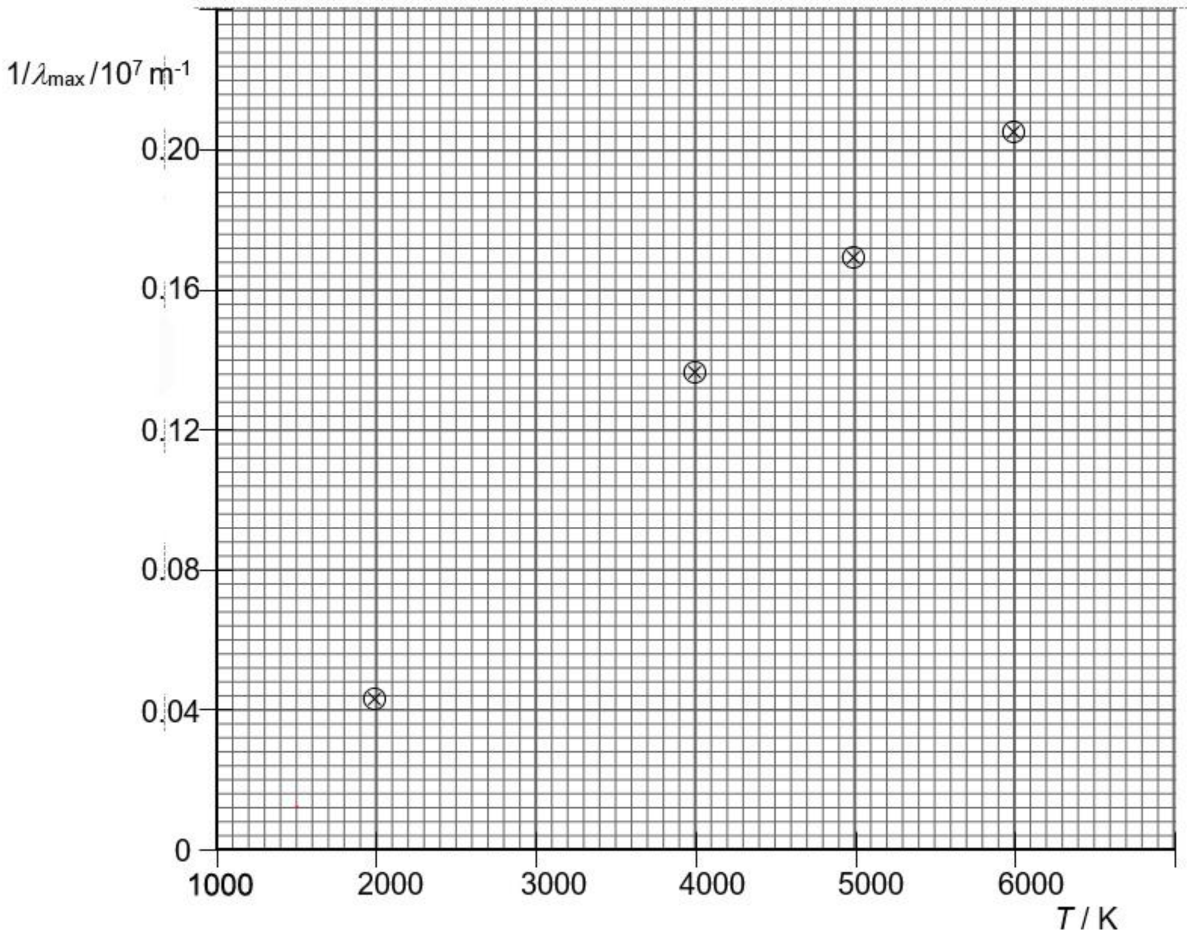

Fig. 8.6

(iii) Use the line drawn in **(c)(ii)** to determine the value of the constant k.

k = ... m K [2]

(d) The passage states the temperature of the corona is far above 5800 K, which is the temperature of the surface of the Sun.

The coronal X-rays detected by SOHO are in the range of wavelengths from 0.10 nm to 10 nm.

Assuming the Sun's corona behaves as an ideal gas, estimate the temperature of the corona.

temperature = ... K [3]

(e) Measurements by SOHO's instrument showed that the coronal mass ejections (CMEs) in the solar wind travel at fast speeds towards the Earth.

(i) Calculate the shortest time at which the CMEs can travel from the Sun to the Earth.

time = ... h [2]

(ii) Explain why CMEs can disable electrical circuits and thereby cause blackouts on Earth.

....

....

....

.... [2]

[Total: 22]

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