Blackbody Radiation

Wien's constant: $b = 2.898 \times 10^{-3}\,\mathrm{mK}$, **Stefan's constant:** $\sigma = 5.67 \times 10^{-8}\,\mathrm{Jm^{-2}K^{-4}}$.

1. Sunspots appear dark, although their temperatures are typically $5000\,\mathrm{K}$, because the rest of the Sun's surface is at a temperature of $5800\,\mathrm{K}$. Find the ratio of the radiation rate of the normal solar surface to that of sunspots. (1.8)

2. An exploding hydrogen bomb develops a temperature of $10^8\,\mathrm{K}$. Assuming that the fireball behaves as a blackbody, what is the value of λ_{max}, at which the distribution has a maximum? What is the energy of the corresponding photon? ($2.9 \times 10^{-11}\,\mathrm{m}$, $43\,\mathrm{keV}$)

3. Repeat the above problem for the cosmic microwave background radiation, which is a blackbody radiation of temperature $2.7\,\mathrm{K}$. ($1.1 \times 10^{-3}\,\mathrm{m}$, $1.1 \times 10^{-3}\,\mathrm{eV}$)

4. The Sun has a radius of $7 \times 10^8\,\mathrm{m}$, and radiates approximately as a blackbody at a temperature of about $6000\,\mathrm{K}$. What is the total power radiated by the Sun? ($4.5 \times 10^{23}\,\mathrm{W}$)

5. Find the surface area of a black body that radiates $1\,\mathrm{kW}$ when its temperature is $500^\circ\,\mathrm{C}$. If the blackbody is a sphere, what is its radius? ($6.27\,\mathrm{mm}$)

6. A star whose emissivity peaks at 4000Å, has a radius of $12 \times 10^5\,\mathrm{km}$. Assuming that the star behaves like a blackbody, find its surface temperature, and the total energy that it radiates every second. ($7245\,\mathrm{K}$, $2.83 \times 10^{27}\,\mathrm{Js^{-1}}$)

7. Each square centimetre of the Sun's surface radiates energy at the rate of $6.3 \times 10^3\,\mathrm{Js^{-1}cm^{-2}}$. Assuming that the Sun radiates like a blackbody, calculate the temperature of the Sun's surface, and with this result, explain mathematically why the colour of the Sun is close to yellow.

   ($5774\,\mathrm{K}$, $\lambda_{\mathrm{max}} \sim 5000\text{Å}$)

8. The brightest part of the spectrum of the star Sirius is at a wavelength of $290\,\mathrm{nm}$. Calculate the surface temperature of Sirius, and also the intensity of its radiation assuming the body behaves like a blackbody. ($10000\,\mathrm{K}$, $5.65 \times 10^8\,\mathrm{Wm^{-2}}$)

9. A gas cloud in a galaxy emits radiation at a rate of $1.0 \times 10^{27}\,\mathrm{W}$. The radiation has its maximum intensity at a wavelength of $10\,\mu\mathrm{m}$. If the cloud is spherical, and radiates like a blackbody, find its surface temperature and diameter. ($290\,\mathrm{K}$, $8.9 \times 10^{11}\,\mathrm{m}$)

10. An object has a temperature of $800^\circ\,\mathrm{C}$. At what temperature will it radiate energy twice as fast?

    ($1276\,\mathrm{K}$)

11. A nuclear bomb at the instant of explosion may be approximated to a blackbody of radius $0.3\,\mathrm{m}$ with a temperature of $10^7\,\mathrm{K}$. What power does it emit? ($6.4 \times 10^{20}\,\mathrm{W}$)

12. A wire of length $1\,\mathrm{m}$ and radius $1\,\mathrm{mm}$ is heated via an electric current to produce $1\,\mathrm{kW}$ of radiant power. Treating the wire as a blackbody, calculate its temperature. ($1294\,\mathrm{K}$)

13. Calculate the solar constant, which is the solar radiation power received by $1\,\mathrm{m^2}$ area on the surface of the Earth. ($1400\,\mathrm{Wm^{-2}}$)

[1] **PTO**

14. When the Sun is directly overhead, the thermal energy incident on the Earth is $1400\,\mathrm{Wm}^2$. Assume that the Sun is a blackbody of radius $7 \times 10^5\,\mathrm{km}$, which is at a distance of $1.5 \times 10^8\,\mathrm{km}$ from the Earth. Find the total intensity the solar radiation, and the temperature of the Sun.

$(6.4 \times 10^7\,\mathrm{Wm}^{-2}, 5800\,\mathrm{K})$

15. The mass of the Sun is $M_\odot = 2 \times 10^{30}\,\mathrm{kg}$, its radius is $R_\odot = 7 \times 10^8\,\mathrm{m}$ and its surface temperature is $T_\odot = 5800\,\mathrm{K}$. Calculate the mass of the Sun lost every second by radiation. Calculate the time taken for the mass of the Sun to diminish by 1%. $(4.4 \times 10^9\,\mathrm{kgs}^{-1}, 144 \times 10^9\,\mathrm{years})$

16. A radiator has its maximum spectral radiance at a wavelength of $10^{-6}\,\mathrm{m}$ in the infrared region of the spectrum. The temperature of the body is now increased so that the radiant intensity of the body is doubled. What is the new temperature? At what wavelength will the spectral radiance have its maximum value? $(3446\,\mathrm{K}, 0.84 \times 10^{-6}\,\mathrm{m})$

17. Using all relevant data from the previous questions, estimate the temperature of the Earth, assuming that it is in radiative equilibrium with the Sun. $(280\,\mathrm{K})$
