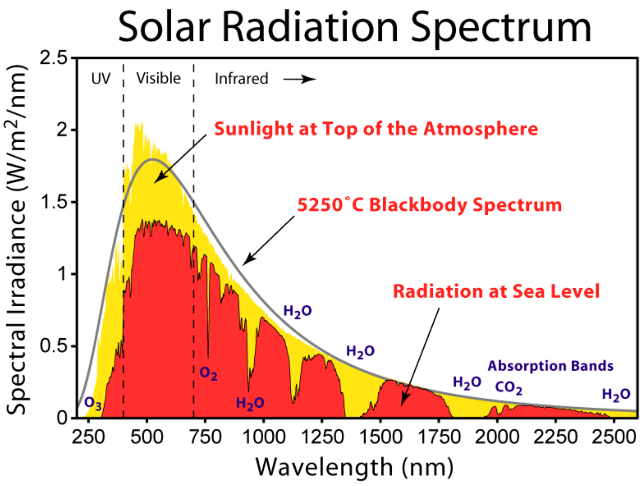
FLIPPED around PHYSICS

9.3 Blackbody radiation

videos

When we observe stars, we can see that they have different colours as well as brightness. The colour of a star is dependent on the peak wavelength of light the star emits.



For example, if we take a look at the spectrum of light from the Sun (our nearest star), we can see the peak wavelength lies towards the middle of the visible spectrum. As a consequence, the Sun appears a yellow colour. You can see that the Sun also emits ultraviolet (UV) and infrared radiation.

Hotter stars will have a peak wavelength which is shifted to shorter wavelengths, and so appear blue. Cooler stars will have a peak wavelength which is shifted to longer wavelengths and so appear red. In fact, the colour of a star is related to its surface temperature.

Wein's displacement law

Wein's displacement law relates the peak wavelength to the surface temperature:

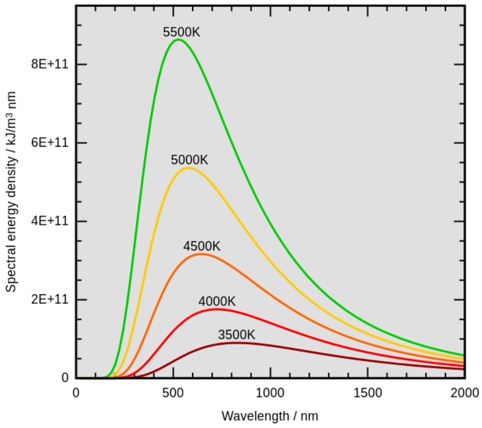
$$\lambda_{max} = \frac{2.9 \times 10^{-3}}{T}$$

where T=surface temperature in kelvin. The constant is known as Wein's displacement constant.

(1) ✎ Calculate the peak wavelength for the Sun, where the effective surface temperature T=5780K.

You can see that the solar radiation spectrum in the diagram, above, is approximated with a curve called a 'blackbody spectrum'. A blackbody is a mathematical construct which approximates the radiation of hot bodies such as stars. You can find out more about black bodies here: https://en.wikipedia.org/wiki/Black_body

We can look at the blackbody spectra of black bodies at different temperatures (see diagram, right) as an approximation of the radiation emitted by stars with different surface temperatures.



You can see that the peak wavelength shifts to shorter wavelengths as the temperature increases (given by Wein's displacement law).

(2) ✏ What is the other change you observe as you move to hotter surface temperatures?

Stefan's Law

We can see that the intensity (*power per square metre*) of radiation increases as the surface temperature increases. Stefan's law (based on black body radiation) shows that the relationship between intensity and surface temperature is given by:

$$I = \sigma T^4$$

where T=surface temperature in kelvin, σ = the Stefan constant = $5.57 \times 10^{-8} W m^{-2} K^{-4}$

(3) ✏ Calculate the intensity of radiation emitted at the surface of the Sun.

The intensity of radiation is a measure of the power per square metre of radiation at the surface. To work out the total power output of a star (called luminosity L), we just need to multiply this number by the surface area (A):

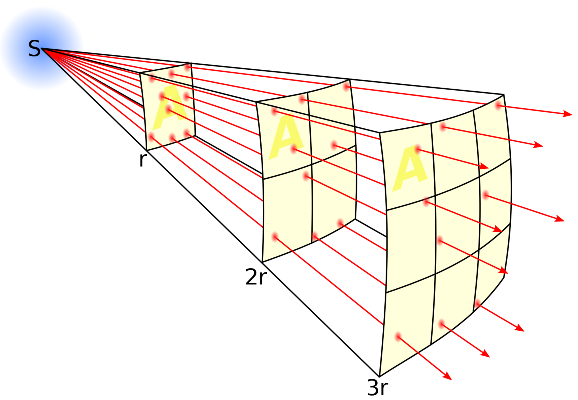
$$L = A\,\sigma T^4 = 4\pi r^2 \sigma T^4$$

where r=radius of the star

(4) ✏ Calculate the luminosity of the Sun. The radius of the Sun = $7 \times 10^8 m$.

Inverse-square problems

Inverse-square problems arise where radiation is emitted isotropically (equally in every direction). The intensity of radiation (power per square metre) falls off as the square of the distance from the radiating source.



To understand this, you should imagine radiation being spread over larger and larger spheres as it propagates outwards.

The diagram, left illustrates this. If the distance from the source is doubled, the intensity falls to a quarter.

We can imagine stars radiating in this way.

The intensity of radiation at a distance d from a star is given by:

$$I = \frac{L}{4\pi d^2}$$

where L is the luminosity of the star in watts

(5) ✐Calculate the intensity of radiation at the top of the Earth's atmosphere from the Sun. The mean Earth-Sun distance = 150 million kilometres.