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Black-body radiation on one page

Every object above absolute zero emits thermal radiation. A black body, an ideal surface that absorbs all incoming light, radiates a spectrum that depends only on its temperature T. This note collects the three formulas you need and a few reference values.

1 Planck's law

The spectral radiance of a black body at wavelength λ is

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5}\,\frac{1}{e^{hc/(\lambda k_B T)} - 1} \qquad (1)$$

where h is the Planck constant, c the speed of light and k_B the Boltzmann constant. A hotter body emits more at every wavelength, and its peak moves to shorter wavelengths (Figure 1).

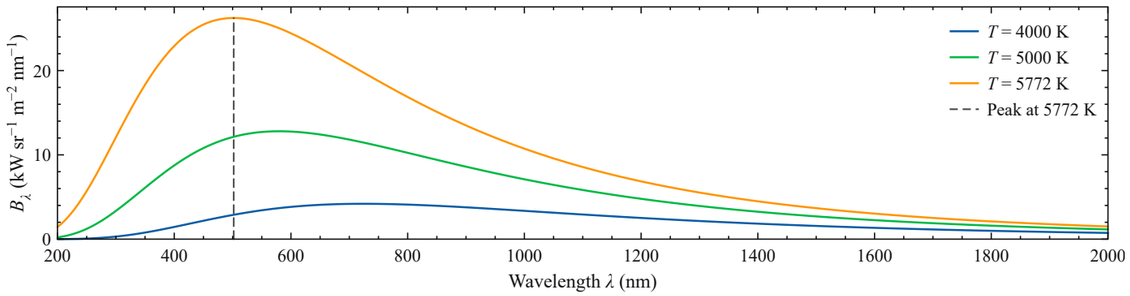

Figure 1 Spectral radiance of a black body at three temperatures. The dashed line marks the peak wavelength at 5772 K.

2 Wien's law and the Stefan–Boltzmann law

The peak wavelength and the total power radiated per unit area follow from Eq. (1):

$$\lambda_{\max} = \frac{b}{T}, \qquad b \approx 2.898 \times 10^{-3}\ \mathrm{m\,K} \qquad (2)$$

$$M = \sigma T^4, \qquad \sigma \approx 5.670 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}} \qquad (3)$$

Table 1 Peak wavelength and radiant exitance of a black body

Temperature	Example	Peak wavelength	Radiant exitance
300 K	Room temperature	9.66 µm	459 W/m²
1000 K	Glowing electric heater coil	2.90 µm	56.7 kW/m²
3000 K	Incandescent lamp filament	966 nm	4.59 MW/m²
5772 K	Effective temperature of the Sun	502 nm	62.9 MW/m²

3 Things to remember

- Doubling the temperature halves the peak wavelength and multiplies the radiated power by 16.
- Real surfaces emit less than a black body: their emissivity ε, between 0 and 1, scales Eq. (3).
- The Sun radiates close to a black body at 5772 K, which puts its peak in visible light.

一页上的黑体辐射

每个绝对零以上的物体都会发出热辐射。黑体是吸收所有入射光的理想表面，辐射出的光谱仅取决于其温度 T。本笔记收集了您需要的三个公式和一些参考值。

1 普朗克定律

黑体在波长 λ 处的光谱辐射亮度为

$$B_\lambda(\lambda, T) = \frac{2hc^2}{\lambda^5}\,\frac{1}{e^{hc/(\lambda k_B T)} - 1} \qquad (1)$$

其中 h 是普朗克常数，c 是光速，kB 是玻尔兹曼常数。更热的身体会散发出

每个波长的能量都更多，并且其峰值移动到更短的波长（图 1）。

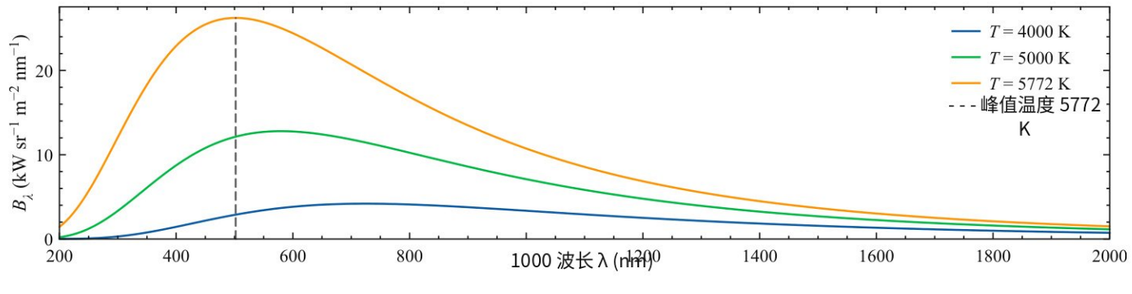

Figure 1 Spectral 黑体在三个温度下的辐射率。虚线标记 5772 K 处的峰值波长。

2 维恩定律和Stefan-Boltzmann定律

峰值波长和每单位面积辐射的总功率由方程（1）得出。(1)：

$$\lambda_{\max} = \frac{b}{T}, \qquad b \approx 2.898 \times 10^{-3}\ \mathrm{m\,K} \qquad (2)$$

$$M = \sigma T^4, \qquad \sigma \approx 5.670 \times 10^{-8}\ \mathrm{W\,m^{-2}\,K^{-4}} \qquad (3)$$

Table 1 Peak 黑体的波长和辐射出射度

温度	例子	峰值波长	辐射出射度
300 K	室温	9.66 µm	459 W/m²
1000 K	发光的电加热器线圈	2.90 µm	56.7 kW/m²
3000 K	白炽灯灯丝	966 nm	4.59 MW/m²
5772 K	太阳有效温度	502 nm	62.9 MW/m²

3 需要记住的事情

- 温度加倍，峰值波长减半，辐射功率乘以 16。
- 真实表面的发射量小于黑体：它们的发射率ε 介于0 和1 之间，比例方程1。 （3）。
- 太阳的辐射接近黑体，温度为 5772 K，可见光达到峰值。