

Why Hotter Bodies Glow Differently



Everyday Observation

When a blacksmith heats a piece of iron, its color changes predictably as its temperature rises.

Dull Red → Reddish Yellow → White Hot

Why does the color change instead of just getting brighter?

The Perfect Radiator: What is a Blackbody?

All bodies (solid, liquid, gas) emit electromagnetic radiation by virtue of their temperature.

A **Blackbody** is a **perfect radiator**. Its radiation depends only on its temperature—not on its size, shape, or material.

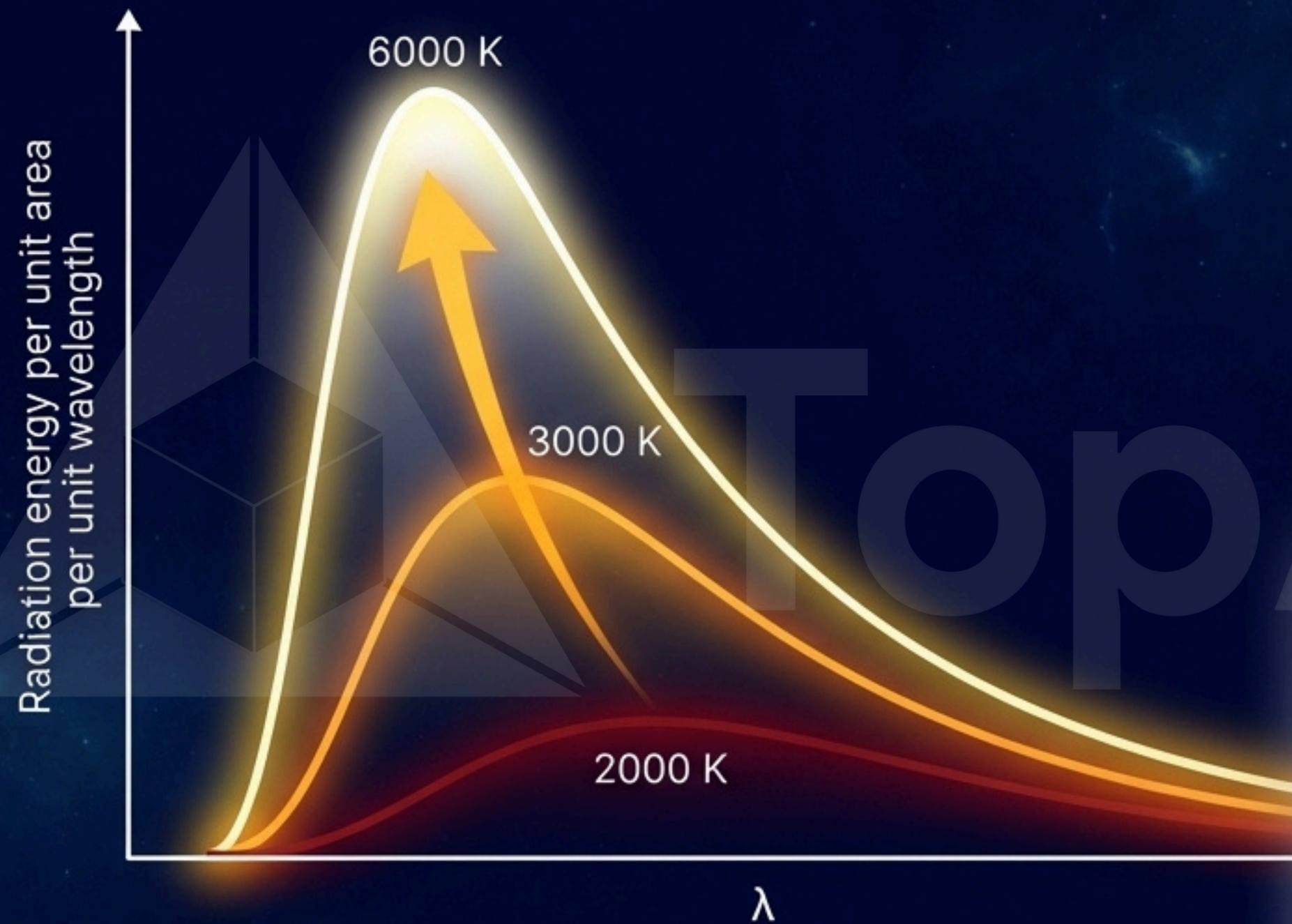
The Key Insight

Thermal radiation is not just one wavelength. It contains a **continuous spectrum** from small to long wavelengths, but the energy content varies across them.



Practice more, score more

The Universal Thermal Spectrum



Observation Panel

1. As temperature increases, the total energy (area under curve) grows massively.
2. The peak wavelength (λ_m) shifts to the left (shorter wavelengths) as the body gets hotter.

Wien's Displacement Law

The wavelength for which energy is maximum (λ_m) decreases with increasing absolute temperature (T).

$$\lambda_m T = \text{constant}$$

Wien's Constant = $2.9 \times 10^{-3} \text{ m K}$

Lower Temperature
Longer Wavelength

Higher Temperature
Shorter Wavelength

Explains the iron flame color shift: Dull Red $\rightarrow$ Yellow $\rightarrow$ White

Stefan–Boltzmann Law

The total energy radiated per unit time (H) by a perfect blackbody is proportional to its surface area and the fourth power of its absolute temperature.

$$H = A \sigma T^4$$

$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$ (Stefan-Boltzmann constant)



Exam Trap

The power is T^4 , not T or T^2 .
A small increase in temperature means a massive increase in radiated heat!

Real-World Radiation: Emissivity & Net Loss

Emissivity

Most bodies aren't perfect radiators. We add a dimensionless fraction e (Emissivity).

Perfect radiator: $e = 1$.
Tungsten lamp: $e \approx 0.4$.

$$H = A e \sigma T^4$$

Net Heat Loss

Bodies emit and receive energy from their surroundings (T_s).

$$H = e \sigma A (T^4 - T_s^4)$$

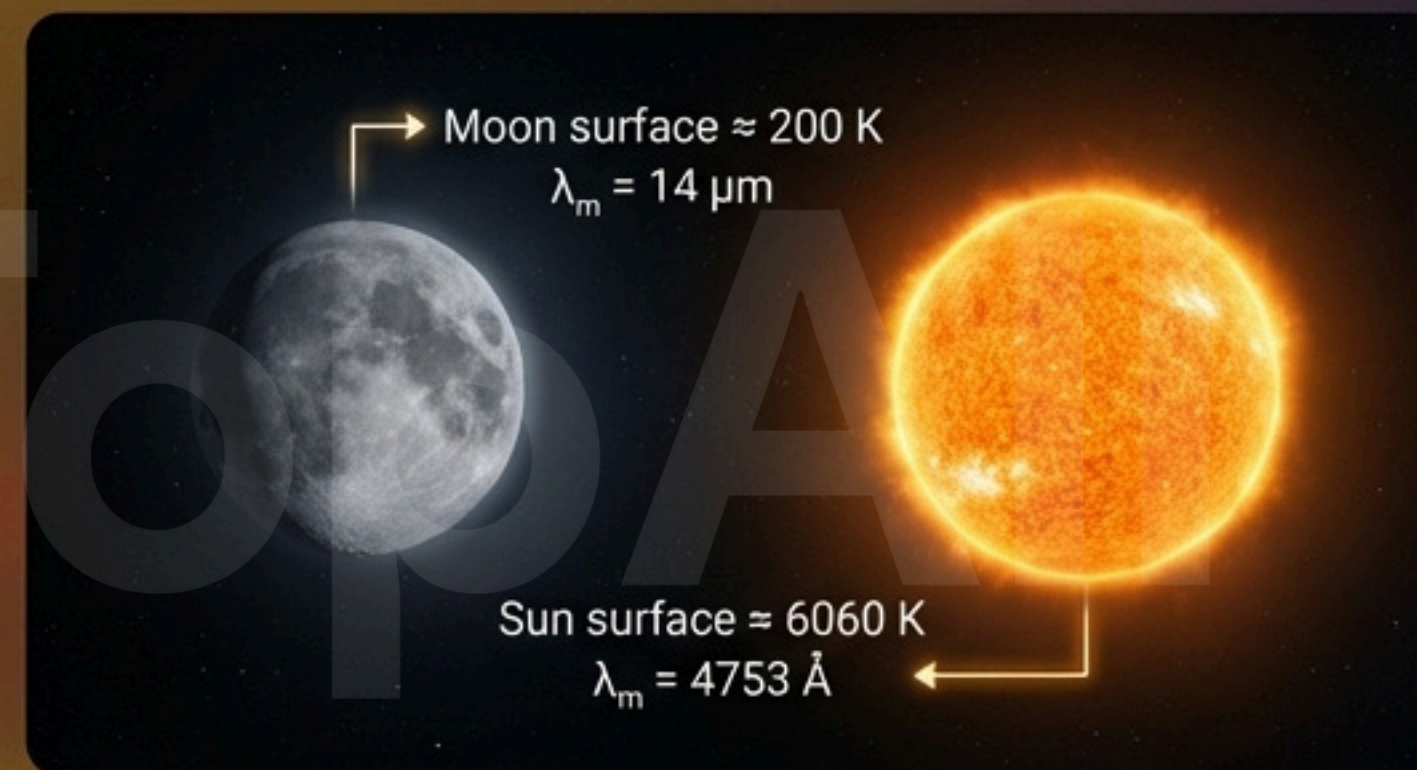


The human body ($\approx 1.9 \text{ m}^2$, $e \approx 0.97$) loses about 66.4 W of net heat in a 22°C room!

Key Takeaways: Measuring the Stars

- ✓ **Blackbodies:** Emit a continuous spectrum depending only on temperature.
- ✓ **Wien's Law:** Peak wavelength shifts left as temperature rises ($\lambda_m T = \text{const}$).
- ✓ **Stefan-Boltzmann Law:** Total radiated energy scales with T^4 ($H = A\sigma T^4$).

Astronomy Link



We use Wien's law to estimate celestial temperatures without ever visiting them.