

Major Concepts in Physics

Lecture 8.

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<http://physics/courses/PHY102.08Spring>

Thermal radiation

- All bodies contain atoms/molecules in motion
- Indeed the speed with which they move is related to the temperature (see later)
- The oscillating electrons will radiate EM waves
 - All bodies at non-zero temperature emit energy as thermal radiation

Thermal equilibrium

- Conversely, all bodies absorb energy coming from EM radiation.
 - Eg. standing in front of a fire, lying in the sun etc
 - Indeed, all forms of life and **almost all physical processes are driven by radiation from Sun**
- Notice: to stay at a fixed temperature all bodies **must** both absorb and emit thermal radiation.

Blackbody radiation

- Idealised body that absorbs all radiation incident upon it is called a blackbody.
- Not just visible light, but UV, IR, X-rays, radio waves etc etc
- Emits also more efficiently than any real body
- Amount of energy E given by Stefan law

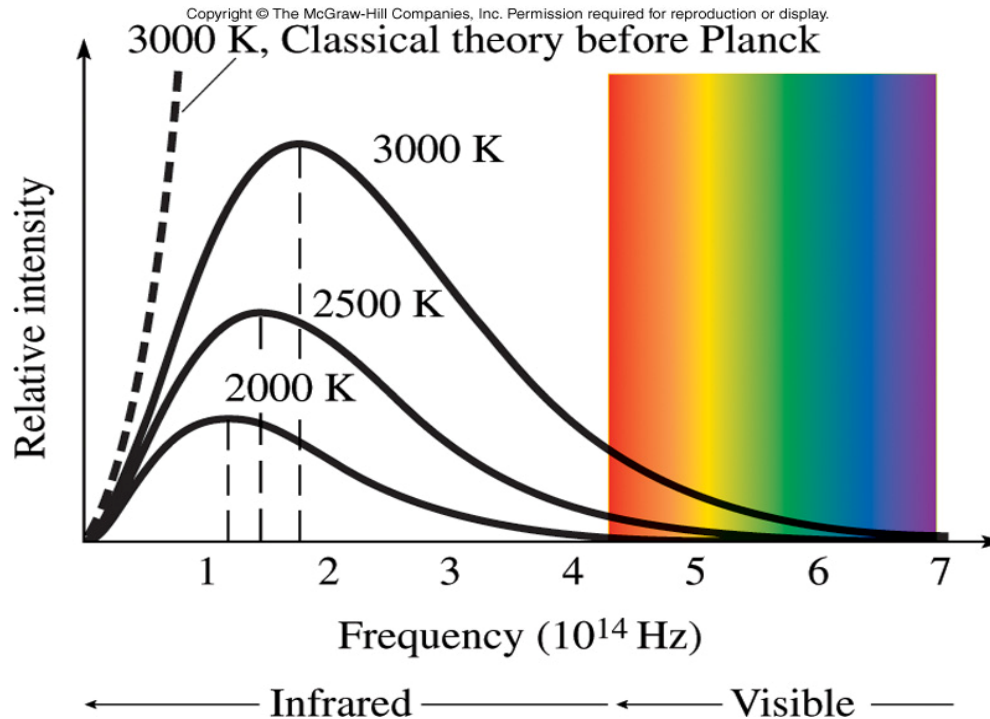
$$E = \sigma AT^4$$

Points to note

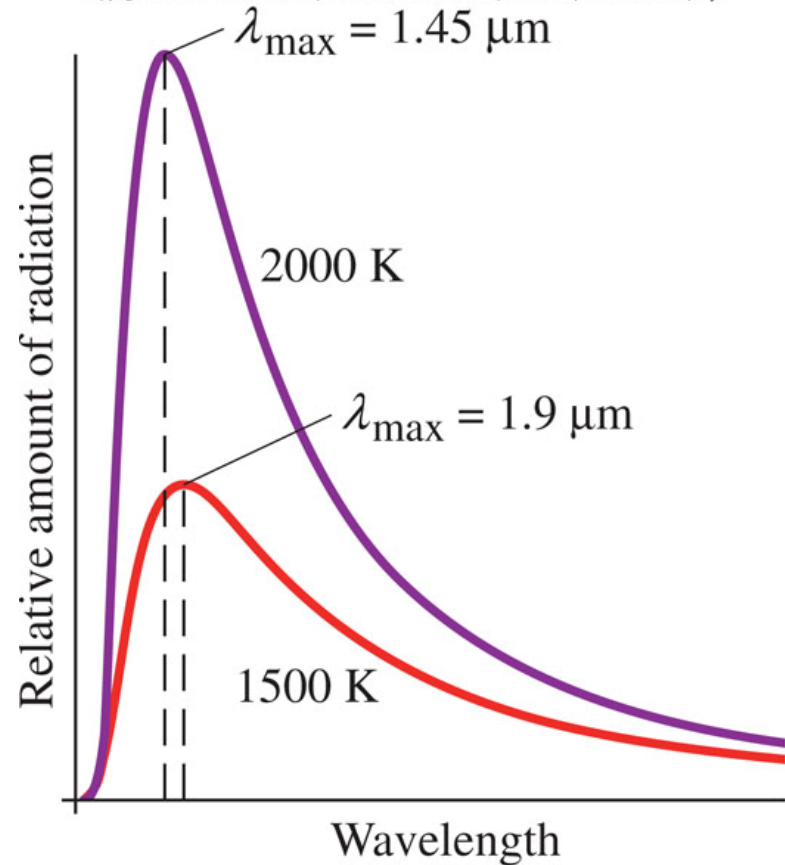
- T measured on absolute temperature scale
- $T=273$ same as 0 degrees celsius (32 F)
- $\sigma = 5.67 \times 10^{-8} \text{ W}/(\text{m}^2 \text{ K}^4)$
- If temperature body doubles what happens to emitted energy ?
 - A: doubles
 - B: quadruples
 - C: halves
 - D: increases by factor of 16

Distribution of blackbody radiation

- Blackbody emits different amounts of energy at different wavelengths



A spectrum shows the amount of radiation emitted at a particular wavelength. For a blackbody, the peak of the spectrum is determined only by its temperature.



Wien's law: $\lambda_{\max} T = 2.898 \times 10^{-3} \text{ m K.}$

Black body demo

Temperature of the Sun

- The maximum rate of energy emission from the Sun occurs at 500 nm. What is the surface temperature of the Sun ?
 - A: 1000000K
 - B: 20000K
 - C: 6000K
 - D: need more information

Turning it around

- Human skin is at 32C. What is the wavelength of maximum power emission from skin ?

A: 10^{-5} m

B: 10^{-3} m

C: 1cm

D: 100 nm

Demo

Energy loss

- A person is sitting in a room whose temperature is 22C. Assuming their surface area to be 2.0 m² estimate their heat loss if their skin is at a temperature of 32C

$$E_{\text{net}} = \sigma A (T^4 - t^4)$$

Greenhouse effect

- Radiant energy from the Sun reaches Earth at a rate of 1.7×10^{17} W. Estimate the mean temperature of the atmosphere ...
 - If Earth is at a constant temp must emit as much as it absorbs
 - Treat as blackbody
 - Ignore reflected light
 - Area of Earth $4\pi R^2$

Continuing

$$T=(E/4\sigma\pi R^2)^{1/4}$$

250 K

Not bad! But not surface temperature ..

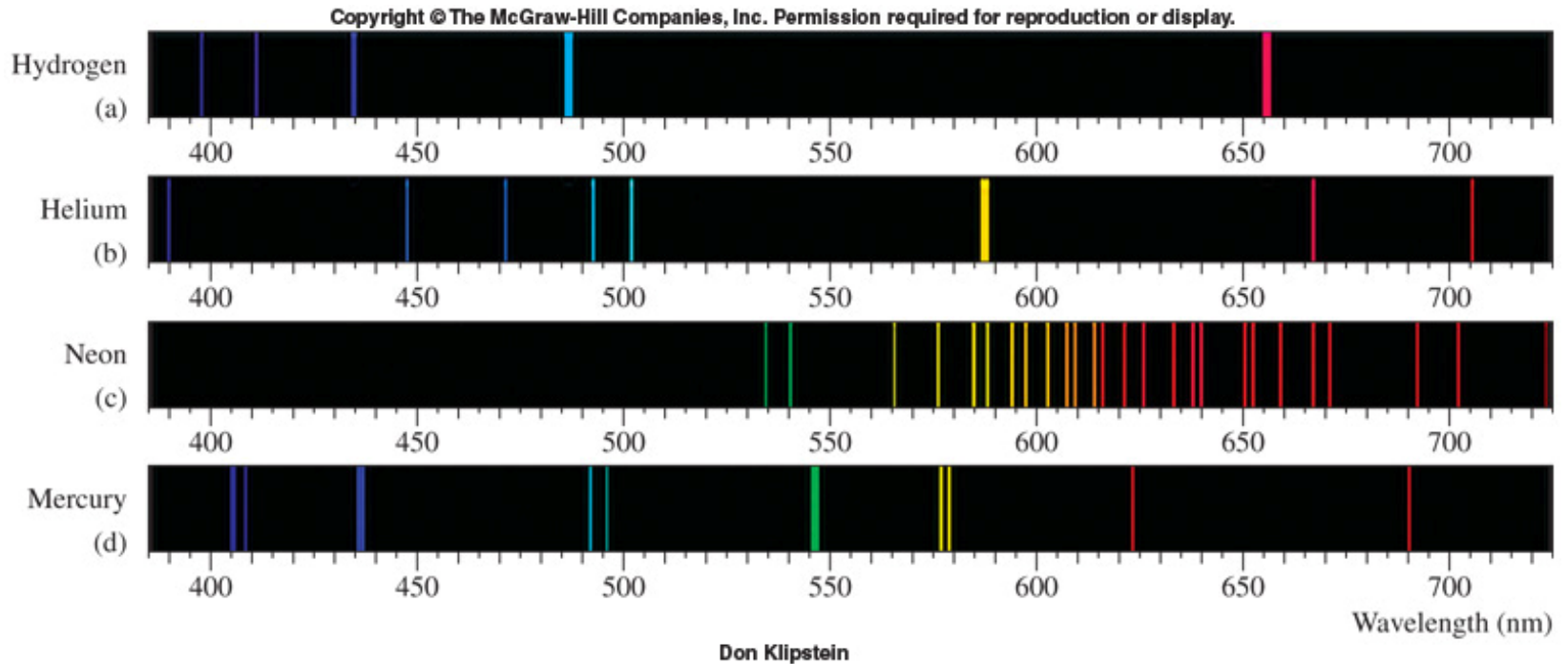
This temperature corresponds by Wien to
wavelengths $\lambda=1.5\times 10^{-2}$ mm – IR !

The atmosphere is opaque to these
wavelengths and hence the surface heats to a
higher temperature.

Line spectra

- So far discussed radiation emitted by solids
 - Find continuous blackbody spectrum
- Interesting to consider radiation emitted by isolated atoms
 - See only *discrete* set of allowed wavelengths depending on element
 - Great puzzle for classical physics. Electrons can orbit atom at any speed/energy – so should radiate at all wavelengths ...

Line emission spectra



Quantum mechanics

- Situation should remind you of allowed wavelengths for stationary waves in tubes
- Atom is like tube. Represent electron not as particle but wave! Discrete radiation reflects allowed wavelengths of electron in atom
- Birth of quantum mechanics ... later